ANNEX 7

Fixed Narrowband Market Review: NGN Cost Modelling

Model Documentation

v3

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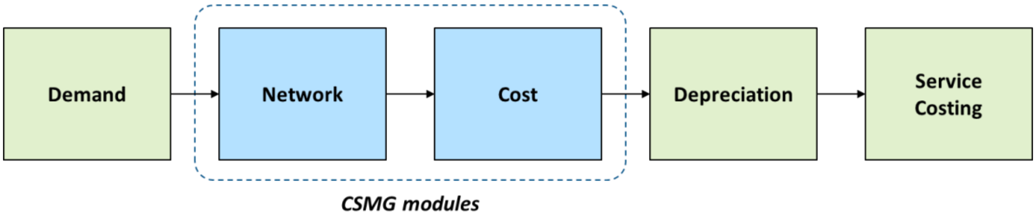
Table of Contents

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.[1] 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 Two earlier versions of this document have been published in support of Ofcom's Narrowband Market Review. The first of these was published in September 2012 as part of Ofcom's consultation on possible approaches to cost modelling ("the September 2012 consultation").[2] A further document was published as part of Ofcom's narrowband market review consultation in February 2013 ("the February 2013 consultation").[3]

1.5 Based on responses received from stakeholders to the February 2013 consultation, the model documentation has been revised in this version. An addendum has also been included which lists relevant points raised by stakeholders to the February 2013 consultation on the model documentation and model, and CSMG's responses.

[1] These modules are combined in the 2.Network.Cost.xlsm workbook.

[2] "Consultation on possible approaches to cost modelling for the Network Charge Control for the period 2013-2016", Ofcom, 28 September 2012. http://stakeholders.ofcom.org.uk/consultations/narrowband-market-review/

[3] "Review of the fixed narrowband services markets, Consultation on the proposed markets, market power determinations and remedies", Ofcom, 5 February 2013. http://stakeholders.ofcom.org.uk/consultations/nmr-13/

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). Analogue exchange line and Integrated Services Digital Network (ISDN) call volumes are used to dimension the modelled network.[4]

2.6 Voice interconnection with other Communication Providers (CPs) is IP-based. The network also includes Time Division Multiplexing (TDM) gateways to interconnect with the hypothetical operator's legacy TDM network during the transition to NGN voice.

2.7 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").

2.8 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 its 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 its own customers.

Timeframe

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

2.10 The model has the functionality for network build to start in 2005/06. However, we assume network build to start in 2007/08.[5] During the network build phase a number of exchanges

[4] Although it may not be possible to fully replicate today's services on an NGN, we use the aggregate call volume to dimension the network as this demand would need to be satisfied through the call services that are ultimately provided.
[5] In its response to the February 2013 consultation, BT did not agree with the proposed start date of the model, for more information see the Addendum in Section 7.

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 2010/11.[6,7]

Existing Assets

2.11 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.

2.12 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

2.13 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. Ongoing opex costs for these items are estimated and applied in the same manner.

2.14 Costs for duct, fibre and some additional property costs 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.

[6] There is a 1 year lag between an exchange being covered by the network and services being offered from that exchange. Consequently, the first year in which the NGN carries traffic is 2008/09 and the time taken from the start of the network build process until the modelled CP can offer services from all exchanges is 5 years.

[7] The build process in the draft model released in September 2012 was assumed to take 10 years. After reviewing stakeholder responses to the September 2012 consultation, this was changed to 4 years. For more information, please see para 7.33 of Annex 13 of the February 2013 consultation.

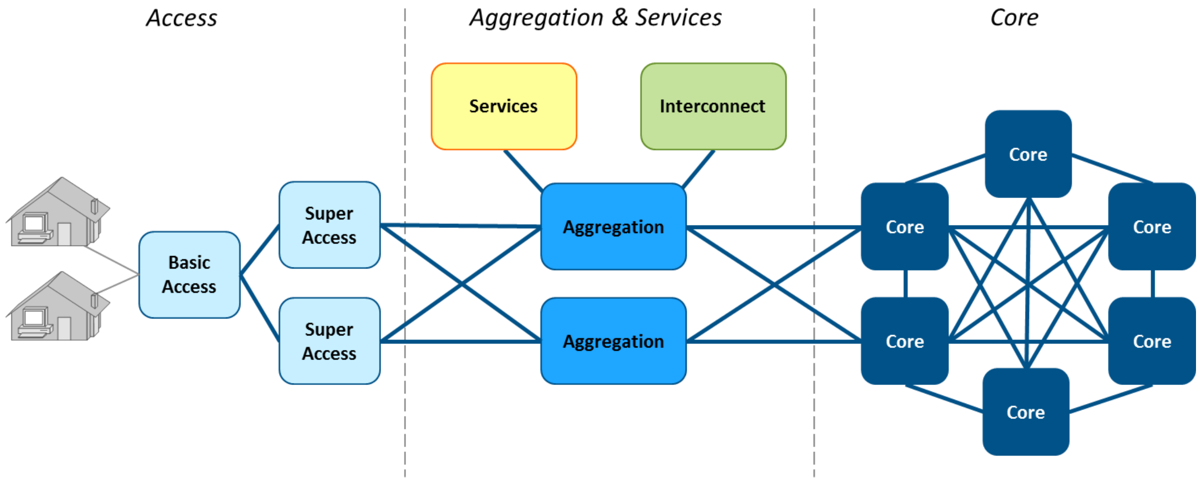
3. Network Architecture

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 illustrative overview of the network architecture showing the relationship between the logical nodes.

Figure 2: NGN Network Logical Architecture[8]



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 and future

[8] The diagram is a simplified representation of the network and does not show all nodes. See Appendix A for discussion on the connectivity between core nodes.

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.

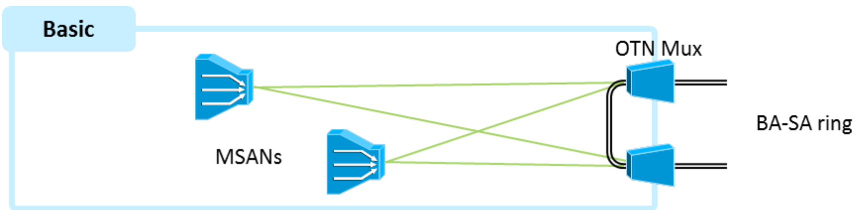
Basic Access Node

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.

