Model documentation for ARCEP

Bottom-up mobile LRIC model for ARCEP (Release 2): Model Documentation

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1 Introduction

Analysys has been commissioned by ARCEP to develop a model of the long-run incremental cost (LRIC) of voice and SMS termination delivered by 2G and 3G mobile network operators in France. The purpose of the model is to assist ARCEP in understanding differences between the top-down models already developed by mobile operators.

The initial model structure that was developed was reviewed by industry as part of a consultation exercise, and we have made some modifications to the model as a result of this. The main amendments are as follows:

- the signalling allocations and network load due to signalling are now calculated on a dynamic, bottom-up basis
- there is an option to model core transmission using costs based on fibre optic rather than leased lines
- the model can account for the practice of swapping the equipment at a cell site when new GSM spectrum becomes available
- EDGE and HSDPA can be modelled more easily
- economic depreciation calculations have been removed and the time period included in the model has been reduced.

These are discussed in more detail in the sections below.

The initial model parameters have been updated with data from operators, which has been used to inform the parameters used in modelling a generic operator. We have also developed operator-specific parameters that fit more closely with the network deployment of individual operators.

For the avoidance of doubt, the parameters used in the generic case are not intended to represent any particular operator, but are rather intended to be representative of the demand, service provision and associated costs that a generic network operator in the French market might reasonably experience.

The remainder of this document is structured as follows:

- Section 2 provides an overview of the model and its structure
- Section 3 describes the traffic module, which calculates network demand
- Section 4 describes the network module, which includes the key cost drivers and deployment algorithms
- Section 5 describes the cost module which calculates total network costs
- Section 6 describes the service costing module, which calculates service costs.

Annex A provides a summary of the treatment of signalling within the model.

2 Model overview

2.1 Scope of model

The scope of the model is based on that described in the document *Bottom-up mobile LRIC model for ARCEP (Release 1): Conceptual Choices.*

The primary objective of the model is to assess on a LRIC basis the network costs of delivering incoming voice and SMS services on 2G and 3G mobile networks. However, data services are also included in order to take account of economies of scope. The model is based on the use of three core technologies and spectrum bands:

- GSM in the 900MHz band
- GSM in the 1800MHz band
- FDD UMTS using 5MHz paired spectrum in the 2.1GHz band.

We have also built into the model the flexibility (by adjusting some of the parameters) to assess the impact on voice and SMS termination costs of deploying EDGE and HSDPA.

The model explicitly calculates only the capital and operating costs associated with network equipment, in particular the following:

- radio network (including base station sites and equipment)
- backhaul (i.e. links from the base stations to the core network)
- backbone network
- core network switching equipment and other assets
- spectrum fees.

The model includes all network costs through the radio network to the core network, up to and including the gateway switches and interconnect ports. The model also includes an estimate of non-network costs.

The model calculates the costs of a single network operator. However, it allows the following inputs to be varied within reasonable bounds:

- traffic per subscriber over time (including, separately, 2G and 3G voice, SMS and data traffic)
- number of 2G and 3G subscribers over time
- roll-out schedule for 2G and 3G networks (including EDGE and HSDPA)
- amount of spectrum available over time by frequency band.

The model calculates the network cost to an operator in delivering voice, SMS and data services to end users. The model explicitly calculates the network costs for the period 1990–2014.

It provides a service cost based on service routing factors and an explicit allocation for the cost of signalling and for the cost of radio channels reserved for GPRS. The model outputs service costs on the basis of historic cost accounting (HCA).

2.2 Model structure

The mobile LRIC model comprises four distinct modules, as shown in Exhibit 1.

