ANNEX 13

Fixed Narrowband Market Review: NGN Cost Modelling

Model Documentation

v2.0

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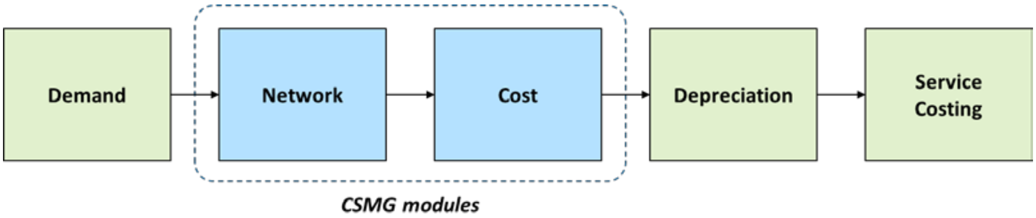
Table of Contents

1. INTRODUCTION

1.1 In June 2012, Ofcom commissioned CSMG to develop a network cost model in support of Ofcom's Fixed Narrowband Market Review. The purpose of the model is to assist Ofcom in estimating the efficient costs of providing wholesale narrowband services.

1.2 The network cost model developed by CSMG comprises two modules (the Network and Cost modules) which fit within the overall scope of Ofcom's Network Charge Control (NCC) model, as shown in Figure 1 below. The other modules in the NCC model have been built by Ofcom.

Figure 1: High Level Model Flow



1.3 This document provides an overview of the Network and Cost modules:

- Section 2 defines the scope of the model;
- Section 3 describes the architecture of the hypothetical network on which the cost model is based;
- Section 4 describes the architecture and logic of the Network and Cost modules. The section describes how the network is dimensioned from the traffic inputs and how this network dimensioning drives costs. The section also describes the outputs that are then used by Ofcom to calculate the unit cost of NCC services;
- Section 5 contains a glossary;
- Appendix A provides further detail regarding the core node infrastructure.

1.4 The first version of this document was published alongside Ofcom's consultation[1] and the draft model published in September 2012. Based on responses from stakeholders, the model documentation has been revised in this version. An addendum has also been included which lists relevant points raised by stakeholders on the model documentation and model, as well as CSMG's responses.

[1] http://stakeholders.ofcom.org.uk/binaries/consultations/narrow-band-market-review/summary/condoc.pdf

2. Scope

Technology

2.1 The cost model represents a hypothetical Next-Generation Network (NGN) in which multiple services are transported over a shared Internet Protocol (IP) network.

2.2 The access network is not modelled. Access lines are assumed to be copper-based.

Geography

2.3 The geographical scope of the model is based on the coverage area of BT's current exchange footprint in the United Kingdom. This includes locations in England, Wales, Scotland and Northern Ireland, with the exception of Hull.

Services

2.4 The modelled NGN supports voice and data services. The network is dimensioned on a bottom-up basis from demand forecasts for voice and broadband access.

2.5 Voice services on the network emulate the Public Switched Telephony Network (PSTN) with both analogue and Integrated Services Digital Network (ISDN) access. Interconnection for voice services with other Communication Providers (CPs) includes both Time Division Multiplexing (TDM) and IP based interconnects.

2.6 The model considers voice calls in which both the originating and terminating lines are on the NGN ("on net"), and calls in which one end of the call is on another CP's network ("off net").

2.7 We consider both retail and wholesale voice services in the model. Retail voice services are provided by the modelled CP directly to its end customers. Wholesale voice services comprise wholesale access and wholesale calls. Wholesale voice access enables a CP to interconnect with the modelled network and use the access segment of the network to reach their own customers. In wholesale calls, the modelled network is also used for call conveyance. Broadband access also encompasses retail and wholesale services. Wholesale broadband access enables a CP to interconnect with the modelled network and use the access segment of the network to reach their own customers.

Timeframe

2.8 Time periods in the model are financial years (April to March). The model considers a 40 year period from 2005/06 to 2045/46.

2.9 We assume network build to start in 2007/08[2]. During the network build phase a number of exchanges are added to the NGN each year until all exchanges have been covered. This build process is assumed to take 4 years, up until the end of 2011/12.[3]

[2] In its response to the September 2012 Consultation, BT did not agree with the proposed start date of the model, for more information see Addendum

[3] The build process in the draft model released in September 2012 was assumed to take 10 year. After reviewing stakeholder responses, this was changed to 4 years. For more information, please see Addendum paragraph 7.32

Existing Assets

2.10 The network module employs a scorched node approach. The location and serving area of BT's exchanges is preserved, however the function of and network elements in each exchange are driven only by the model and not actual, existing network deployment.

2.11 All nodes are assumed to require each of the following:

- DC power, battery back-up and generator
- AC power and Uninterrupted Power System (UPS)
- Air Conditioning
- Security
- Environmental Alarms
- Fire suppressant
- Cable management
- Management network

2.12 These "property" costs are not modelled individually on a bottom-up basis. Instead, an average capital cost per rack is estimated and applied proportionally to the network equipment based on rack space occupancy. We calculate the on-going costs as a percentage of the upfront capital cost (20%[4]) and apply them proportionally in the same manner.

2.13 Costs for duct and fibre are included in the cost module, however these costs do not form part of the bottom-up analysis. They are applied later as a mark-up in Ofcom's service costing module.[5]

[4] This operating cost excludes electricity supply costs which are calculated in addition to this. For more detail see section 4 of this document, "Unit operating costs".

[5] See Annex 12 for a description of this approach.

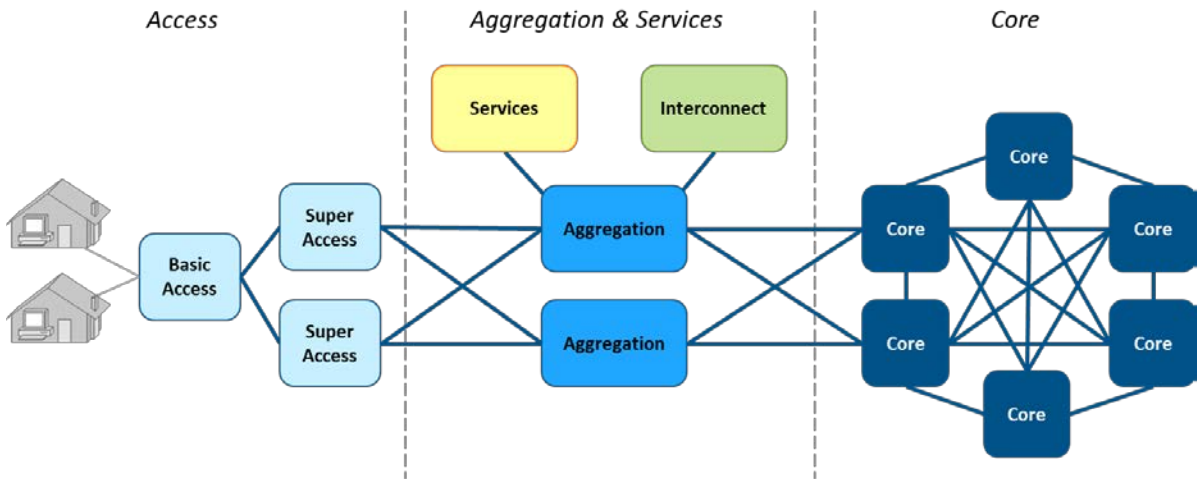
3. Network Architecture

Overview

3.1 The modelled NGN comprises of a series of interconnected logical nodes. Each of these node types performs specific functions which are described in the remainder of this section.

3.2 Figure 2 provides an overview of the network architecture showing the relationship between the logical nodes.

Figure 2: NGN Network Logical Architecture[6]



3.3 The modelled network supports multiple services on a common infrastructure. Voice and data services are supported for both residential and business customers.

3.4 The network is designed for high-availability, consistent with the expectations for PSTN voice services (typically 99.999% availability). General principles of the network architecture are that:

- Nodes are dual-parented, providing redundant network pathways to protect against the failure of a node.
- Multiple connections are used between nodes with diverse paths to protect against cable breaks. In the majority of cases ring topologies are used to redundantly connect multiple nodes. Two diversely routed point-to-point connections are used for small, remote access nodes where a ring would be cost-prohibitive.
- Network electronics are dimensioned to allow for traffic to be rerouted in failure conditions. This includes duplication of components within network elements (e.g. control units, switch fabrics and high-bandwidth interfaces) and in some cases duplication of the network element itself.

3.5 In line with industry norms, the modelled NGN is based on IP technology. For cost efficiency, the underlying transmission network is Ethernet based. Between sites, Dense Wavelength Division Multiplexing (DWDM) over fibre has been selected for high-capacity

[6] See Appendix A for discussion on the connectivity between core nodes

and future scalability. The DWDM connections are implemented using Optical Transport Network (OTN) equipment.

3.6 Multi-Protocol Label Switching (MPLS) is used in the core network. MPLS enables connection-oriented paths to be established across a connectionless (e.g. IP) network which facilitates Quality of Service (QoS) management and capacity planning.

Access Node Categorisation

3.7 Access nodes are the locations which aggregate physical access connections from end-users. There are approximately 5,600 access nodes, which correspond to MDF sites (Main Distribution Frame sites, also known as local exchanges) on BT's network.

3.8 Access nodes are segmented into 10 categories. The categories are based on the characteristics of each exchange in relation to the split of residential/business premises and the total number of residential premises served.

3.9 There is a degree of co-location between logical nodes in the network. Given the hierarchy of *Basic Access Node > Super Access Node > Aggregation Node > Core Node*, the co-location rule is such that every parent node will be co-located with a 'child' node. For example, every Core Node is co-located with an Aggregation Node.

3.10 Physical sites in the network have the combined functionality of all the logical nodes located at that site.

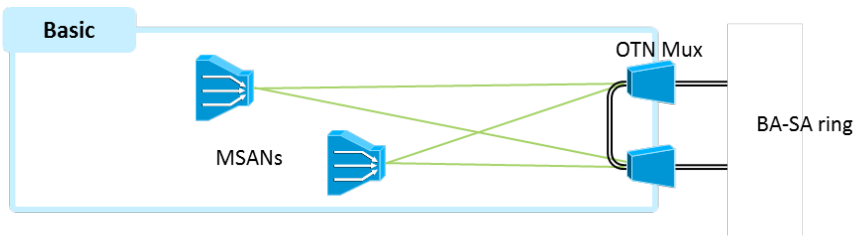
Basic Access Node

3.11 The Basic Access (BA) Node is the most common type of access node. All BA Nodes are dual-parented to Super Access (SA) Nodes. There are approximately 4,000 BA Nodes.