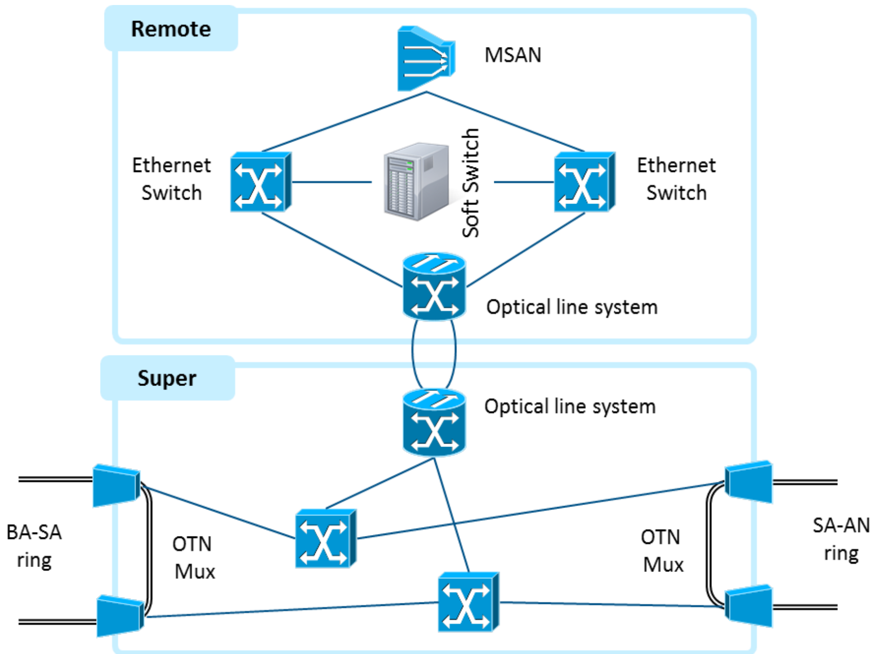
3.16 **Optical Transport Network (OTN) Multiplexer**: The OTN Multiplexer enables multiple point-to-point connections to be set up over a fibre ring. The OTN provides Gigabit Ethernet ports for connection to the MSANs and 10Gbps Ethernet ports for aggregating the traffic on the ring. OTN multiplexers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

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 a nationwide voice network. In the case of BT's existing network this function is currently provided by UXD5 switches at a similar number of locations.

Figure 4: Remote Access Node and Corresponding Super Access Node



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 softswitch 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, softswitch 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.[9]

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

Super Access Node

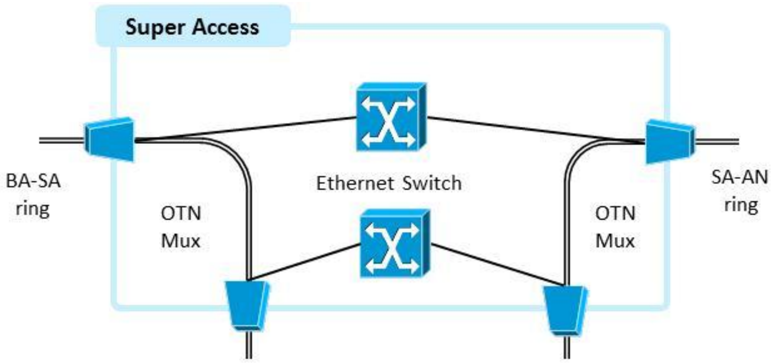
3.23 The Super Access (SA) Node sits between, on the one hand the BA and RA Nodes and, on the other, the Aggregation Node (AN) in the network hierarchy and aggregates traffic from the BA Nodes. All SA Nodes are dual-parented to ANs.

3.24 Each SA Node is co-located with a BA Node (for simplicity, co-located nodes are not shown in Figure 5 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).

[9] Note that for convenience in the model, both ends of the OLS connection are captured on the sheet which dimensions the Remote Access Node.

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.

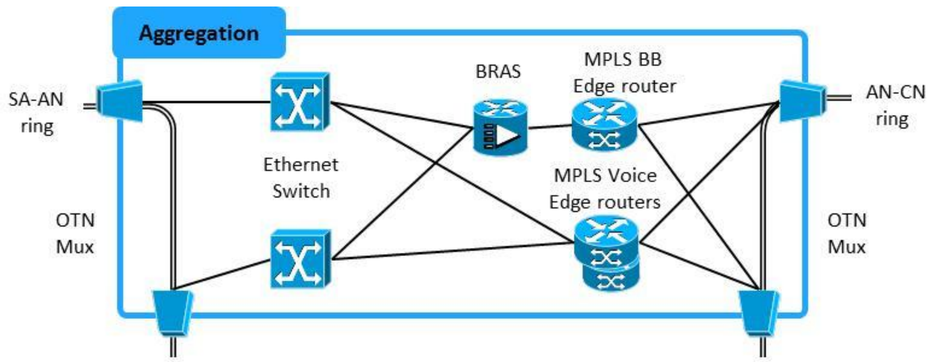
3.31 Voice and broadband traffic are separated in the AN by an Ethernet switching layer. Voice traffic is switched directly to MPLS Edge routers, whilst broadband traffic is directed via Broadband Remote Access Servers (BRAS).

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.[10] 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.

[10] For further information see para 7.19 of Annex 13 of the February 2013 consultation

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.

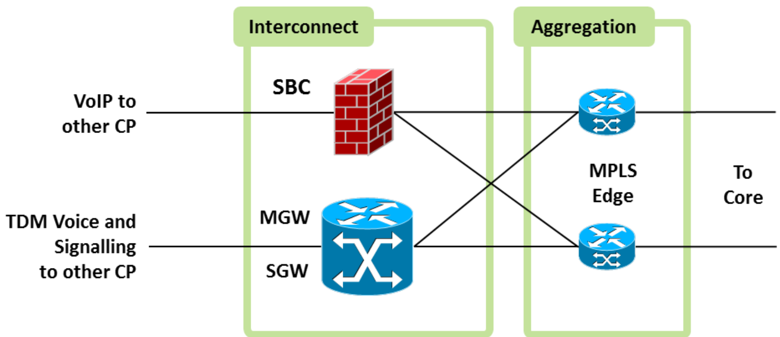
3.39 It is common practice in nationwide voice networks to have multiple, geographically-diverse points of interconnection (PoI) to enable efficient routing of voice calls between networks and provide redundancy in the event of a node failure. In specifying the quantity of INs, a trade-off is made between 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).[11]

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.