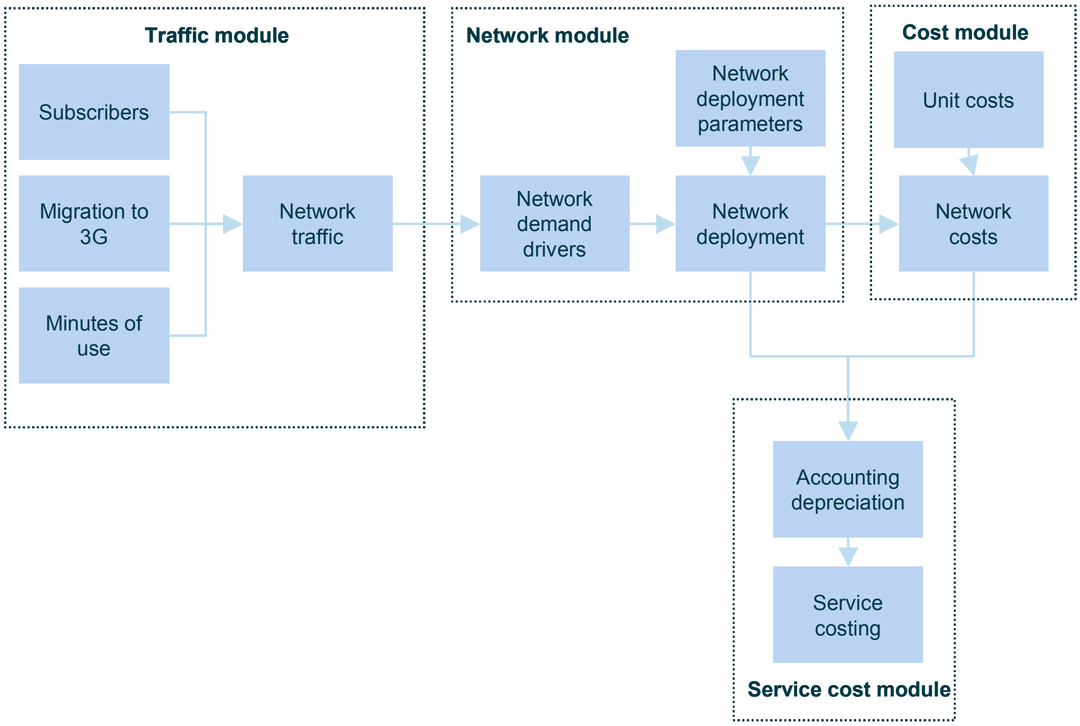


Exhibit 1: *Model structure*

- The **traffic module** produces network demand forecasts based on forecasts of how number of subscribers, traffic per subscriber and market share evolve over time.
- The **network module** produces the asset demand required to support the input level of subscriber demand, based on a projected network deployment.
- The **cost module** outputs the network costs incurred, based on asset costs and asset demand produced by the network module.
- The **service costing module** allocates costs between services and outputs service costs based on HCA.

Key to calculation diagrams

In the following sections, we use calculation flow diagrams to describe the relationship between inputs, parameters, calculations and outputs in the model. A key to the colour conventions used in these diagrams is given in Exhibit 2.

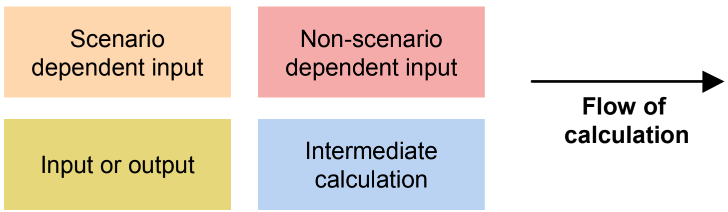


***Exhibit 2:** Key to calculation flow diagrams*

2.3 Model inputs

Since the initial model release, the focus of the model development has been to calibrate it against data provided by the French mobile operators.

Operator-specific parameters are based as far as possible on actual operator inputs, or in order to match model output to operator inputs. However, it has been necessary in some cases to modify operator inputs in order to calibrate to the asset counts and overall costs reported.

Although we understand that the capacity of certain assets may have varied over time as technology evolves, parameters used for capacity remain constant over time in the model. We base capacity assumptions on the last year of information from operators, and calibrate to the actual number of assets currently deployed. We capture the cost impact of changes over time in capacity by means of the MEA cost trends in the cost module.

For the generic operator we make the following assumptions in the base case:

- 33% market share
- traffic per subscriber based on an average of the traffic of all three operators
- network roll-out later than Orange and SFR but earlier than Bouygues
- access to spectrum consistent with that available to Orange and SFR

- radio network deployment using a mix of 900 and 1800MHz spectrum based on Orange and SFR practice, and microcells based on an average of all the operators
- switching parameters (e.g. Mobile Switching Centre (MSC) capacity, minimum number of MSCs) based on an average of the traffic of all three operators
- a mix of leased line and microwave backhaul based on an average of all operators
- core transmission technology based on leased lines
- unit cost data and cost trends based on an average of all operators.

In considering the 'average' we have not always taken a simple mathematical average, since in some cases data is not consistent between the operators or with other information available to us, or is missing for one or more operators.