3.12 At the BA Node, customers' copper access lines are terminated for PSTN, ISDN and broadband access. The copper lines terminate on Multi-Service Access Nodes (MSANs). The BA Node has limited switching functionality to provide network resilience and node redundancy in the event of optical equipment or MSAN failure.

3.13 BA Nodes are connected on a ring topology, with multiple BA Nodes sharing a network ring with a pair of SA Nodes (BA-SA ring). The ring provides redundant routes in the event of a cable break and dual-parents the BA Nodes to protect against failure of one of the SA Nodes.

Figure 3: Basic Access Node



Key Elements

3.14 **Multi-Service Access Node (MSAN)**: The MSAN terminates copper lines for PSTN, ISDN and broadband services. It acts as a gateway, adapting the data and signalling for these services into IP packets for the NGN (and *vice versa*). The MSAN has a Gigabit Ethernet interface for

IP traffic. Voice and data traffic is kept logically separate on this interface using Virtual Local Area Network (VLAN) tags.

3.15 VLAN tagging allows for differential QoS treatment of different traffic types (e.g. voice, data) by the separation of one physical network into multiple independent logical networks. This allows for PSTN-quality management of voice services over the shared physical network.

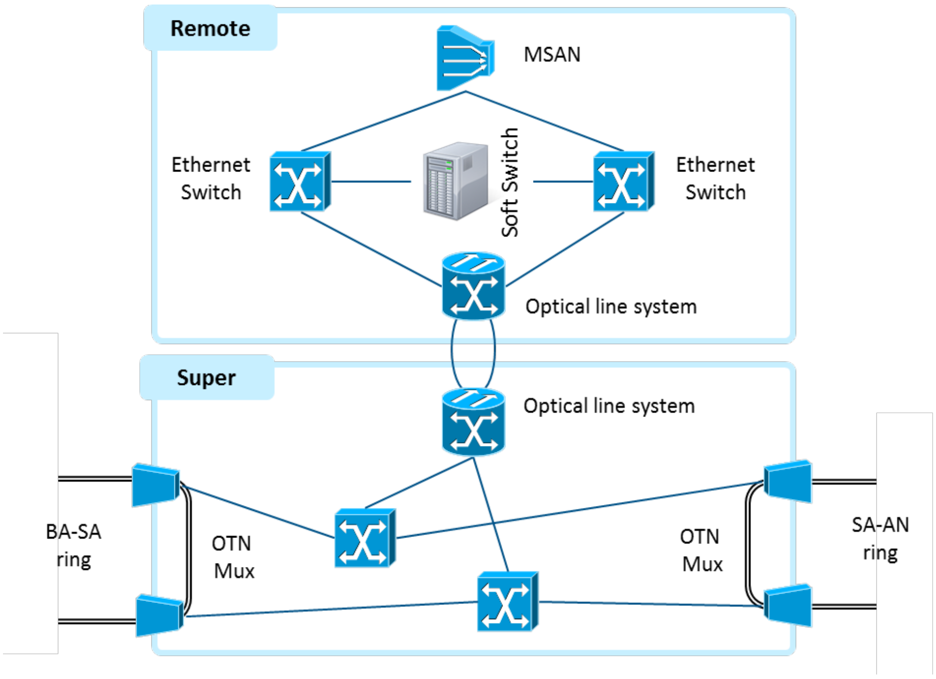
3.16 **Optical Transport Network (OTN) Multiplexer**: The OTN Multiplexer enables multiple point-to-point connections to be set up over a fibre ring. The OTN provides Gigabit Ethernet ports for connection to the MSANs and 10Gbps Ethernet ports for aggregating the traffic on the ring.[7]

Remote Access Node

3.17 The Remote Access (RA) Node is a special type of access node that serves small and/or remote communities. The RA Node serves the same function as the BA Node, but due to its geographic location it is not connected to the Super Access Node on a ring topology. Instead, two diversely routed point-to-point connections are used. Based on the distribution of BT exchange sites, the model assumes there are 1,600 RA Nodes.

3.18 500 of the RA Nodes are assumed to be located in areas (e.g. highlands and islands) with a higher risk of prolonged network failure. In these cases, the RA Nodes incorporate a small Softswitch to maintain local voice services in the event that the node becomes isolated from the rest of the network. This is consistent with the design of BT's 21CN voice network which sought to emulate the function currently provided by UXD5 switches at these locations in BT's TDM network.

Figure 4: Remote Access Node and Corresponding Super Access Node



[7] OTN multiplexers are dimensioned in pairs – an OTN North which faces the customer premise, and OTN south which faces the Core; An exception to this rule is made at the Core Node, where an OTN South sits on the AN-CN ring and an OTN North would sit on a CN-CN ring

Key Elements

3.19 **Softswitch:** A Voice over IP (VoIP) switch that is able to route voice calls and thus support local voice services in the event that the RA Node becomes isolated. The soft switch interoperates with the call servers in the core network under normal operation. This softswitch is only present in 500 of the 1,600 RA Nodes in the network.

3.20 **Ethernet Switch:** There is a redundant pair of Ethernet switches in the RA Node. The Ethernet switches provide connectivity within the RA Node between the MSAN, soft switch and optical line system.

3.21 **Optical Line System:** The optical line system provides point-to-point Ethernet connectivity between the RA Node and the SA Node. The optical line system takes the place of the ring-based DWDM equipment used in the BA Node as a ring-based topology is unlikely to be cost-effective for remote locations.

3.22 Multi-Service Access Node (MSAN): (as above).

Super Access Node

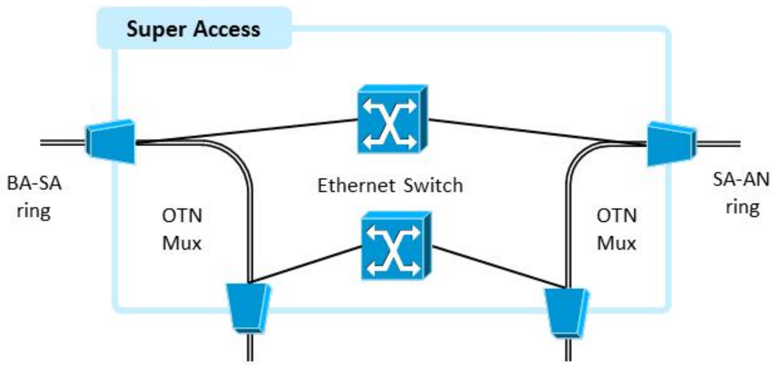
3.23 The Super Access (SA) Node sits between, on the one hand the BA and RA Nodes and, on the other, the Aggregation Node (AN) in the network hierarchy and aggregates traffic from the BA Nodes. All SA Nodes are dual-parented to ANs.

3.24 Each SA Node is co-located with a BA Node (for simplicity, co-located nodes are not shown in this diagram or Figures 6, 7 and 8). There are approximately 1,100 SA Nodes in the modelled network.

3.25 Each SA Node aggregates traffic from approximately 6 BA Nodes under normal conditions, and must be capable of handling traffic from 12 BA Nodes under failure conditions (i.e. in the event that one of the two pathways to parent nodes is severed).

3.26 The SA Node sits on two DWDM rings: one aggregating the traffic from the 'child' BA Nodes (BA-SA ring), and the other facing two parent ANs (SA-AN ring). This ensures multiple redundant pathways in the network between the BA Nodes and ANs.

Figure 5: Super Access Node



Key Elements

3.27 **Ethernet Switch**: There is a redundant pair of Ethernet switches in each SA Node for traffic aggregation. The switches have Gigabit Ethernet interfaces to connect to the OTN on the BA Node ring and 10 Gbps Ethernet interfaces to connect to the OTN on the AN ring.

3.28 OTN Multiplexer (as above).

Aggregation Node

3.29 The Aggregation Node (AN) sits between the SA Nodes and Core Nodes. Each AN is co-located with an SA Node. All ANs are dual-parented to Core Nodes. There are 106 ANs in the modelled network.

3.30 Each AN aggregates traffic from approximately 10 SA Nodes under normal conditions. Since SA Nodes are dual-parented to ANs, each AN must be able to handle the traffic of approximately 20 SA Nodes under failure conditions.

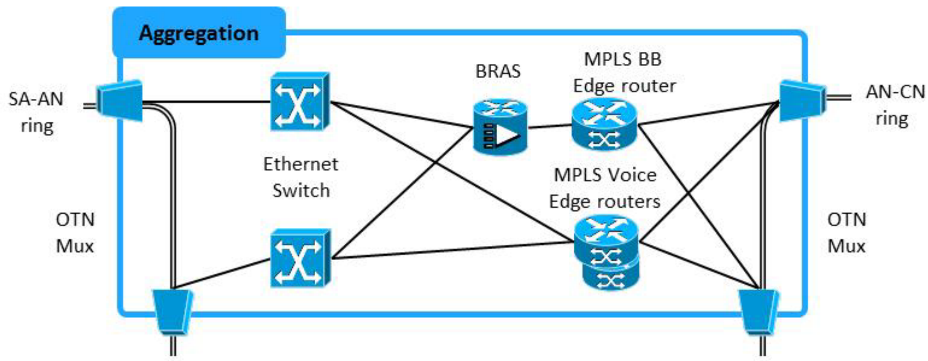
3.31 Voice and broadband traffic are separated in the AN by an Ethernet switching layer. Voice traffic is switched directly to MPLS Edge routers, whilst broadband traffic is directed via Broadband Remote Access Servers (BRAS).

3.32 The BRAS logically separates the wholesale and retail traffic. Wholesale traffic is transported to an Interconnect Node. The model assumes that the retail broadband traffic is aggregated at a central point in the network for peering with other ISPs.

3.33 MPLS is used to provide a single multi-service core network with QoS assurance for voice. MPLS Edge routers are connected to MPLS Core routers (located in the Core Nodes) using 10Gbps Ethernet. The Ethernet connections are transported inter-site using the OTN network. Note that separate MPLS Edge routers are used for voice and broadband services. MPLS BB edge routers are not explicitly modelled as they do not drive voice costs[8]. The broadband traffic share of the MPLS core network is however included because this is a common asset across both the voice and broadband networks.