[11] Some stakeholders suggested a different number of interconnect nodes should be used in the model. For further details see para 7.5 of Annex 13 of the February 2013 consultation.

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 costs in the model. The IP interface of the MGW is Gigabit Ethernet. The TDM interface of the MGW is channelized STM-1.[12] 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 physical SNs in the modelled network, each co-located with an AN. SNs are connected to the network via 10GE to the MPLS edge routers in the AN with which the SN is co-located.

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

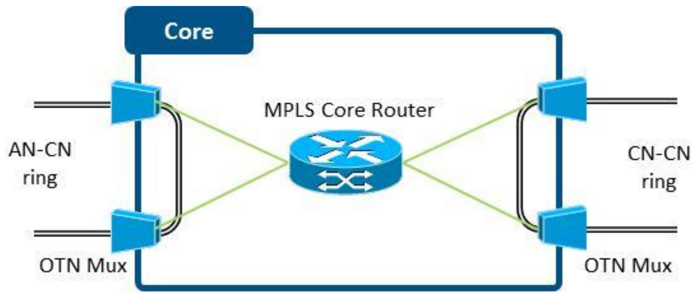
3.54 The role of the Core Node (CN) is to transport traffic between ANs. There are 20 CNs in the modelled network, each co-located with an AN.

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 outer 12 CNs are

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

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

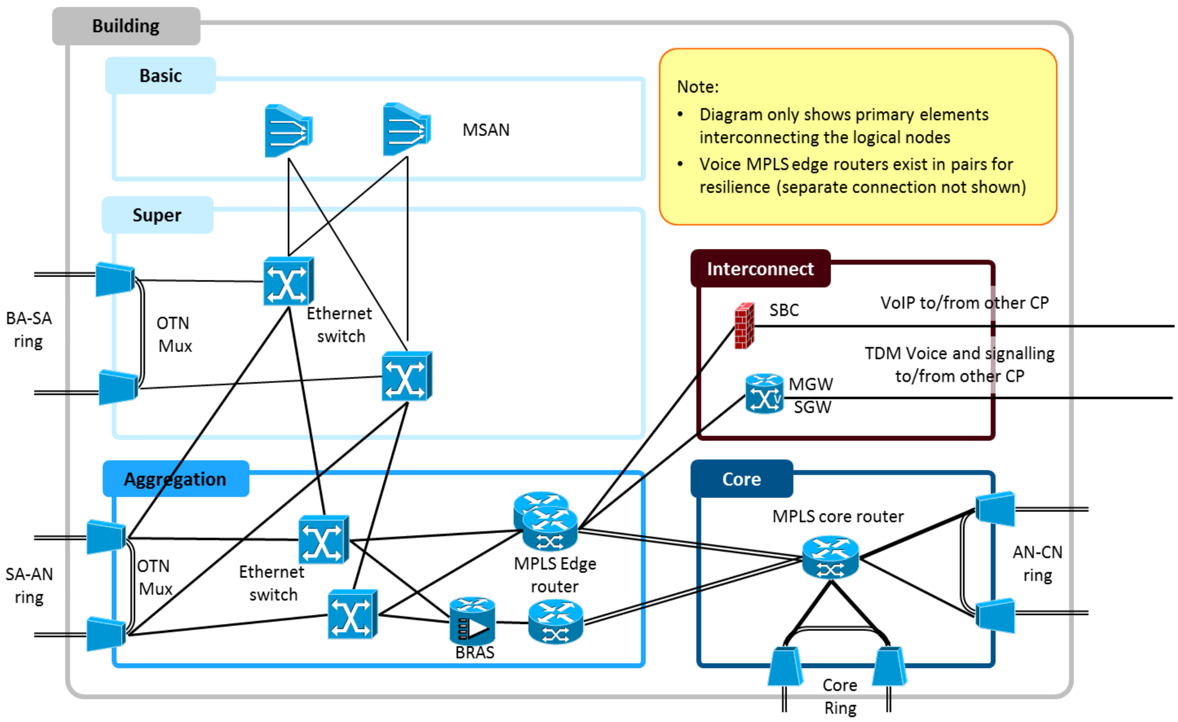
3.56 **MPLS Core Router**: MPLS core routers forward MPLS packets from one edge router towards another edge router. The MPLS core routers have 10Gbps Ethernet interfaces facing the edge routers and for core-core interconnection.

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[13]) – 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
Transit calls (Cross-Core)	IN – AN – CN* – AN – IN

[13] The service nodes modelled in the network are co-located with ANs. Two instances of this co-located combination exist in the network.

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

3.66 Figure 10 does not include signalling pathways which, for the purposes of billing and the provision of 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).