We have conducted a number of sensitivity tests on the base case generic operator. Our tests helped us to review inputs about which we were relatively uncertain, and the impact of those that vary by operator in order to help understand cost differences between the operators.

2.4 Model results

The model calculates the network costs for 2G and 3G networks, and allocates these between network services to produce a blended service cost for incoming voice and SMS services based on HCA. The results are presented in real 2006 terms.

3 Traffic module

3.1 Introduction

The purpose of the traffic module is to generate a forecast for the demand on the 2G and 3G networks. The flow of calculation in the module is shown in Exhibit 3.

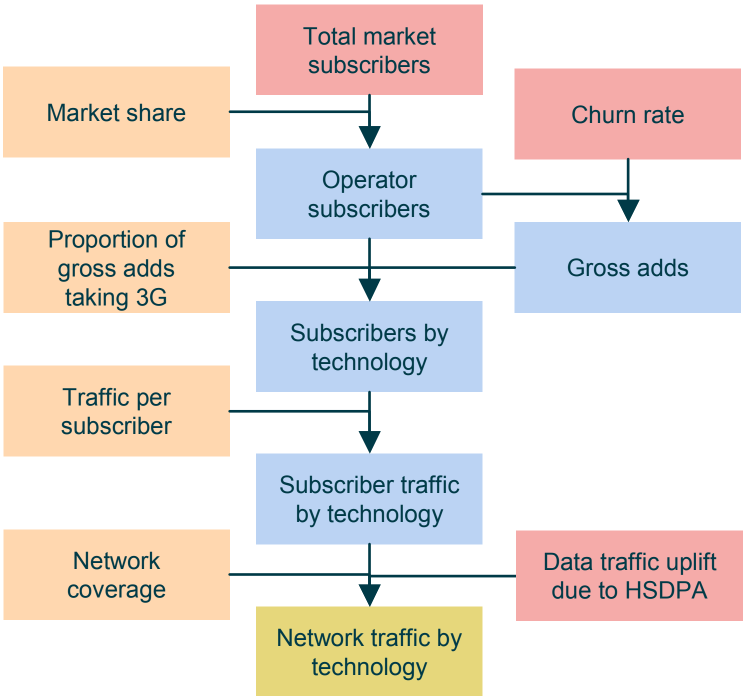


Exhibit 3:

Traffic module calculation flow

For a key to the colour conventions used in this diagram, see Exhibit 2 above.

The subscriber numbers of the modelled operator are calculated based on the total number of subscribers in the market and an assumed market share for that operator.

The migration of subscribers from 2G to 3G from which we derive the number of subscribers by technology is forecast based on an assumed handset churn rate and an assumption about the proportion of churning subscribers that take 3G handsets in each year.

Traffic per subscriber is extrapolated from the current average monthly usage of voice, SMS and data services. Services are split between on-net, incoming and outgoing calls. Traffic per subscriber is multiplied by the number of subscribers to give the service demand for the total subscriber traffic by technology.

The service demand measure at this point in the module is the level of demand generated by subscribers with 2G and separately, 3G handsets. This traffic is 're-balanced' between the 2G and 3G networks based on their respective coverage and assumptions made on capacity requirements, in order to calculate the service demand that is actually delivered on each network (the 'network traffic by technology'). In particular, this accounts for the roaming of 3G subscribers onto 2G networks where 3G coverage is not available. A proportion of 3G traffic is also forced onto the 2G network based on the assumption that the 3G network in the early years does not have sufficient capacity to carry all traffic generated by 3G handsets. No traffic is lost in this rebalancing process.

3.2 Scenario options implemented in the traffic module

There are a number of scenario options within the traffic module, listed below by traffic category.

Voice and video

- average minutes per subscriber over time
- proportion of outgoing minutes that are on-net minutes over time
- incoming minutes as a proportion of outgoing minutes over time
- average incoming voicemail minutes per subscriber over time
- average voicemail retrieval minutes per subscriber over time
- ratio of 3G voice use to 2G voice use as a proxy for usage patterns of early adopters over time
- proportion of 3G users who are active users of video calls
- proportion of minutes that would be video minutes if both originating and called party are in coverage over time.

SMS

- outgoing messages per average subscriber over time
- proportion of outgoing messages that are on-net messages over time
- incoming messages as a proportion of outgoing off-net minutes over time
- average notification messages per incoming voice mail call
- push SMS as a proportion of incoming messages
- ratio of 3G message use to 2G message use as a proxy for usage patterns of early adopters over time.