3.34 The AN is also the attachment point for logical Services Nodes and Interconnect Nodes. These nodes are described below.

Figure 6: Aggregation Node



Key Elements

3.35 **Broadband Remote Access Server (BRAS):** The BRAS terminates end-user broadband sessions and routes traffic to ISP networks. The BRAS has Gigabit Ethernet interfaces.

3.36 **MPLS Edge Router:** MPLS edge routers perform IP routing and adapt IP traffic for switching across the MPLS core network. In the NGN network model, MPLS edge routers are used for voice traffic (media and signalling) from both end-users and interconnections with other CPs. The MPLS edge router has 10Gbps Ethernet interfaces. MPLS edge routers for broadband are not modelled as these do not contribute to voice costs.

[8] For further information see Addendum paragraph 7.17

3.37 **OTN Multiplexer:** As above for the SA-AN ring. The OTN multiplexers in the AN-CN ring provide 10Gbps Ethernet ports for connection to the MPLS edge routers and 100Gbps ports for aggregating traffic onto the AN-CN ring.

Interconnect Node

3.38 The Interconnect Node (IN) supports TDM and IP voice interconnection between the hypothetical NGN network and other CP networks.

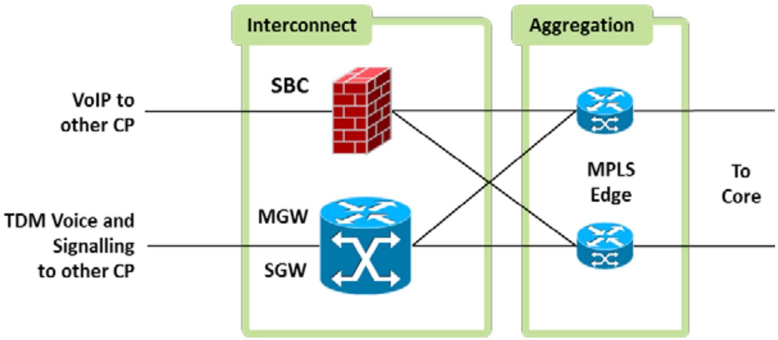
3.39 It is common practice in nationwide voice networks to have multiple, geographically-diverse points of interconnection (PoI) to enable efficient routing of voice calls between networks and provide redundancy in the event of a node failure. In specifying the quantity of INs, a trade-off is made between transmission network capacity and interconnect equipment. That is, if there are fewer PoI, calls must be carried further on the network and therefore transmission costs are higher; conversely with more PoI the call route is shorter which reduces transmission costs but investment in interconnect equipment is higher as more PoI must be equipped,

3.40 In the modelled network, INs are located at each of the 20 core nodes. The number of INs in the model is consistent with the 20 points of interconnect provided by BT for wholesale broadband connect (WBC)[9].

3.41 MPLS edge routers in the AN connect the IN equipment to the MPLS core network. The MPLS edge routers have separate interfaces for TDM and IP voice interconnects. Traffic for TDM interconnection is passed to media gateways (MGW) to perform the conversion from VoIP to TDM and vice versa. Traffic for IP interconnection is passed to session border controllers (SBC).

3.42 The interconnects are dimensioned to allow for rerouting of traffic in the event of a network failure.

Figure 7: Interconnect Node



Key Elements

3.43 **Session Border Controller (SBC):** The SBC provides a secure boundary for media and signalling traffic at the border of the CP's network, isolating the internal network from that of interconnecting CPs. Whilst it is technically possible to separate the media and signalling pathways, the volume of traffic at each of the 20 voice interconnects in the modelled network is relatively low favouring the combined SBC approach. The SBC has Gigabit Ethernet interfaces.

[9] Some stakeholders suggested a different number of interconnect nodes should be used in the model. See Addendum paragraph 7.5 for further discussion

3.44 **Media Gateway (MGW):** The MGW converts traffic between VoIP (on the NGN) and TDM voice (for the interconnecting CP). The modelled network assumes that the MGW device encompasses both media and signalling conversion capabilities. These are itemised as separate cost items in the model. The IP interface of the MGW is Gigabit Ethernet. The TDM interface of the MGW is channelized STM-1.[10] The MGW signalling gateway converts between Session Initiation Protocol (SIP) signalling (on the NGN) and Signalling System No. 7 (SS7) signalling (for the interconnecting TDM CP).

3.45 The MGW STM-1 interface is connected to a TDM cross-connect to distribute the traffic to interconnecting CP networks. The cost of TDM cross-connect is not explicitly captured in the NGN model as it is not part of the cost of NGN delivered call origination or call termination.

Service Node

3.46 The Service Node (SN) houses the intelligence in the network. It provides control and service layer functionality. There are 2 SNs in the modelled network, each co-located with an AN. SNs are connected to the network via the AN network equipment.

3.47 The voice-related servers in the SN are duplicated 1+1 across sites for resilience. In the event of a complete failure of one of the two service nodes, redundant capacity in the remaining service node is sufficient to maintain network quality.

Key Elements

3.48 **RADIUS Server**: RADIUS (Remote Authentication Dial In User Service) enables user authentication, ensuring that subscribers are authorised to use certain services on the service provider network.

3.49 **DNS Server**: The DNS (Domain Name System) Server translates between host names and machine-readable IP addresses.

3.50 **Call Server**: The Call Server is involved in both routing calls and the provision of supplementary services such as call waiting, conferencing, etc.

3.51 **Directory Server**: The Directory Server is an index that maps network resources (numbers) to IP addresses to enable calls to be routed to the required end-point.

3.52 **Voicemail Server**: The Voicemail Server provides voicemail service to end-users, including the storage of recorded voicemail data.

3.53 Gigabit Ethernet Switch: (as above).

Core Node

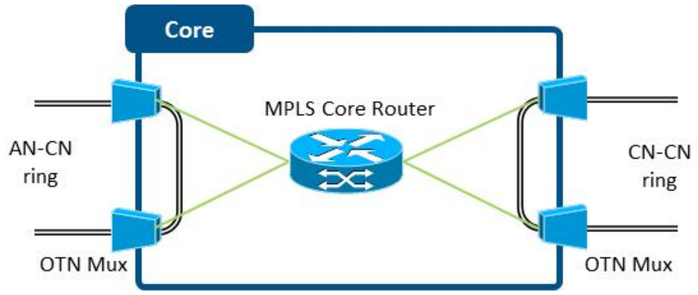
3.54 The role of the Core Node (CN) is to transport traffic between ANs. There are 20 CNs in the modelled network, each co-located with an AN.

3.55 The CNs are highly meshed, enabling efficient routing of traffic and provide resilience against equipment or site failure. To provide a balance between routing efficiency and resilience on the one hand, and cost on the other, the CNs are segmented into an inner core of 8 nodes and an outer core of 12 nodes. The 8 inner CNs are fully meshed, whilst the

[10] A channelized STM-1 interface provides 63 E1 (2.048Mbps) connections. Each E1 connection can support up to 30 concurrent 64kbps voice channels.

outer 12 CNs are each connected to 3 of the inner CNs. Further detail on the topology of the core network is presented in Appendix A.

Figure 8: Core Node



Key Elements

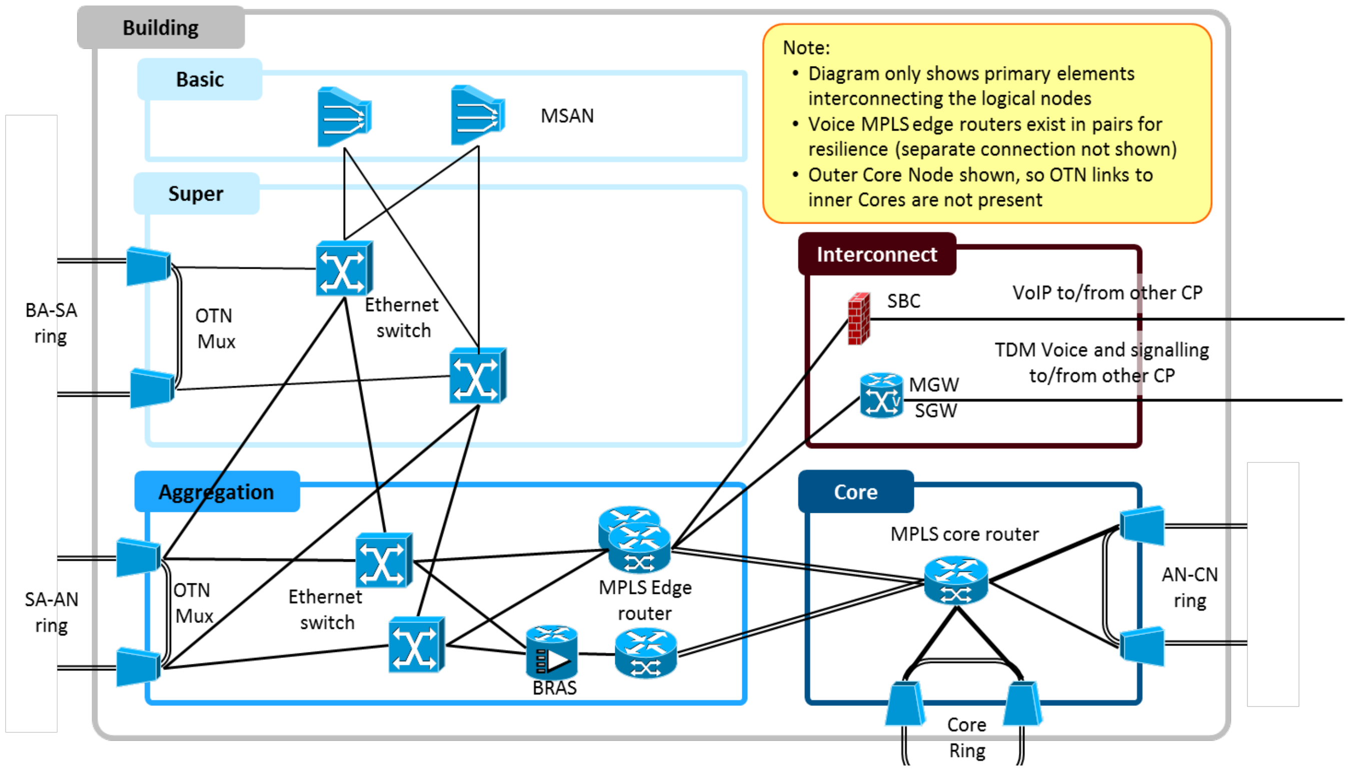
3.56 **MPLS Core Router**: MPLS core routers forward MPLS packets from one edge router towards another edge router. The MPLS core routers have 10Gbps Ethernet interfaces facing the edge routers and for core-core interconnection.