4. Model Implementation and Assumptions

Overview of Network and Cost Modules

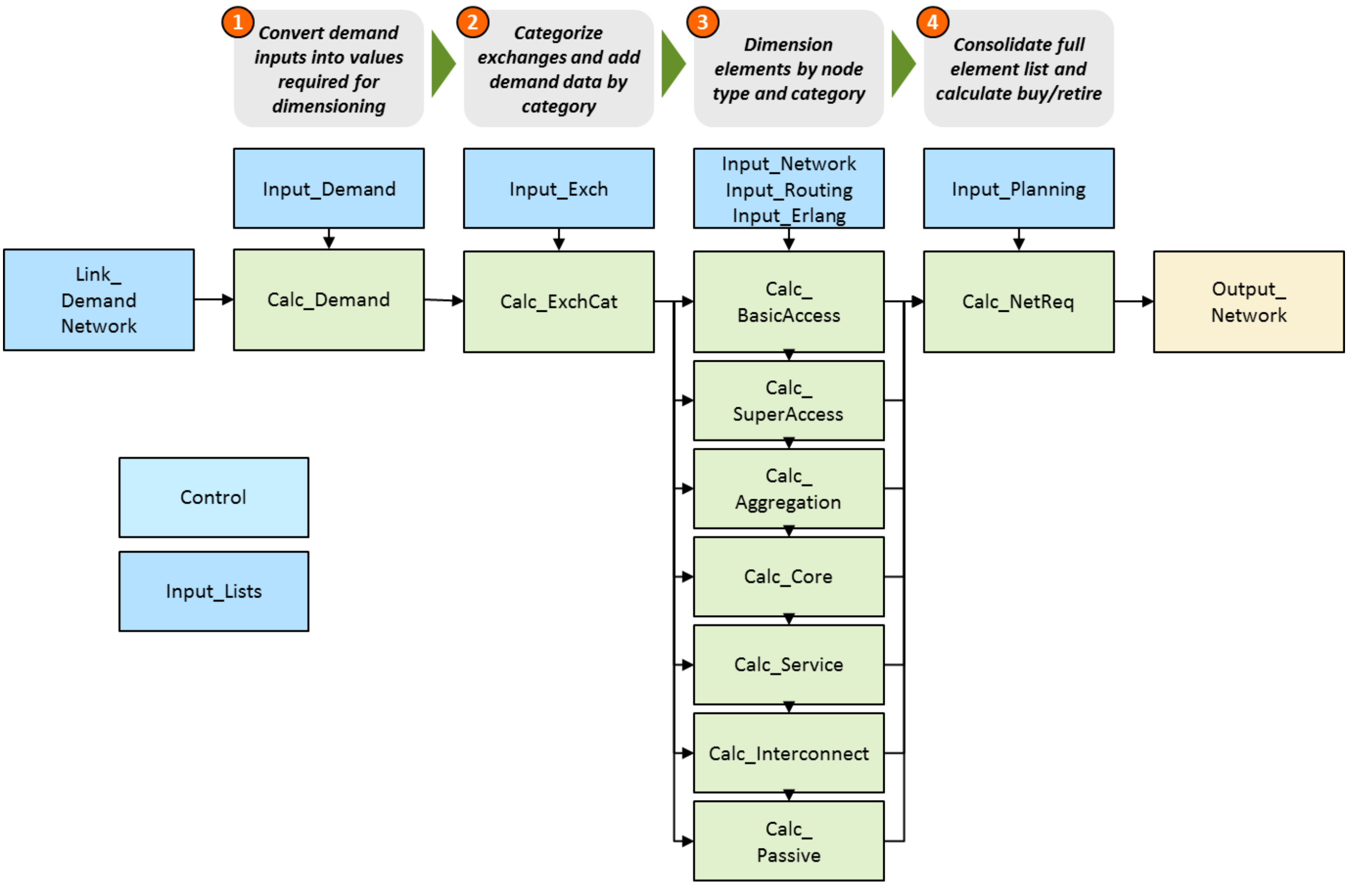
4.1 As outlined in the introduction to this document, CSMG has developed two modules (the Network and Cost modules) that are components within Ofcom's NCC model.[14] The Network module takes the traffic demand forecasts from the demand module and dimensions a network to carry this traffic. The Cost module 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



[14] 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: a voice busy hour (for voice only traffic) and a network busy hour (that considers both voice and data traffic).[15] 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 in each direction at the IP layer, based on the use of a G.711 codec.[16,17]

4.7 The model assumes there are 1.45 call attempts per successful call to account for unsuccessful calls (31% 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.[18]

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 categories 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**
i	25000 – 30000	**70**

[15] For further information on busy hour relationships, see para 7.17 of Annex 13 of the February 2013 consultation
[16] This includes IP and transport headers and is based on a sample interval (i.e. packetisation delay) of 10ms
[17] Some stakeholders suggested that bandwidth requirements would decrease as industry transitioned to new lower bandwidth codecs such as G.279.However it is still uncertain, if, when and for how long such a transition would occur. For more information, see para 7.36 of Annex 13 of the February 2013 consultation.
[18] 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

j	30000+	**66**
Total		**5,581**

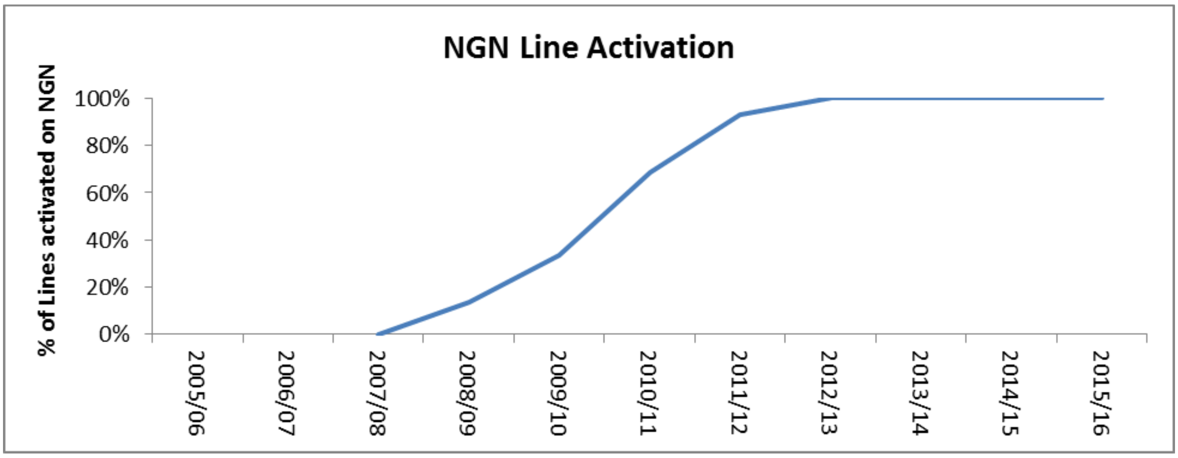
4.9 The higher-order nodes (i.e. SA, AN and CN) are co-located with the BA nodes. In the BT 21CN design, the selection of exchange buildings to house the higher-access nodes is a function of factors such as available space, power and redundant cable entry points plus geographic location. In line with 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 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:

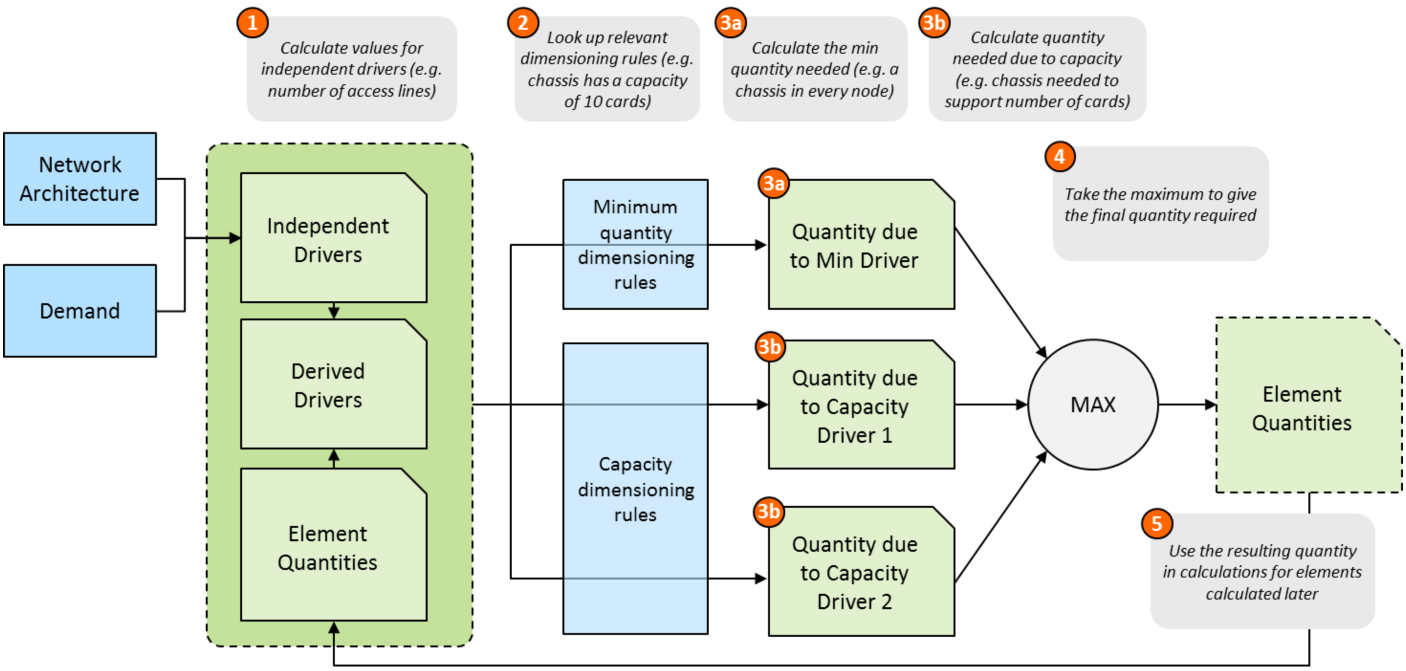
- MinDriver is the minimum number of an element that is required by the network architecture, independent of demand (i.e. the minimum quantity of a network element that would be required if there was no network traffic).
- Two capacity drivers - CapacityDriver1 and CapacityDriver2 - which identify the 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 The model uses a capacity utilisation threshold of 70% for components which are dimensioned directly by demand drivers, for example the bandwidth of a network port.[19]

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, independent of network load or topology.[20]

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.

[19] For more information, please see Addendum para 7.6.
[20] 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 the September 2012 consultation and the February 2013 consultation.

Figure 15: Asset Lifetimes by Equipment Type

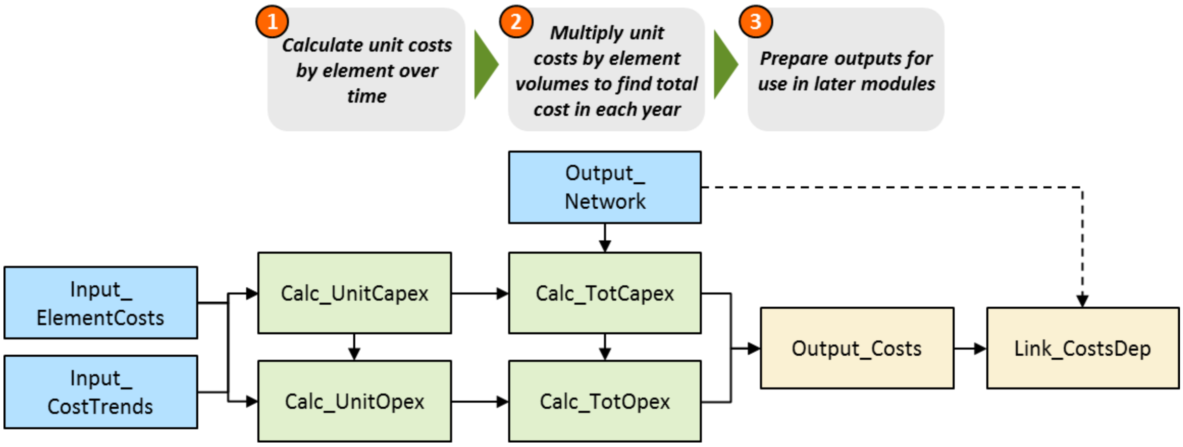
Equipment Type	Asset Lifetime in Model (Years)
OTN	8
MSAN	5
Routers & Switches	5
Synchronisation Sources	10
Rack	10
SBC, MGW & SGW	8
Servers & Software	5
Cabling	10

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.

Cost Module

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 six cost trend categories in the model. The historic cost trend assumptions by category are shown in Figure 17 below.[21]

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	-1%	-1%	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	-3%	-3%	Based on IDC forecasts and CP responses to information requests
Passive Equipment	0%	0%	Based on IDC forecasts and CP responses to information requests
Labour	-3.5%	-3.5%	CSMG Assumption

[21] We flatten the capex and opex trend for forecast periods. By 2026/27 all cpex and opex trends are flat (i.e. 0% in real terms).

4.24 The model uses the Retail Price Index (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 2012/13 prices) for each network element. These CSMG estimates are based on industry benchmarks and have been refined based on CP responses to Ofcom information requests and responses to the September 2012 consultation and the February 2013 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.[22] 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 Operations and Business Support Systems (OSS/BSS) in the model. OSS/BSS support fulfilment, assurance and billing processes for voice and data services. We have modelled OSS/BSS costs with a fixed cost component based on per-subscriber data received from CP information requests. We have also incorporated the cost of pre-launch feasibility tests for the network into the OSS/BSS costs.