Data

- 2G data usage per subscriber over time
- 3G data usage per subscriber over time.

The traffic module also includes options to adjust other parameters including:

- market share in terms of subscribers
- proportion of gross additions taking 3G handsets
- 2G network coverage over time
- EDGE network coverage over time
- 3G network coverage over time
- HSDPA network coverage over time.

We consider two possible scenarios for the deployment of HSDPA.

- Since HSDPA is included by default in the later releases of UMTS, the default scenario is to assume that if an operator merely wishes to provide higher data rates near the centre of a cell, then there is no impact on the maximum cell radii achievable or on unit deployment costs.

- As a more aggressive deployment scenario we consider the case that an operator wishes the higher data rates to be available to subscribers even at the cell edge. Due to the effects of cell breathing this means that the maximum cell radii possible are reduced under this scenario. We also consider an increase in the levels of 3G data traffic forecast in HSDPA coverage areas, to reflect the greater capability of the network, and include additional unit costs for equipment.

3.3 Detailed description of module contents

This section contains a sheet-by-sheet description of the contents of the traffic module.

Scenario

This sheet contains the scenario switches that may be used to alter key input parameters of the model. The different input parameters for each scenario are entered on this sheet. A description of each scenario is given in Section 3.2 above.

Inputs

The different input parameters for each scenario are entered on this sheet. A list of all scenario options is given in Section 3.2 above.

The proportion of incoming, on-net and outgoing traffic is based on actual operator data where possible. In years in which no real data is available, proportions of voice and video minutes are worked out based on assumptions made in the *traffic* sheet, while proportions of incoming, on-net and push SMS are assumed to remain constant.

All voicemail-related traffic is based on real data where available and proportions are assumed to keep a steady state in the forecasts.

For the generic operator we assume historical traffic to be equal to a weighted average of actual operator data and we make the following assumptions for subscriber demand in the forecast:

- voice traffic is assumed to grow by 0.5% a year
- SMS traffic is assumed to grow by 1% a year
- 2G data traffic decreases by 1% a year, based on the assumption that heavy data users switch to 3G
- 3G data traffic decreases by 2% a year, based on the assumption that heavy users switch to 3G first and the average usage volume is diluted over time by less heavy users.

Geotypes

This sheet contains the definition of the geotypes used in the mobile LRIC model. The model calculates the share of traffic in each geotype based on the share of population in the geotype, adjusted to assume a decreasing traffic per head as geotypes become more rural. In this way, the share of traffic in each geotype accounts for a share of population commuting between rural and urban areas.

We use the same assumptions for the mix of traffic in both 2G and 3G networks, but adjust for network coverage so that the 3G network traffic is relatively concentrated in urban areas, particularly in early years of deployment.

Geotypes are defined at the commune level, with each of the 36 000 communes being allocated to a specific geotype. Our analysis of cell site distribution across France indicates that this is a reasonable predictor of cell site density and consequently the allocation to geotype is primarily based on population density. The population boundaries between different geotypes are chosen to coincide with rapid changes in population density in the geotypes, as illustrated in Exhibit 4 below. The rural communes are also identified as either mountainous or non-mountainous.

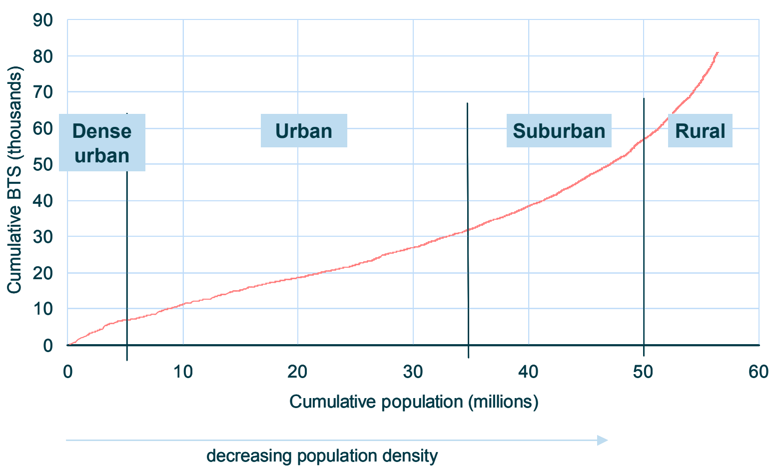


Exhibit 4:

Cut-offs for geotypes (cumulative population and cumulative base transceiver stations (BTSs)

Subscribers

This sheet produces a forecast of the number of subscribers by technology for the modelled operator. As a first step, total market subscribers are forecast based on mobile service penetration trends. This total is multiplied by the assumed market share of the generic operator to give its subscriber numbers. An assumption about the level of churn is used to calculate gross adds. Finally, an input specifying the share of gross adds who will adopt 3G determines how many of the gross adds will become 3G subscribers. This gives the split between 2G and 3G subscribers.