3.57 **OTN Multiplexer**: The OTN multiplexers in the AN-CN ring provide 10Gbps Ethernet ports for connection to the MPLS routers and 100Gbps ports for aggregating traffic onto the AN-CN ring. The OTN multiplexers in the CN-CN ring provide 10Gbps ports for connection to the MPLS routers and 100 Gbps ports for connecting traffic onto the CN – CN ring.

Example of Co-location

3.58 The figure below gives an example of a co-located core node (without service node elements shown).

Figure 9: Co-located Core Node (Service Node not shown)



3.59 Each node in a co-located node building has one less pair of OTN equipment than when located independently, as node equipment can be cabled directly to higher-node (e.g. Super Access node to Aggregation node) equipment.

3.60 Co-located nodes exist in four combinations:

- BA – SA
- BA – SA – AN
- BA – SA – AN (with IN and SN[11]) – CN
- BA – SA – AN (with IN and without SN) – CN

Call Pathways for Modelled Services

3.61 All voice calls on the modelled network pass through either one or two ANs. The ANs house the routing capability in the network.

3.62 The table below (Figure 10) reflects the modelled media pathways for various call services on the NGN.

3.63 In some cases, due to the network architecture, a call may have multiple pathway options, depending on the characteristics of each node (e.g. if the AN has an international interconnection point or not). While this variation is mathematically accounted for in the model through use of probabilities, the individual call paths are not separated out in the table below. Additional nodes that may be passed in a call are enclosed in parentheses. Asterisks are used in the call paths to denote where multiple CNs may be passed.

3.64 For off-net calls only outgoing call paths are shown. Incoming calls traverse the nodes in reverse order.

3.65 International calls are routed to a subset of the INs which handle interconnects with CPs in other countries.

Figure 10: List of Modelled Call Services

Services	Logical Call Pathway
On-net NGN calls (Single Aggregation Node)	BA – SA – AN – SA – BA
On-net NGN calls (Cross-Core)	BA – SA – AN – CN* – AN – SA – BA
Off-net outgoing calls (National Single AN)	BA – SA – AN – IN
Off-net outgoing calls (National Cross-Core)	BA – SA – AN – CN* – AN – IN
Off-net outgoing calls (International)	BA – SA (– AN – CN*) – AN – IN
On-net NGN to Legacy calls	BA – SA (– AN – CN*) – AN – IN
Transit calls (Single Aggregation Node)	IN – AN – IN

[11] The two service nodes modelled in the network are collocated with ANs – two instances of this collocated combination exist in the network

Transit calls (Cross-Core)	IN – AN – CN* – AN – IN

Legend:
BA: Basic Access Node
SA: Super Access Node
AN: Aggregation Node
CN: Single Core Node
CN*: One or more Core Nodes
IN: Interconnect Node

3.66 Figure 10 does not include signalling pathways which, for the purposes of billing and the provision of intelligent network services and call features, pass the AN and SN (potentially via one or more CNs). However we have not modelled signalling pathways in the model as the bandwidth required for these is not considered material (less than 0.01% of total bandwidth and traffic).

3.67 On-net Legacy to Legacy calls do not use NGN elements described above (although there are some shared assets such as duct and accommodation). As these call types are not provided by the modelled network, they are not shown in the table above (Figure 10).

4. Model Implementation and Assumptions

Overview of Network and Cost Modules

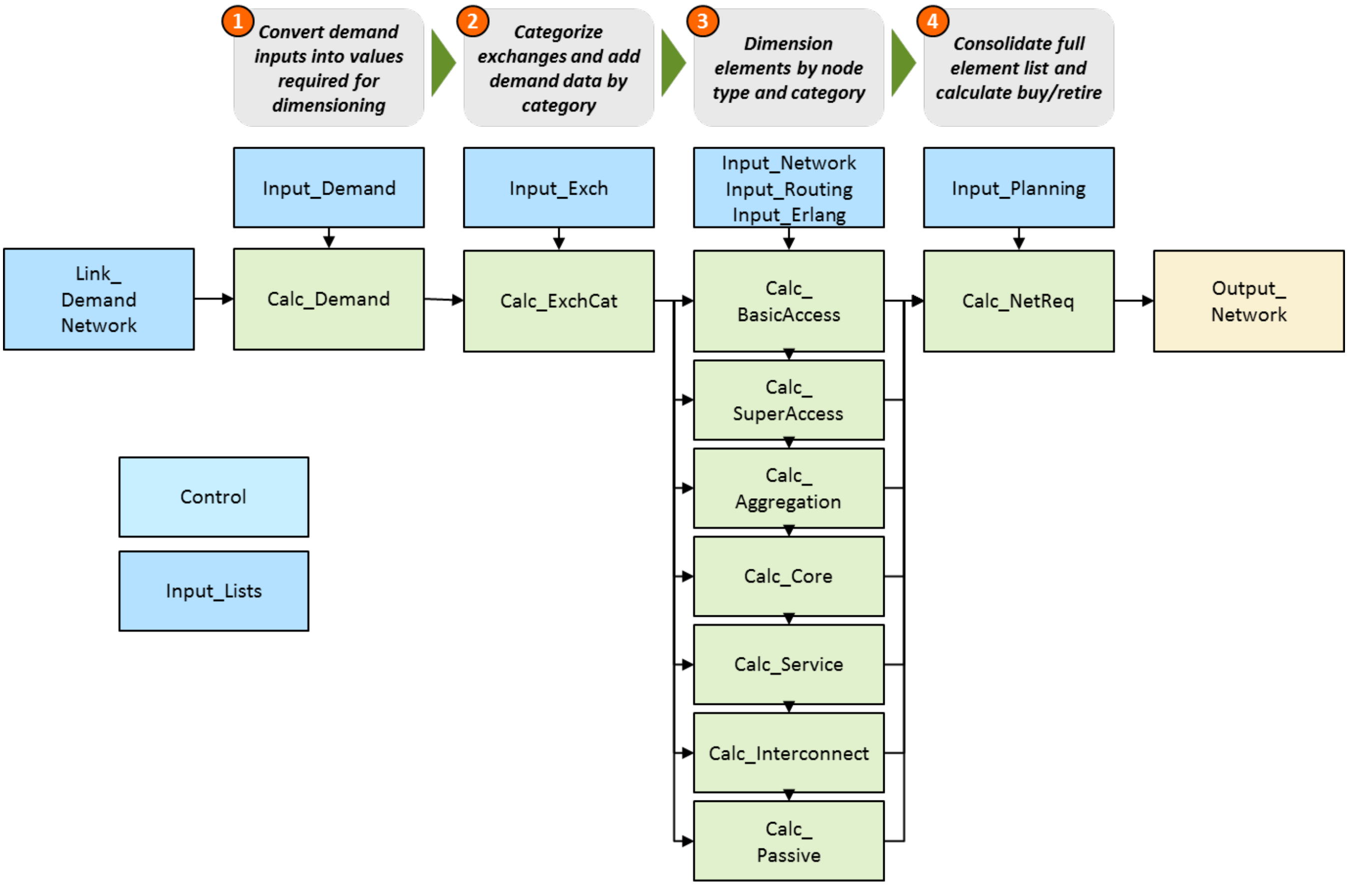
4.1 As outlined in the introduction to this document, CSMG has developed two modules (the Network and Cost modules) that are components within Ofcom's NCC model.[12] The Network module takes the traffic demand forecasts from the demand module and dimensions a network to carry this traffic. The Cost module calculates the capital and operating expenditure required to build the dimensioned network. The outputs from this module are used by the Economic module to calculate how costs are recovered over time and across services.

4.2 In Section 3 of this report, we identified the type of NGN that we are seeking to model. The remainder of this document will discuss how we have modelled this network and determined its costs.

Network Module

4.3 The Network module takes the network architecture, and demand inputs and dimensions the NGN to satisfy peak demand. An overview of the logic of the network module is shown in Figure 11 below.

Figure 11: Network Module Overview



[12] Both modules are contained within a single Excel Workbook: 2.Network.Cost.xlsm.

Call Demand

4.4 The Network module dimensions a network to carry the traffic forecast in the Demand module. The network is dimensioned to be able to carry the traffic that occurs during the busy hour. In order to use the traffic forecasts expressed in minutes for network dimensioning, we convert the traffic to busy hour megabits per second (BH Mbps).

4.5 The model considers two non-concurrent busy hours[13]: a voice busy hour (for voice only traffic) and a network busy hour (that considers both voice and data traffic). The model assumes that the voice busy hour occurs during the working day, and is driven by business calls. 9% of daily voice traffic occurs in the voice busy hour. The network busy hour is assumed to be in the early evening (outside of work hours) and driven primarily by residential data traffic. 8% of daily voice traffic and 9% of data traffic occurs in the network busy hour.

4.6 The model assumes that a voice call on the modelled NGN requires 135 kbps[14] in each direction at the IP layer, based on the use of a G.711 codec[15].

4.7 The model assumes there are 1.1 call attempts per successful call to account for unsuccessful calls (9% of calls are unsuccessful). The model does not include bandwidth requirements of call-setup or account for call-setup traffic in output figures, as these are insignificant. [16]

Categorisation of Exchanges and Network Deployment

4.8 BT currently has over 5,500 local exchanges covering the UK. These exchanges have different numbers of total lines and different proportions of business and voice lines. To account for the variation between exchanges, we define 10 different types of BA node in the model. We categorise the BA nodes based on the number of residential lines per exchange as shown in Figure 12 below.