Figure 18: Network Element Capital Costs

Asset	Example Asset Name in Model	2012/13 Capex (2012/13 prices)(£)
MSAN Chassis	BA_MSAN_Chassis	10,000
MSAN GE client card	BA_MSAN_GE client card	500
MSAN Voice Gateway	BA_MSAN_Voice gateway	1,000
OTN GE client port	BA_OTN_GE client port	300
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	4,500
OTN Chassis	BA_OTN_Chassis	8,000
Sync Primary	CN_Sync_Primary	40,000

[22] 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. As discussed in Annex 12 of the February 2013 consultation, capitalising the retirement cost and including it in the total capital expenditure is considered to be more consistent with the application of Original Economic Depreciation.

Switch GE client port	SA_Switch_GE client port	65
Switch GE client card	SA_Switch_GE client card	4,500
Switch 10GE client port	SA_Switch_10GE client port	250
Switch 10GE client card	SA_Switch_10GE client card	5,500
Switch Chassis	SA_Switch_Chassis	6,000
Edge 10GE port	AN_Edge_10GE port (client side)	1,500
Edge 10GE card	AN_Edge_10GE card (client side)	16,000
Edge Chassis	AN_Edge_Chassis	30,000
OTN 100 GE line card	CN_OTN-S_100GE line card	30,000
OTN 100 GE client card intrasite	CN_OTN-N_100GE client card intrasite	20,000
Core MPLS 10GE client port	CN_MPLS_10GE client port	4,500
Core MPLS 10GE client card	CN_MPLS_10GE client card	50,000
Core MPLS 10GE line card	CN_MPLS_10GE line card	50,000
Core Router Chassis	CN_Router Chassis	70,000
Call Server	SVC_Call Server	5,000,000
Directory Server Hardware	SVC_Directory Server_Hardware	15,000
Directory Server Software licence (per voice subscriber)	SVC_Directory Server_Software licence	0.15
Voicemail Server Hardware	SVC_Voicemail Server_Hardware	500,000
OSSBSS Fixed	SVC_OSSBSS_Fixed	50,000,000
Session Border Control GE line card	IN_Session Border Control_GE line card	4,500
Session Border Control Chassis	IN_Session Border Control_Chassis	80,000
Session Border Control Software licence	IN_Session Border Control_Software licence	20,000
Media Gateway GE line card	IN_Media Gateway_GE line card	15,000
Media Gateway TDM line card	IN_Media Gateway_TDM line card	25,000
Media Gateway Chassis	IN_Media Gateway_Chassis	20,000
Media Gateway Software licence	IN_Media Gateway_Software licence	50,000
Signalling Gateway Software licence	IN_Signalling Gateway_Software licence	350,000
Softswitch	RA_Softswitch	10,000
OLS GE client port	RA_OLS_GE client port	3,000
OLS GE line port	RA_OLS_GE line port	3,000
OLS Chassis	RA_OLS_Chassis	3,000
Cabling	SA_Cabling	150
Racks	BA_Rack	7,500

Unit Operating Costs

4.31 Operating costs (excluding power) for each network element in the model are assumed to be 14%[23] of capital costs.

4.32 We calculate the cost of power based on power usage per network element and the trended cost per kWh in the UK for industrial power supply. Power cost inputs are based on several data sources including CP-provided cost estimates and Eurostat data. 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.

[23] Some specific assets have opex percentages where the evidence we have collected from CPs suggests this is appropriate.

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

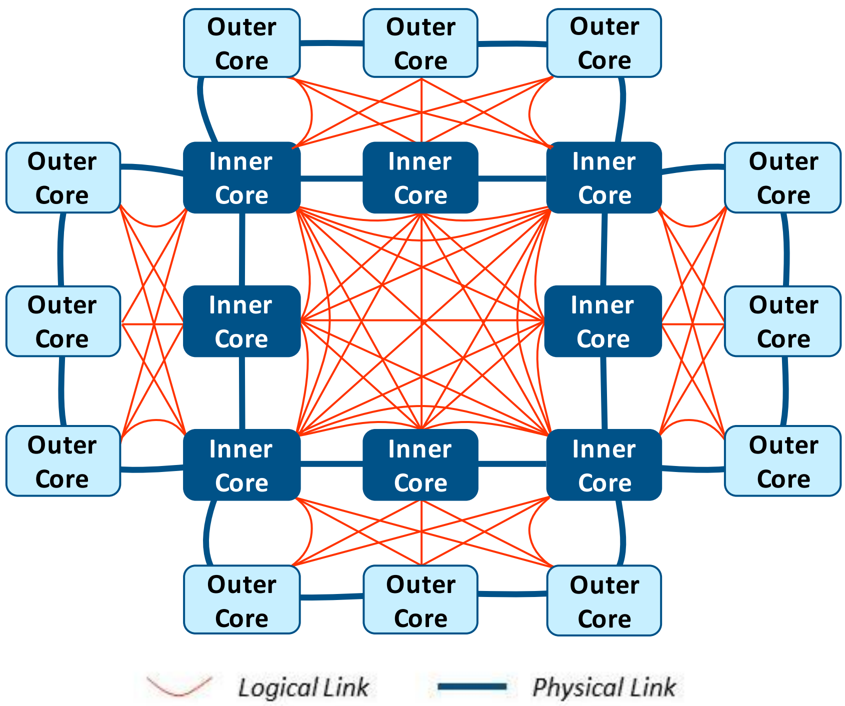
Architecture

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 Logical 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 (Figure 21).

6.13 Thus, the weighted average number of nodes passed from transit originating at a core node is 1068 / 400 = 2.67 nodes.[24] This probability is used in the routing table calculations as a routing factor input for multiple core nodes passed (“Multi CN”).

[24] For calls that route across multiple core nodes, the number of core nodes passed is 1048/380 = 2.76. This is derived from tha table below, excluding the cases where a single core node is passed.