Actual data is used for years in which this is available.

Traffic

This sheet first calculates subscriber demand based on the subscriber numbers calculated in the previous sheet, and then performs adjustments to this subscriber demand to give the service demand on both the 2G and 3G networks.

Subscriber traffic is taken from the *Inputs* sheet. The proportion of incoming, on-net and outgoing traffic is based on actual data where possible. Where no real data is available for proportions of incoming and on-net voice and video minutes, their volumes are estimated on the basis of operator market share and parameters describing the propensity to call people on the same network; the proportion of outgoing minutes to different types of destination; and incoming minutes as a proportion of outgoing minutes to each of those destinations.

Subscriber traffic is then converted into network traffic based on the mix of 2G and 3G subscribers and the coverage of the 3G network compared to the 2G network. In the most complex case, an on-net call from a 3G subscriber could be either:

- an on-net 3G call (the called party is also a 3G subscriber and both are in coverage)
- a 3G–2G call consisting of an outgoing 3G call and an incoming 2G call (the calling party is in coverage and calling either a 2G subscriber or a 3G subscriber who is roaming on the 2G network)

- a 2G–3G call consisting of an outgoing 2G call and an incoming 3G call (the calling party is roaming on the 2G network and calling a 3G subscriber who is in coverage)
- an on-net 2G call (the calling party is roaming on the 2G network and calling either a 2G subscriber or a 3G subscriber who is also roaming on the 2G network).

When a call is transferred from a 3G to a 2G network, we apply conversion factors such that video calls become voice calls. Traffic is not reduced in volume when moving between the 2G and 3G networks, although the model does retain the flexibility to do so.

Output

This sheet contains the outputs of the traffic module that are used as inputs to the network module: traffic carried on the operator's own 2G and 3G network, network coverage of both 2G and 3G networks, and number of subscribers.

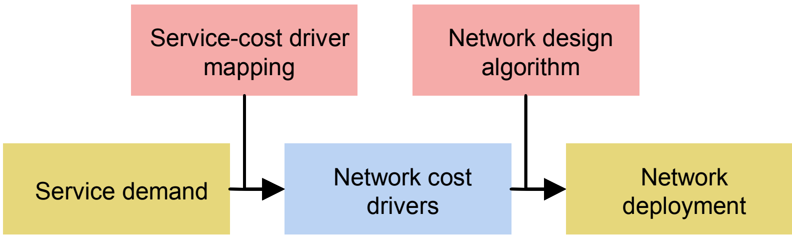
Lists

This sheet contains several lists that are referenced elsewhere in the model.

4 Network module

4.1 Introduction

The network module takes as input the forecasts of service demand produced by the traffic module. The flow of calculation in this module is illustrated in Exhibit 5. The input of the module, taken from the traffic module, is the service demand on the 2G and 3G networks. This is converted into network cost drivers by means of a service-cost driver mapping;, and the cost drivers are used in the network design algorithms to derive the number of assets required. The output of the module is the network deployment (i.e. the number of assets deployed in each year).



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 5: *Network module flow of calculation*

4.2 Detailed description of module contents

This section contains a sheet-by-sheet description of the contents of the network module.

Linked inputs

This sheet links to the outputs of the traffic module (operator choice, service demand, coverage and subscriber numbers).

A switch allows the user to select an operator manually, otherwise the choice of operator is linked to the traffic module.

Params – 2G

This sheet contains the parameters used in the network design algorithm for 2G network deployment, including the parameters relating to the availability of 900MHz and 1800MHz spectrum. The amount of spectrum may vary over time.

Params – 3G

This sheet contains the parameters used in the network design algorithm for 3G network deployment.

We have included additional parameters since Release 1, relating the Signalling Radio Bearer (SRB) channel. This is a standard 3.4kbit/s channel in the 3G radio network and we assume that it is used to convey location updates and SMS.