Figure 12: Exchange Categorisation

Exchange Category	Number of Residential Premises Served	Quantity of Exchanges
a	0 – 750	**1,625**
b	750 – 1500	**1,136**
c	1500 – 3000	**774**
d	3000 – 5000	**464**
e	5000 – 10000	**635**
f	10000 – 15000	**409**
g	15000 – 20000	**249**
h	20000 – 25000	**153**

[13] For further information on busy hour relationships, see Addendum paragraph 7.14
[14] This includes IP and transport headers and is based on a packet size of 10ms
[15] Some stakeholders suggested that bandwidth requirements would decrease as industry transitioned to new lower bandwidth codecs such as G.279. As a result, CSMG included functionality in the model to decline voice bandwidth over time from 2015 to 2020, simulating a change in the default industry codec to one based off of G.729. However, a further scenario has been included with no transition, as it is still uncertain, if, when and for how long such a transition would occur. For more information, see Addendum
[16] Bandwidth requirement of call setup was 0.006% of total bandwidth and 0.004% of voice bandwidth in the initial year, both declining over time. In terms of traffic, call setup accounted for 0.01% of total traffic and 0.01% of voice traffic, again both proportions declining after the initial year

i	25000 – 30000	**70**
j	30000+	**66**
Total		**5,581**

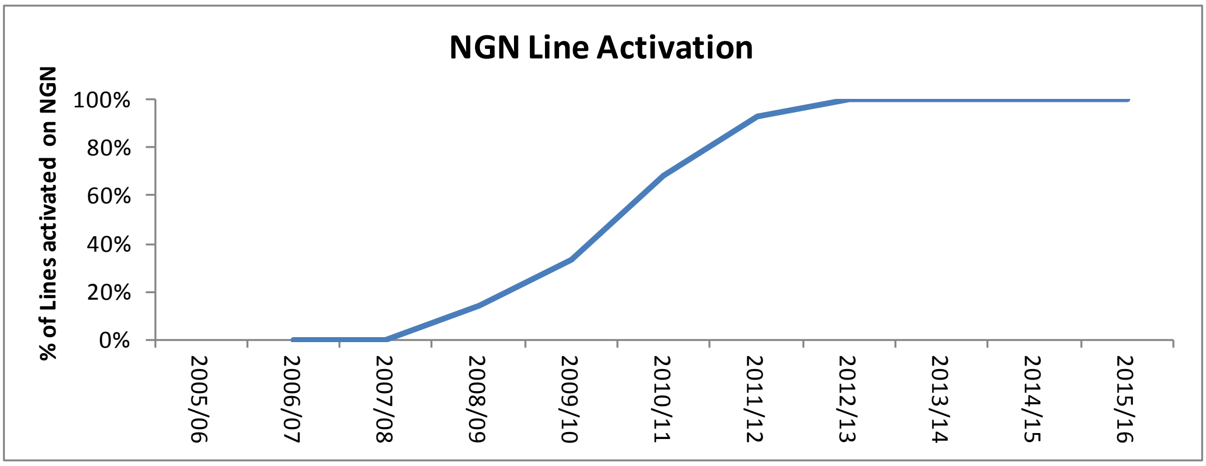
4.9 The higher-order nodes (i.e. SA, AN and CN) are co-located with the BA nodes. In the BT 21CN design, the selection of exchange buildings to house the higher-access nodes is a function of factors such as available space, power and redundant cable entry points plus geographic location. In line with this approach, co-location sites in the modelled network are not determined by residential line count (i.e. we do not assume the 20 sites with the largest number of residential lines are the locations of the core nodes) but rather the higher-order nodes are distributed across the BA node categories in the model.

4.10 The NGN network is built over a period of 4 years, commencing 2007/08. The NGN reaches full deployment in 2011/12 (i.e. 100% of local exchanges are NGN).

4.11 The network build is linked to the BA node categorization; the implementation plan assumes that for each category, the BA nodes in that category are built within a single year. We assume that all higher-order nodes (i.e. SA, AN and CN) are built during the first year.

4.12 The model assumes that a node starts to carry NGN traffic (the line is "activated") in the year after it is built. Therefore the first year in which the NGN carries traffic is 2008/09.

Figure 13: Line Activation to NGN



Dimensioning of Elements

4.13 Each network element type has up to three drivers that determine the quantity of the element required in the model:

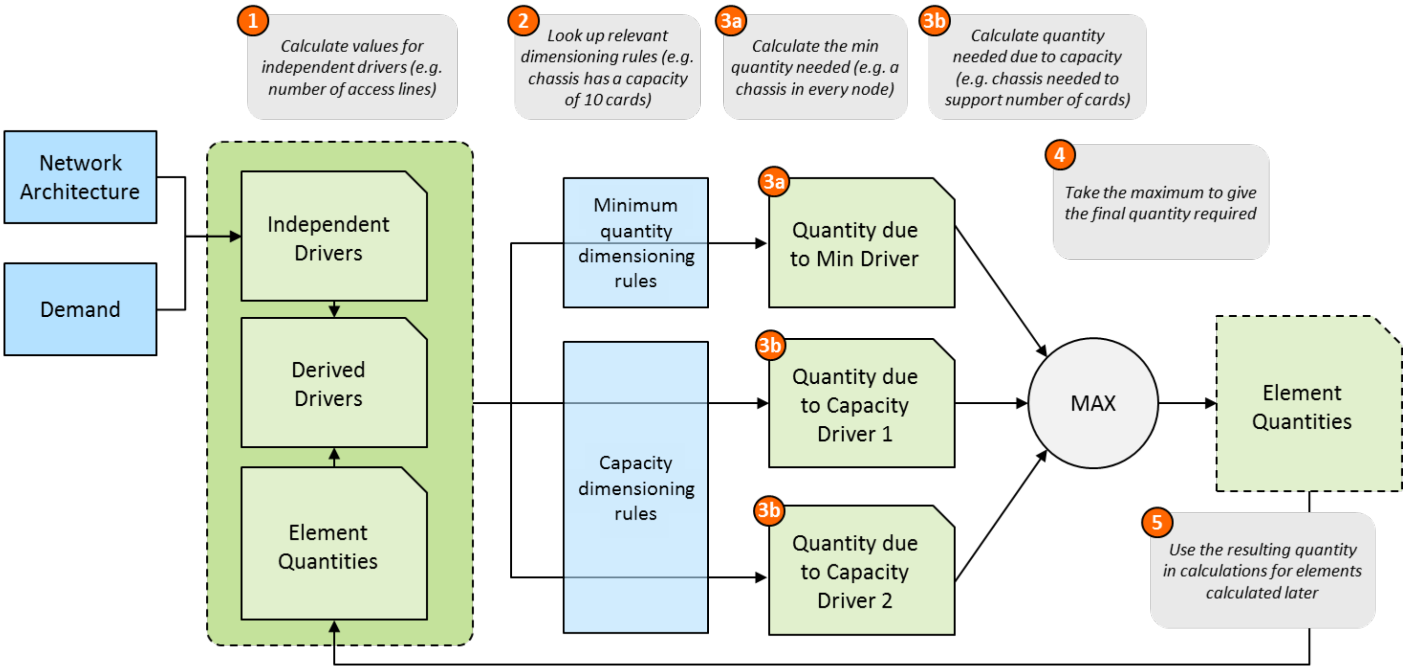
- MinDriver is the minimum number of an element that is required by the network architecture, independent of demand (i.e. the minimum quantity of a network element that would be required if there was no network traffic).
- Two capacity drivers - CapacityDriver1 and CapacityDriver2 - which identify the drivers that determine how the quantity of the network elements are scaled. The capacity drivers are either (a) direct demand inputs (e.g. a function of traffic or lines); or (b) derived inputs (e.g. the number of network elements is derived from the quantity of another network element).

4.14 To simulate the capacity planning and implementation functions of a real-world operator, the model incorporates a capacity utilisation threshold. The threshold is used in conjunction with the maximum load each component can deliver to determine when capacity is expanded. Where equipment is dimensioned to cope with additional load in failure scenarios, its maximum load is adjusted to reflect this.

4.15 This version of the model uses a capacity utilisation threshold of 70%[17] for components which are dimensioned directly by demand drivers, for example the bandwidth of a network port.

4.16 For the majority of elements, we follow a common approach to determine the required quantity for each network element in each year of the model. This approach is illustrated in Figure 14.

Figure 14: Element Dimensioning Approach



4.17 The model is also able to accommodate exceptions to the above approach. For example, in the case of network synchronisation the model always assumes three primary reference clock sources[18], independent of network load or topology.

4.18 We calculate BA node dimensioning using the exchange categories described above. Dimensioning occurs by calculating the number of each network element required per exchange according to network and demand rules. These per-exchange values are then multiplied by the number of nodes in that exchange category, taking into account remote nodes and those co-located with SA Nodes. The model then calculates the total number of network elements required in all nodes, along with the average number per node across all exchange categories.

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[17] For more information, please see Addendum paragraph 7.23

[18] Voice networks require accurate synchronization for correct operation. Primary reference clocks provide a highly accurate time source for the network elements. Multiple clock sources are used for redundancy.

Calculate the Buy and Retire for Different Elements

4.19 Once the model has calculated the total number of elements required, it calculates the additional quantities required in each year given advanced planning requirements, the elements purchased for additional capacity and those purchased to replace retired equipment. The model will also calculate the quantity of network elements retired.

4.20 Assets in the network model are retired at the end of their useful lives and replaced if still required. As in real-world operations, there is variation between the useful lives of different network elements in the model. We have populated the model with asset life estimates which have been informed by CP responses to Ofcom information requests and responses to Ofcom's consultation.