Figure 21: Average Number of Core Nodes Passed in Transit

<table>
<tr><th>Source Node</th><th>Quantity</th><th>Destination Node</th><th>Quantity</th><th>Routes (Source x Destination)</th><th>Nodes Passed</th><th>Routes x Nodes Passed</th></tr>
<tr><td rowspan="3">Inner Node on two rings</td><td rowspan="3">4</td><td>Inner / same ring</td><td>7</td><td>28</td><td>2</td><td>56</td></tr>
<tr><td>Outer / same ring</td><td>3</td><td>12</td><td>2</td><td>24</td></tr>
<tr><td>Outer / other ring</td><td>9</td><td>36</td><td>3</td><td>108</td></tr>
<tr><td rowspan="3">Inner Node on three rings</td><td rowspan="3">4</td><td>Inner / same ring</td><td>7</td><td>28</td><td>2</td><td>56</td></tr>
<tr><td>Outer / same ring</td><td>6</td><td>24</td><td>3</td><td>48</td></tr>
<tr><td>Outer / other ring</td><td>6</td><td>24</td><td>3</td><td>72</td></tr>
<tr><td rowspan="5">Outer Node</td><td rowspan="5">12</td><td>Inner / same ring</td><td>3</td><td>36</td><td>2</td><td>72</td></tr>
<tr><td>Inner / other ring</td><td>5</td><td>60</td><td>3</td><td>180</td></tr>
<tr><td>Outer / same ring</td><td>2</td><td>24</td><td>3</td><td>72</td></tr>
<tr><td>Outer / adjacent ring</td><td>6</td><td>72</td><td>3</td><td>216</td></tr>
<tr><td>Outer / other ring</td><td>3</td><td>36</td><td>4</td><td>144</td></tr>
<tr><td>All Nodes</td><td>20</td><td>Same CN</td><td>1</td><td>20</td><td>1</td><td>20</td></tr>
<tr><td colspan="4">Total</td><td>400</td><td></td><td>1068</td></tr>
</table>

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 (Figure 22) 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 THE FEBRUARY 2013 CONSULTATION

Overview

7.1 A number of stakeholder responses to Ofcom's February 2013 consultation specifically focussed on the network cost module of the model ("the February 2013 NCC model").[25] This section summarises these stakeholder comments and details CSMG's responses.

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

MSAN Costs

7.3 MSAN access cards and voice gateways have zero cost in the February 2013 NCC model. BT argued that this is incorrect as they are involved in call setup and teardown.[26]

CSMG response

7.4 We agree with BT that the voice gateways are included in call control and therefore it is correct to include them in the cost model. The model assumptions regarding the dimensioning and cost of voice gateways are based on data received from CPs through information requests and third-party sources of information on MSANs. Analysis of this data determined that the number of subscribers is the principal driver of voice gateway volumes. Procuring voice gateways to meet a given number of subscribers will provide sufficient capacity to serve the expected busy hour call volume and busy hour call attempts of those subscribers.

7.5 MSAN access cards, as part of the access network, are outside of the scope of the model, and any functionality relevant to the core network that they possess are assumed to be incorporated into the costs and functionality of the MSAN voice gateways and chassis.

Utilisation Assumptions

7.6 Vodafone considers that adopting a utilisation assumption of 70% is too conservative and believes that 80% would be more appropriate.[27]

CSMG response

7.7 The previous utilisation analysis was refreshed using the latest available model and CP-provided data. It was determined that the current utilisation assumption of 70% remains appropriate for the model based on the information received.

Average Busy Hour Call Length

7.8 Three disagrees with the change from average call length of 4 minutes (in the September 2012 NCC model) to 1.3 minutes (in the February 2013 NCC model), as 4 minutes is corroborrated by Three's internal research.[28]

CSMG response

[25] http://stakeholders.ofcom.org.uk/binaries/consultations/narrow-band-market-review/summary/condoc.pdf
[26] BT response to the 2013 February consultation, para 9.95.
[27] Vodafone response to the 2013 February consultation, page 37.
[28] Three response to the 2013 February consultation, page 16.

7.9 This issue has been further investigated. Based on further information gathered from CPs relating specifically to the average call length in the busy hour only (as opposed to the average call length across all hours), the average call length in the busy hour has been increased to 2.9 minutes.

Routing Table Inputs

7.10 Three states that the model has some hardcoded numbers in the routing table, which had been calculated in the September 2012 NCC model, and was unclear whether the hardcoding is intentional.[29]

CSMG response

7.11 The routing table has been amended to ensure that all hardcoded and calculated values are marked correctly. An additional section showing routing factor probabilities has been included above the routing table to make the routing table factor calculations more transparent.

Core Node Dimensioning

7.12 Three states that Aggregation Nodes are correctly driven by the data busy hour but that the same is not true of Core Nodes.[30]

CSMG response

7.13 The Calc_Core sheet has now been corrected to be driven by the proportion of voice minutes in the data busy hour.

Redundancy Headroom

7.14 Three questions why interconnect circuits have an additional 20% redundancy headroom built in. It is unclear to them why this is the case only for interconnect.[31]

CSMG response

7.15 In general, the modelled network is dimensioned with 1+1 redundancy to provide capacity for fail-over in the event of a network failure. For the interconnects, the 20% redundancy headroom fulfils the same objective. The reason for a lower capacity (20% versus 100%) is that traffic can be distributed across multiple interconnects in the event that one fails.

Power Costs

7.16 BT considers power costs to be exceptionally low in the February 2013 NCC model. BT claims that these costs should be approximately 11p/kWh, where they are 5p/kWh in the February 2013 NCC model.[32]

CSMG response

7.17 This issue has been investigated and we found that power costs were indeed understated. These inputs have been corrected, based on analysis using multiple data sources (e.g. data requested from CPs and Eurostat power trend data).

[29] Three response to the 2013 February consultation, page 16.
[30] Three response to the 2013 February consultation, page 17.
[31] Three response to the 2013 February consultation, page 18.
[32] BT response to the 2013 February consultation, para 9.99.

Plant Equipment Costs

7.18 BT believes that while power and cooling are modelled, their associated capital costs in the form of equipment has not been modelled. According to BT, indicative costings based on the Openreach LLU price list indicate that these costs have been under-estimated by at least £2,000 per annum per rack.[33]

7.19 BT also points out that Super Access Node rack unit costs are half that of other rack costs in the February 2013 NCC model.[34]

CSMG response

7.20 We have performed further analysis on rack costs using secondary sources and additional CP data. Based on this analysis, the cost per rack was increased to £7,500 (capex), with annual opex of £1,100.