Figure 15: Asset Lifetimes by Equipment Type

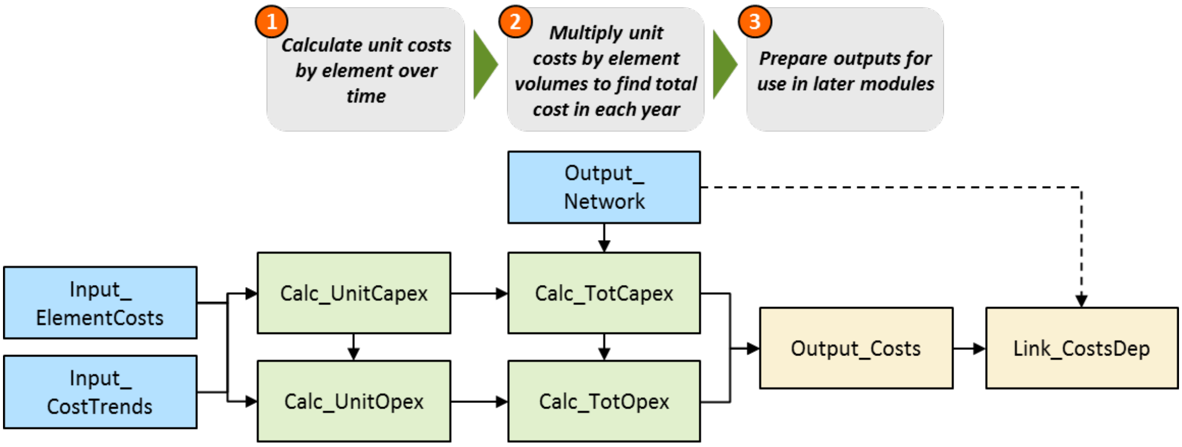
Equipment Type	Asset Lifetime in Model (Years)
OTN	8
MSAN	5
Routers & Switches	5
Synchronisation Sources	10
Rack	10
SBC, MGW & SGW	8
Servers & Software	5
Cabling	10
Property, Ducts and Fibre	50

4.21 The model assumes a planning lead time of one year. Network elements required to meet expected demand in the following year are planned, purchased and installed in the current year. This allows the NGN operator to stay ahead of expected demand on the network, and reflects typical planning and build cycles in response to, or in anticipation of, changing demand.

<u>Cost Module</u>

4.22 The Cost module takes its inputs from the Network module and produces total network cost estimates. The outputs from this sheet are then used as inputs in the Economic module, which implements the economic depreciation algorithm. An overview of the cost module logic is shown in Figure 16 below.

Figure 16: Cost Module Overview



Element Unit Costs over Time

4.23 The model calculates the unit costs (both capex and opex) of each network element over the life of the network. After 2025/26 capex and opex trends are assumed to remain constant for the remainder of the modelling period in real terms. There are seven cost trend categories in the model. The cost trend categories are shown in Figure 17 below.

Figure 17: Cost Trends by Category

Trend Category	Nominal Capex Trend	Nominal Opex Trend	Rationale
Property	2%	2%	Based on Grant-Thornton data on commercial property prices
Racks & Cooling	-2%	-2%	Based on IDC forecasts and CP responses to information requests
Software and platforms	-2%	-2%	Based on IDC forecasts and CP responses to information requests
Active Equipment	-5%	-5%	Based on IDC forecasts and CP responses to information requests
Passive Equipment	-1%	-1%	Based on IDC forecasts and CP responses to information requests
Labour	4%	4%	CSMG Assumption

4.24 The model uses the Retail Price Index[19] (RPI) to convert the nominal values for capex price trend and opex price trend to real values. .

4.25 The model includes a capex and opex trend for Labour to allow for installation costs to be capitalised and retirement costs to be trended for each network element.

Unit Capital Costs

4.26 The base year for asset costs in the model is 2012/13. Asset costs for other years are determined by applying cost trends on a forward-looking or historical basis. Figure 18 presents the assumed real capital costs in 2012/13 (in 11/12 prices) for each network element in this version of the model. These CSMG estimates are based on industry benchmarks and have been refined based on CP responses to Ofcom information requests and responses to Ofcom's consultation.

4.27 Installation costs are captured in the model through estimates of man-hours and labour rates.

4.28 In addition, the retirement cost of assets has also been included as part of capital expenditure.[20] This cost to decommission each network element is based on the number of man hours required and the cost of labour.

4.29 Estimates for the number of man-hours for installation and retirement are based on CP responses to Ofcom information requests.

4.30 We include the capital cost of Business and Operations Support Systems (BSS/OSS) in the model. BSS/OSS support fulfilment, assurance and billing processes for the retail and wholesale voice and data services. We have modelled BSS/OSS costs with a fixed cost component based on per-subscriber data received from CP information requests.

Figure 18: Network Element Capital Costs

Asset	Example Asset Name in Model	2012/13 Capex (2011/12 prices)(£)
MSAN Chassis	BA_MSAN_Chassis	11,300
MSAN GE client card	BA_MSAN_GE client card	500
OTN GE client port	BA_OTN_GE client port	450
OTN GE client card	BA_OTN_GE client card	2,000
OTN 10GE line card	BA_OTN_10GE line card	5,300
OTN 10GE client port	BA_OTN_10GE client port	600
OTN 10GE client card	BA_OTN_10GE client card	5,000
OTN Chassis	BA_OTN_Chassis	12,000
Sync Primary	CN_Sync_Clock	40,000
Switch GE client port	SA_Switch_GE client port	100

[19] This is the same RPI as used in Ofcom's NCC calculation

[20] Functionality has been included to allow retirement costs to be treated as capital or operating expenditure. By default, retirement costs are treated as capital expenditure. For more information, see Addendum

Switch GE client card	SA_Switch_GE client card	4,000
Switch 10GE client port	SA_Switch_10GE client port	250
Switch 10GE client card	SA_Switch_10GE client card	5,000
Switch Chassis	SA_Switch_Chassis	7,000
Edge 10GE port	AN_Edge_10GE port (client side)	1,650
Edge 10GE card	AN_Edge_10GE card (client side)	25,000
Edge Chassis	AN_Edge_Chassis	35,000
OTN 100 GE line card	CN_OTN_100GE line card	30,000
OTN 100 GE client card intrasite	CN_OTN_100GE client card intrasite	20,000
Core MPLS 10GE client port	CN_MPLS_10GE client port	5,000
Core MPLS 10GE client card	CN_MPLS_10GE client card	50,000
Core MPLS 10GE line card	CN_MPLS_100GE line card	55,000
Core Router Chassis	CN_Router Chassis	100,000
Call Server Hardware	SVC_Call Server_Hardware	1,000,000
Call Server Software licence (per voice subscriber)	SVC_Call Server_Software licence	4
Directory Server Hardware	SVC_Directory Server_Hardware	25,000
Directory Server Software licence (per voice subscriber)	SVC_Directory Server_Software licence	0.15
Voicemail Server Hardware	SVC_Voicemail Server_Hardware	800,000
OSSBSS Fixed	PAS_OSSBSS_Fixed	50,000,000
Duct	PAS_Duct	176,300,000
Fibre	PAS_Fibre	662,400,000
Session Border Control GE line card	IN_Session Border Control_GE line card	5,000
Session Border Control Chassis	IN_Session Border Control_Chassis	100,000
Session Border Control Software licence	IN_Session Border Control_Software licence	25,000
Media Gateway GE line card	IN_Media Gateway_GE line card	19,800
Media Gateway TDM line card	IN_Media Gateway_TDM line card	30,000
Media Gateway Chassis	IN_Media Gateway_Chassis	19,200
Media Gateway Software licence	IN_Media Gateway_Software licence	70,000
Signalling Gateway Software licence	IN_Signalling Gateway_Software licence	400,000
Softswitch	RA_Softswitch	10,000
OLS GE client port	RA_OLS_GE client port	2,500
OLS GE line port	RA_OLS_GE line port	2,500
OLS Chassis	RA_OLS_Chassis	3,000
Cabling	SA_Cabling	150
Racks	BA_Rack	2,000

Unit Operating Costs

4.31 Operating costs (excluding power) for each network element in the model are assumed to be 20% of capital costs. These opex percentages are applied to year-average costs (as a fair representation of the opex base in that year) rather than year-end costs.

4.32 We calculate the cost of power based on per network element power usage and the trended cost per kWh in the UK for industrial power supply. The network element power usage assumptions are based on standard equipment vendor guidelines and CP responses to information requests.

4.33 Air conditioning requirements are assumed to be proportional to per element power consumption. We assume that each kW required by network equipment produces heat that requires 0.8 kW of cooling. This estimate is benchmarked to equipment vendor guidelines and CP responses to information requests.

Calculation of Total Costs and Module Outputs

4.34 The total annual capital expenditure for each network element is calculated as the product of that year's unit capex (including equipment and labour costs) and the number of network elements purchased in that year. As discussed above, the network elements purchased in each year are an output of the Network module.

4.35 The total annual operating expenditure is the unit opex for that year, multiplied by the number of elements in operation during that year.

4.36 The total network capex and opex provide inputs to the economic depreciation module. In addition to the total cost outputs, the element unit capex and opex trends and element outputs from the cost module are also used by the economic depreciation algorithm in the Economic module. The adjusted routing factors from the Network module are also used in the Economic module to allocate the costs of network element output to network services.

5. Glossary

Abbreviation	Definition
BRAS	Broadband Remote Access Server
BSS	Business Support Systems
BT	British Telecom
CE	Customer Edge
CP	Communications Provider
DNS	Domain Name Server
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
eNUM	E.164 Number Mapping
GE	Gigabit Ethernet
IMS	Internet Protocol Multimedia SubSystem
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
M2M	Machine-to-Machine
MCP	Mobile Communications Provider
MDF Site	Main Distribution Frame Site
MGW	Media GateWay
MNO	Mobile Network Operator
MPLS	Multi Protocol Label Switching
MSAN	Multi-Service Access Nodes
NGN	Next Generation Network
OSS	Operations Support Systems
OTN	Optical Transport Network
PE	Provider Edge
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephony Network
RADIUS	Remote Authentication Dial In User Service
SBC	Session Border Controller
SGW	Signalling GateWay
TDM	Time Division Multiplexing
UPS	Uninterrupted Power Supply
VoIP	Voice over Internet Protocol
VLAN	Virtual Local Access Network

6. Appendix A: Core Node Architecture

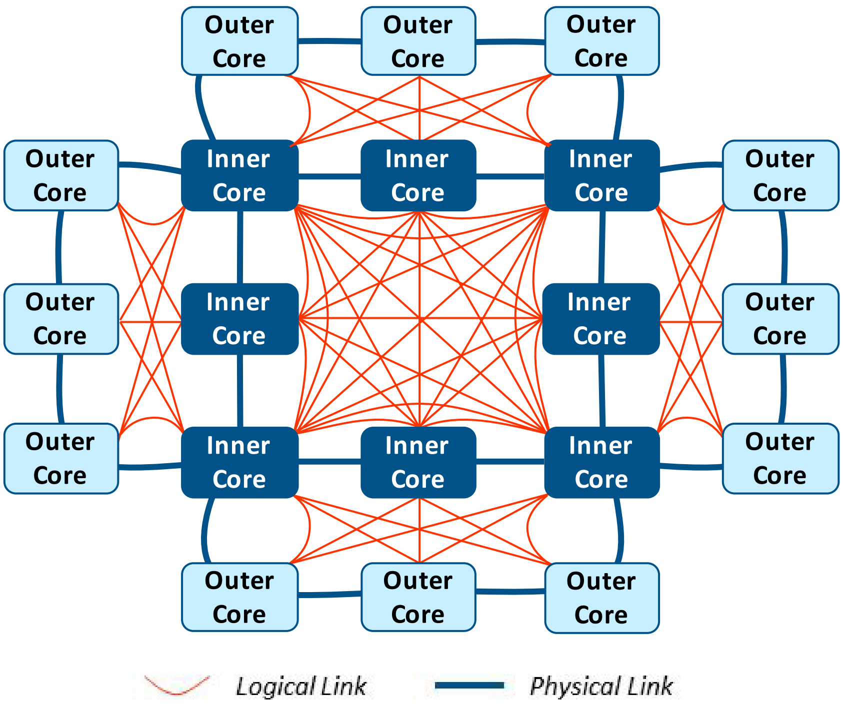
Architecture

6.1 The core network has been designed to balance inter-connectivity (which is beneficial for efficient routing and resilience) with cost.

6.2 The network core consists of 8 inner core nodes and 12 outer core nodes arranged in five physical OTN rings. One of these rings is dedicated to interconnecting the inner core nodes (the "inner ring"); the other four rings connect outer core nodes to inner core nodes (the "outer rings").

6.3 The network model does not explicitly distinguish between inner and outer core nodes. Average values are used to determine equipment volumes across both types.

Figure 19: Core Node Architecture



Input 1: Average Links Per Core Node

6.4 At the IP/MPLS layer, the inner core nodes are fully meshed; each inner core node logically connects to the other seven nodes of the inner core.

6.5 The outer core nodes are not fully meshed. At the IP/MPLS layer, each outer core node logically connects to three of the inner core nodes.

6.6 The model uses the average number of outgoing links per core node in the network dimensioning calculations. The average number of outgoing links can be determined by summing all links and dividing by the total number of core nodes (128/20 = 6.4). This is illustrated in the table below.

Figure 20: Outgoing Links per Node

<table>
<tr><th>Node Type</th><th>Number of Nodes</th><th>Ring Type</th><th>Outgoing Links Per Node</th><th>Total Outgoing Links Per Ring Type</th><th>Total Outgoing Links</th><th>Average Outgoing Links Per Node</th></tr>
<tr><td>Outer Core</td><td>12</td><td>Outer</td><td>3</td><td>36</td><td rowspan="5">128</td><td rowspan="5">6.4</td></tr>
<tr><td rowspan="2">Inner Core nodes on two rings</td><td rowspan="2">4</td><td>Outer</td><td>3</td><td>12</td></tr>
<tr><td>Inner</td><td>7</td><td>28</td></tr>
<tr><td rowspan="2">Inner Core nodes on three rings</td><td rowspan="2">4</td><td>Outer</td><td>6</td><td>24</td></tr>
<tr><td>Inner</td><td>7</td><td>28</td></tr>
</table>

Input 2: Average Rings per Core Node

6.7 Each of the 12 outer core nodes is connected to one ring each.

6.8 Of the inner core nodes, four connect to three rings, and four connect to two rings.

6.9 The average number of rings per core node is thus, [(12 x 1) + (4 x 3) + (4 x 2)] / 20 = 1.6.

6.10 The network architecture requires two OTN chassis per ring (one for the “east” direction and the other for “west”). There are therefore an average of 3.2 OTN chassis per core node.

Input 3: Core Nodes Per Core Transit

6.11 Traffic on the core network can take a variety of paths depending on its source and destination. Some of these paths may involve two, three or four core nodes.

6.12 Assuming traffic is evenly distributed across the core nodes, the average number of core nodes in a path across the core can be calculated as a simple weighted average. The data for this calculation are presented in the table below.

6.13 Thus, the weighted average number of nodes passed from transit originating in the inner core is 2.7 nodes.

Figure 21: Average Number of Core Nodes Passed in Transit

Source Node	Quantity	Destination Node	Quantity	Nodes Passed
Inner Node on two rings	4	Inner / same ring	7	2
		Outer / same ring	3	2
		Outer / other ring	9	3
Inner Node on three rings	4	Inner / same ring	7	2
		Outer / same ring	6	2
		Outer / other ring	6	3
Outer Node	12	Inner / same ring	3	2
		Inner / other ring	5	3
		Outer / same ring	2	2
		Outer / adjacent ring	6	3
		Outer / other ring	3	4

Input 4: Core Nodes Used per Transit to Internet Exchanges

6.14 Two core nodes link to the internet exchange. In order to minimise the average number of nodes transited to reach it from any other core node, these nodes should be on the inner ring. In addition, it is assumed that these two nodes are adjacent to each other.

6.15 The table below is used to calculate the weighted average number of core nodes transited to reach either of the two internet exchange-linked nodes.

Figure 22: Core Nodes Used per Transit to Internet Exchanges

Node Type	Nodes Passed	Quantity	Total	Average Number of Core Nodes Transited
Inner Core nodes	1	2	2	2.2
	2	12	24	
	3	6	18	

7. Addendum: Responses to Model Consultation Document

Overview

7.1 A number of stakeholder responses to Ofcom's consultation[21] were specifically focussed on the network cost module of the model. This section summarises these stakeholder comments and CSMG's responses.

7.2 Where applicable, we have combined similar points raised by multiple CPs and highlighted any relevant differences, if significant. Issues are discussed in no particular order.

Voice and Data Dimensioning

7.3 In its response, Everything Everywhere (EE)[22] questioned why voice is expressed in terms of volume per line whereas data is expressed in terms of peak usage. EE makes the point that in a cost model of this type it is important for there to be clarity around exactly what is driving cost (which has generally been considered to be peak usage in previous such models) and the relationship between voice and data as a result.

CSMG response

7.4 Voice is expressed in volumes per line to calculate the total output in MB per line. However voice is also expressed in terms of its peak bandwidth (kbps), and this is used for dimensioning purposes. Peak usage for both voice and data is used to dimension the network and drive associated costs.

Points of Interconnect (PoIs)

7.5 A number of CPs disagreed with the choice of 20 PoIs in the draft model. Some CPs argued that fewer PoIs should be used, whereas others argued the quantity should be increased.

7.6 ITSPA[23] and [✂][24] stated that a sufficient number of PoIs could be 6 or 7 to achieve the necessary level of coverage. ITSPA disagreed with Ofcom's concern that a reduced number of PoIs would have an impact on transmission times and efficiency and argued this would only be the case if the number of PoIs was reduced to 1 or 2. [✂] argued that the 27+2 PoIs specified by NGNuk was dictated by the OTA, BT and other large CPs and disregarded the views of many smaller CPs. It concluded that there was no requirement for 20 PoIs other than to fit BT's existing network topology.

7.7 Other CPs argued for a higher number of PoIs. [✂][25] proposed that the correct number should be 27+2, as although there was no requirement for so many, all CPs should have interconnection at these locations. CWW[26] argued that 28 (or 27+1) would be the correct number of PoI's as Aberdeen would no longer be required to be a PoI due to CWW's acquisition of Thus.

CSMG response

[21] http://stakeholders.ofcom.org.uk/binaries/consultations/narrow-band-market-review/summary/condoc.pdf
[22] Everything Everywhere response to the September 2012 Consultation, page 3
[23] ITSPA response to the September 2012 Consultation, page 2
[24] [✂] response to the September 2012 Consultation, page 2
[25] [✂] to the September 2012 Consultation, page 4
[26] CWW response to the September 2012 Consultation, page 8

7.8 The rationale for utilising 20 PoIs is that it is consistent with the 20 points of interconnect provided by BT for wholesale broadband connect (WBC), BT's 21C broadband service. However, the model functionality has been extended to allow sensitivity analysis on varying the number of PoIs (between a minimum of 1 and a maximum of 106).[27] A greater number of PoIs in the model now drives increased costs in terms of PoI equipment however it also results in less traffic crossing the core and therefore reduced capacity requirements in the core network (a greater proportion of off-net calls are single aggregation node).

Architecture of Interconnect Nodes

7.9 CWW believes[28] that there should be 28 Interconnect Nodes in the model. Of these, 17 should be located at the Core Nodes with remaining 11 at the Aggregation Nodes. CWW explains that these 11 aggregation interconnect nodes can be split into three different categories and that these should all be treated and modelled differently.

CSMG response

7.10 The model architecture assumes as a simplifying assumption that all the Interconnect Nodes (PoIs) in the model are treated equally and are co-located with the Aggregation Nodes.

Model Sensitivity

7.11 BT claimed in its response[29] that the model is relatively insensitive to volume changes, which suggests that the design used in the model is not as optimal as it could be and therefore service specific costs do not vary as much as they should do in relation to traffic volumes. BT suggest that this could be a reason for the relatively low Pure LRIC of call termination produced by the model. CWW also raised the level of insensitivity of some elements, with CWW specifically identifying the lack of sensitivity of call-servers, SBCs and back-haul transport equipment to traffic changes.

CSMG response

7.12 The insensitivity of the draft model to volume changes is primarily due to two factors. First, the hypothetical network in the model has full national coverage. In smaller exchanges, equipment quantities are driven by the minimum quantity per exchange for coverage, rather than capacity.

7.13 Second, the draft model included a highly distributed call server architecture. In combination with relatively high-capacity call servers, this led to over-dimensioning of call server capacity. In the revised model, the number of call-server locations has been reduced to address this issue. The model's sensitivity to changes in volume is discussed further in Annex 14.

Unit Capex and Opex Cost Trends

7.14 H3G noted[30] that the output capex cost trends in the "Output_Costs" which feed into the Economic module, refer only to the trend in equipment unit capex and ignore the trend in

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[27] This sensitivity analysis can be found in Annex 14.
[28] CWW response to the September 2012 Consultation, page 8
[29] BT response to the September 2012 Consultation, page 4
[30] H3G response to the September 2012 Consultation, page 7

total unit capex (including both equipment and implementation costs). The same applied for opex trends, which Three noted did not capture trends in electricity prices.

CSMG response

7.15 This was an error which has now been corrected. In the revised version of the model, the output capex trends incorporate labour cost trends, and the opex trends incorporate electricity prices, as well as underlying equipment price trends.