7.21 The Super Access Node rack cost input has been investigated and the error has been corrected with the updated rack capex.

Implementation Days and Costs

7.22 BT considers that implementation costs in the model are too low and suggest that they should be taken from an S135 response submitted by BT on 24 October 2012.[35]

CSMG response

7.23 Implementation costs were determined using a range of inputs including data from other CPs, obtained through information requests. Based on our analysis of all inputs received we are confident that the implementation costs in the model are representative of actual costs.

Additional Costs

7.24 BT states that its own 21CN cost model includes elements (specifically costs of OSS/BSS, feasibility studies, and Intelligent Network systems) that the February 2013 NCC model either omits completely or includes but understates.[36]

CSMG response

7.25 We consider that the costs of a feasibility study can reasonably be included in the implementation cost for an NGN. In light of BT's comments we have sought input from CPs on the cost of such a study. Representative figures for capex and opex to support a study have been included in the model. In addition, we would also expect that feasibility costs would be partly included in the price of purchasing network equipment (and therefore recovered in relation to network equipment).

7.26 OSS/BSS costs are included in the model as a part of the Service Node. These have been estimated using a number of inputs, including cost data from other CPs. We believe the current cost of OSS/BSS is fair and reasonable.[37]

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[33] BT response to the 2013 February consultation, para 9.105.
[34] BT response to the 2013 February consultation, para 9.107.
[35] BT response to the 2013 February consultation, para 9.142.
[36] BT response to the 2013 February consultation, para 9.144.
[37] We have made an adjustment to the opex recovered from the OSS/BSS to reflect the fact that this asset is also being used to recover other administration costs.

7.27 Intelligent Network systems are not included in the model. Although these systems may be present in an operator network, the associated costs would be recovered by number translation services (NTS). Cost recovery for NTS is beyond the scope of the model.

Opex Trends

7.28 BT claims that the 5.75% weighted average reduction in real input prices year-on-year is excessive, and should be replaced with 2% (from its own research). BT's secondary research also suggests that in a survey of other regulator cost models, the UK model is the only one that has decreasing opex over time in nominal terms.[38,39]

CSMG response

7.29 Following the February consultation we requested additional data on opex cost trends from CPs via infrormation requests. Based on the information received we have adjusted the opex cost trends in the model. The percentage annual reduction in real input prices has been reduced. We also allow the input prices to flatten during the forecast period. By 2025/26 all real input price trends are flat (i.e. 0% yearly change in real terms).

100GE Equipment

7.30 BT's secondary research suggests that the UK network cost model is the only one (in the above-mentioned survey) to include 100GE line cards. The majority of the other benchmark models use 10GE line cards. The core router costs, as a result, are in the mid-to-high range.[40]

CSMG response

7.31 100GE line cards are being used today by CPs in real-world networks of comparable scale to the modelled network. Although 100GE equipment would not have been available in the early years of the model, we use the 100GE equipment prices (trended backwards to the network launch year) as a proxy for the cost of equipment that would have been available to deliver the required capacity at that time, e.g. using multiple 10GE connections.

Network Element Cost Increases

7.32 Three states that there were some large increases in certain unit costs in the February 2013 NCC model compared to the September 2012 NCC model that do not seem to be explained (e.g. call server hardware, session border controller).[41]

CSMG response

7.33 The input assumptions in the September 2012 NCC model were provisional. These were subsequently refined based on new data provided by CPs.

Service Nodes

7.34 Three notes that the February 2013 NCC model appears to include provision of a single service node. Three believes that there should be at least [✂].[42]

[38] Analysys Mason (on behalf of BT Wholesale) response to the 2013 February consultation, page 46.
[39] BT response to the 2013 February consultation, para 9.137.
[40] Analysys Mason (on behalf of BT Wholesale) response to the 2013 February consultation, page 33.
[41] Three response to the 2013 February consultation, page 17.
[42] Three response to the 2013 February consultation, page 17.

CSMG response

7.35 The model is dimensioned to incorporate a pair of service nodes. Having further analysed service node data received from CPs via information requests, we have determined that a pair of service nodes – each with internal 1+1 redundancy – is an appropriate number for the network.

<u>*Call Server Software licences*</u>

7.36 Vodafone and Three question the approach to the treatment of call server software licences. We discuss their responses and changes we have made to the model as a result of these comments in Annex 6.[43, 44]

<u>*Voicemail Servers*</u>

7.37 BT states that voicemail server costs are attributed across all call types whereas they should be attributed just across call termination. In a fixed network, these costs are primarily triggered by call termination and therefore contribute towards pure LRIC costs. By definition, voicemail servers do not generate outbound calls.[45]

CSMG response

7.38 Based on the information received on voicemail server costs from CPs, we understand that the primary driver of voicemail cost is the number of subscribers. It therefore does not follow that the costs should contribute to the pure LRIC costs of call termination.

<u>*MSAN Synchronisation*</u>

7.39 BT claims that the model incorrectly ignores the costs of Ethernet timing synchronisation and that these costs should be included.[46]

CSMG response

7.40 The issue of MSAN synchronisation has been investigated further with CPs. We found BT was the only CP which employed MSAN synchronisation. None of the other CPs surveyed provide synchronisation to their MSANs. Based on the evidence, it does not appear to be required to provide voice services and we have therefore not included the costs in the model.

<u>*Model Start-date*</u>

7.41 BT and Virgin Media stated that the model start-date of 2005 was 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). [47,48]

CSMG response

7.42 Based on evidence we have collected regarding the time of NGN deployment in the UK, we continue to believe that a 2007/08 start date for network deployment is appropriate. Note that the model is designed to permit an earlier start date if desired, hence the model

[43] Vodafone response to the 2013 February consultation, page 29.
[44] Three response to the 2013 February consultation, page 7.
[45] BT response to the 2013 February consultation, para 9.141.
[46] BT response to the 2013 February consultation, para 9.11.
[47] BT response to the 2013 February consultation, para 9.12.
[48] Virgin Media response to the 2013 February consultation, page 15.

timeframe extends back to 2005/06. Please also refer to the explanation in paragraph 7.31, above.

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