Busy Hour Relationships

7.16 CWW[31] claim that the modelled network busy hour traffic appeared to be merely the sum of the four individual busy hours of residential voice, residential data, business voice and business data (the model assumes concurrent busy hours for all four, all in the network busy hour). This would not necessarily be the correct level of traffic actually experienced in the network busy hour and may as a consequence be incorrectly dimensioning the network actually required to accommodate the peak load. Furthermore CWW noted that a CP with a business focus would have concurrent voice and data busy hours. Vodafone raised[32] a similar point in their response.

CSMG response

7.17 The network busy hour is based on an assumption of non-concurrent busy hours. Therefore the peak load on the network is based on load in the network busy hour and is not merely the sum of the voice busy and data busy hour. The model assumes that the network is operated by a CP with both business and residential consumers meaning the network busy hour is driven by residential broadband traffic. Therefore non-concurrent busy hours are appropriate. The use of multiple non-concurrent busy hours is explained in more detail in the revised documentation in paragraph 4.5.

Missing MPLS Edge Routers

7.18 [✂] pointed out[33] that some assets (e.g. data traffic MPLS edge routers) are omitted (at least according to the documentation, paragraphs 3.34 and 3.37).

CSMG response

7.19 The data traffic MPLS edge routers are not modelled as they are solely used for broadband services and do not drive voice costs. They are also not required by the model to dimension elements which carry voice traffic. For these reasons, MPLS edge routers have been omitted from the model, which is explained in the model documentation, in the sections referenced above.

Amount of inbound traffic

7.20 [✂] also pointed out[34] that the ratio of inbound (termination) traffic to outbound traffic should be consistent with market statistics and vary with the assumed market share of voice traffic (a small operator has relatively fewer calls on-net and consequently more inbound traffic).

[31] CWW response to the September 2012 Consultation, page 6, paragraph 3.5
[32] Vodafone response to the September 2012 Consultation, page 6
[33] [✂] response to the September 2012 Consultation, page 5
[34] Ibid., page 7

CSMG response

7.21 The call split estimates have been changed to properly account for the 50% "steady state" market share of the modelled CP. For example, the proportion of total calls that are on-net is assumed to be the square of the market share, as it is assumed that there is no bias towards calling on-net. A sensitivity has been included in the model that allows the "steady state" market share of the modelled CP to be changed. As the call splits are driven by the assumed market share, changing the market share assumption also changes the call splits.[35]

7.22 Once set, the call splits between outbound and inbound are held constant through the lifetime of the model as a simplifying assumption.

Upstream and Downstream Traffic

7.23 [✂] also suggested[36]: "that the way in which the asymmetry of upstream and downstream data traffic is taken into account in the model leads to a mis-allocation of costs between voice (symmetrical) and data (asymmetrical) services, at least for assets where there is a clear upstream/downstream direction (e.g. in the backhaul and aggregation network). Services should be allocated relevant asset costs based on the peak capacity required, given by the maximum of the up and downstream needs, rather than on the basis of 'total MB sent and received'".

CSMG response

7.24 Asymmetry of traffic is taken into account for output (work done) but not for dimensioning. Peak capacity requirement is used for dimensioning, which is aligned with [✂] proposed methodology.

Utilisation

7.25 [✂] suggested[37] that a maximum asset utilisation level of 70% (as used in the model) could be too conservative and that a maximum utilisation figure nearer 80% could be justified.

CSMG response

7.26 70% utilisation was supported by the weighted average of responses provided by CPs as part of Ofcom's information request. However, there was a reasonably wide range of responses provided by CPs for this, and therefore a sensitivity has been included to allow this utilisation percentage to be easily changed.[38]

Model Start-date

7.27 BT stated[39] that the model start-date of 2005 is not appropriate and that the start date of the model should coincide with the start of the new review period. In addition BT makes the point that the model utilises elements which were not available in 2005 (e.g. 100GE core routers).

CSMG response

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[35] This sensitivity analysis can be found in Annex 14.
[36] [✂] response to the September 2012 Consultation, page 5
[37] [✂] further response to the September 2012 Consultation, page 4, paragraph 22
[38] The model was found to be relatively insensitive to changes in asset utilisation, so this sensitivity has not been included in Annex 14.
[39] BT response to the September 2012 Consultation, page 14, paragraph 10.14

7.28 A sensitivity has been included to understand the impact of moving the start date forwards to 2009 (the beginning of the last review period) or 2012 (the beginning of the new review period).[40] Based on evidence we have collected regarding the time of NGN deployment in the UK, we now believe that a 2007/08 start date is appropriate.

Year-end vs. Year-average Assets

7.29 [✄] pointed out[41] that the model uses year-end rather than year-average assets. [✄] suggested that opex should be driven by year average assets and that there is thus probably slightly too much opex as a result.

CSMG response

7.30 The in-life opex formula from 2006/07 onwards has been changed to use the average of the year's asset base rather than the end-of-year asset base. The retirement opex calculation remains unchanged.

Erlang Table Lookup Error

7.31 [✄] has indicated[42] an error in the Erlang table which results in an incorrect look-up. BT also identified and raised this error. The formula using the call blocking percentage input resulted in a look-up on the Erlang table that pointed to an incorrect column, causing the wrong "Erlangs carried" value to be chosen.

CSMG response

7.32 This error has been investigated and fixed; the Erlang table look-up is now correct as the correct column is now referenced by the formula.

NGN Migration Profile

7.33 BT noted[43] that the Ofcom model assumes 62% of users are acquired by the NGN operator in the first year, with the remainder acquired over 10 years. BT believed this was unrealistic and that building up over 5 years would be more appropriate for a new entrant or for a TDM operator migrating to NGN.

CSMG response

7.34 The migration profile in the revised model has a more modest and gradual initial migratory phase followed by a rapid increase in exchange line migration in subsequent years, with an overall shorter migration period than before (rollout happens over 4 (with a 1 year lag before services are launched) rather 10 years). This reduction in the migration period was based on further research on the amount of time it has taken for other national NGNs to deploy.

Voice Codec

[40] This sensitivity anlaysis can be found in Annex 14.
[41] [✄] response to the September 2012 Consultation, page 8, paragraph 3.1.1
[42] Ibid., page 8, paragraph 3.1.2
[43] BT response to the September 2012 Consultation, page 14, paragraph 10.15

7.35 CWW[44] and Vodafone[45] has stated that a lower bit rate codec will be adopted as a long term outcome to increase network efficiency, and so, it may be more reasonable to model the voice codec in use as a declining variable across time, rather than a constant. This issue was raised by CWW as well.

CSMG response

7.36 Functionality has been included in the model showing the transition from the higher bit rate G.711 codec (135kbps) to lower bit rate G.729 (72kbps) codec in the updated model. However, as it is still uncertain, if, when and for how long such a transition would occur the base case scenario still assumes no transition between codecs.

Network Architecture - Nodes

7.37 [✂] believe[46] that the network architecture concerning the numbers of super access, aggregation and core nodes are too arbitrary and do not reflect an efficient NGN network.

CSMG response

7.38 The network has been modelled using a 'scorched node' approach, based on existing network node locations. Thus, the number of BA nodes in the model is pre-determined and based on the existing distribution of node sites. In considering the location of higher level nodes, we took account of the network architecture of BT in deploying its NGN (noting that whilst it has not deployed voice services on this network, it has deployed other services such as broadband). Whilst there may be more flexibility in the location of higher level nodes than in the location of the BA nodes (which are fixed in the scorched node approach), we think that the architecture of the model is not arbitrary, but represents a reasonable approach to the location of nodes that would be implemented in an efficient national NGN, supporting multiple services.

TDM Interconnection

7.39 Vodafone has highlighted[47] that the model currently assumes that 40% of all interconnecting traffic will remain TDM in perpetuity and that this is counter-intuitive. Vodafone believes it may be more reasonable to match the interconnecting TDM proportion to the proportion of the modelled operator's traffic that is on TDM, i.e. a percentage that falls to 0% once it can be assumed that all efficient fixed operators have adopted NGN. This issue was also raised in CWW's response.

CSMG response

7.40 Decreasing the proportion of interconnecting TDM traffic in the model decreases the requirements for media gateway and signalling gateway equipment, however it increases the requirements for session border controllers. As discussed in Annex 11, we are no-longer including the cost of TDM interconnection in the termination or origination costs stack. Consequently, the proportion of interconnecting TDM traffic has not impact on the model outputs.

Unit Prices Adjustment

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[44] CWW response to the September 2012 Consultation, paragraph 3.8
[45] Vodafone response to the September 2012 Consultation, page 5
[46] [✂] response to the September 2012 Consultation, page 1
[47] Vodafone response to the September 2012 Consultation, page 5

7.41 CWW believes[48] that in selecting unit prices for the modelled network operator there may need to be a downward adjustment to reflect the prices that would ensue if the modelled operator and all other operators were in practice buying NGN equipment, rather than maintaining service on legacy equipment.

CSMG response

7.42 Many CPs are already buying NGN equipment and so, it is unlikely that the market for network equipment would see any significant price decreases as a result of the move to NGN. Furthermore any price decrease due to local activity would assume that the network equipment market is priced at the local level, whereas equipment pricing may be based on a global basis. No change has therefore been made to the unit prices of NGN equipment.

Use of Openreach Products

7.43 BT have suggested[49] that we consider the use of "Openreach EOI [Equivalence of Inputs] costs where appropriate," in order to "reflect the network choices new entrants are likely to make." In its response[50] to the second round of S135 information requests conducted for this model, BT provided EOI costs for relevant Openreach products for the purpose of this analysis.

CSMG response

7.44 An analysis has been conducted to enable the comparison of the cost of building backhaul capability in the model to the costs that a new entrant might incur if they were to purchase Openreach products on an EOI basis. The analysis represented a scenario where the existing OTN connections (1 GE and 10GE) in the model were replaced with similar EBD (Ethernet Backhaul Direct) products from Openreach. For the purposes of this analysis, the cost of fibre and duct were not included. Additionally, 100GE OTN connections in the core were also not included as part of the analysis.

7.45 The results showed that the difference in cost of buying and using Openreach EBD was around 10% compared to the new entrant building and owning the backhaul itself.

[48] CWW response to the September 2012 Consultation, paragraph 3.9
[49] BT response to the September 2012 Consultation, page 7, paragraph 5.2
[50] BT response to the October 2012 S135 Information Request

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