We note that the capacity of a 3G radio cell may be limited either by the number of available codes which are assigned to channels by the NodeB or by the level of interference at the mobile device; traffic loading conditions determine which of these is the limiting factor. Based on a consideration of these issues we use conversion factors between data and voice channel capacity and between SRB and voice channel capacity. In the base case we assume that the larger data channel is 3 times more efficient than the voice channel, and that the SRB channel is half as efficient as the voice channel in terms of traffic-carrying capacity.

Params – 3G spectrum

This sheet contains the parameters relating to the availability of 3G spectrum. The type and amount of spectrum may vary over time, and this sheet enables different scenarios to be modelled. It also includes a factor to apply to the cell radii in the case that an operator employs an aggressive HSDPA deployment.

Params – other

This sheet contains the network design parameters relating to the network elements that may be used by both the 2G and 3G networks, including the level of site sharing between the 2G and 3G networks, the configuration of the backhaul network, and the deployment of switch sites.

Cost drivers

This sheet converts the service demand output by the traffic module into specific cost drivers, which drive the deployment of network assets. Traffic is first converted into busy hour Mbit/s. Busy hour traffic in the radio network is dimensioned in voice-equivalent terms. This is a more predictable measure than data-equivalent terms, since the efficiency with which data can be carried depends on the bandwidth provisioned. Subscribers and selected roaming services are added to the list of services at this point to enable them to be used in the formulation of the network cost drivers. A matrix that maps services to cost drivers is used to calculate the network cost drivers.

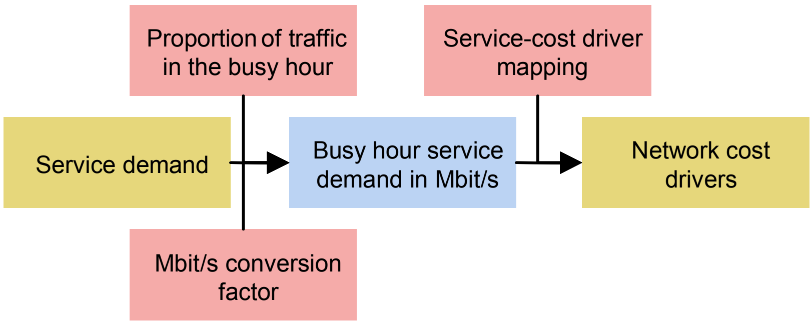


Exhibit 6: *Cost driver calculation flow*

For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

The typical calculation flow is shown in Exhibit 6, although it is different for some cost drivers – 2G radio traffic, 3G radio interface traffic, 3G backhaul traffic – as these cost drivers need to be broken down by geotype, while others are only required at an aggregate level.

In the 2G network, the cost drivers do not include the use of dedicated signalling channels or radio channels reserved for GPRS since these are accounted for separately. In particular, the cost driver for 2G radio traffic excludes SMS and data traffic, which is consistent with the exclusion of the SDCCH and PDCH channels from the Erlang table on the *Erlang* sheet. In the 3G radio network, we model SMS as a traffic load on a 3.4kbit/s SRB channel, so include this load within the cost drivers.

The MSC processing cost driver is based on the number of signalling messages required by each type of call from information provided by operators. The routing factors used take into account the average duration of a call, the number of call attempts per call, as well a conversion to a voice-equivalent Erlang measure.

Proportions of traffic traversing the core network and core network overheads are set in the *Params – 2G* and *Params – 3G* sheets for BSC–MSC, BSC–SGSN, RNC–MSC, RNC–SGSN and inter-MSC traffic.[1] Proportions correspond to traffic needing to be carried between switch sites where switches are not collocated at a single site and are used to derive core network traffic cost drivers. Traffic overheads for packet headers etc. are also incorporated in the cost drivers.

The *Cost drivers* sheet outputs proportions of 2G and 3G traffic in the core and radio network, which are used in the allocation of signalling costs in the service cost module.

Reasonable growth inputs

This sheet contains the design utilisation, scorched node allowance, look-ahead periods and headroom drivers. Although the look-ahead periods are fixed, the impact of these is variable over time, so that average asset utilisation increases as scale is reached.

Parameters in this sheet have been adjusted for calibration purposes, based on data provided by the French operators.

Network design – 2G

This sheet contains the network design algorithms that create the asset demand projections for assets used in the 2G network. Exhibit 7 below provides a simplified representation of some of the network elements included in the 2G network design algorithm.

[1] BSC: base station controller; SGSN: serving GPRS support nodes; RNC: radio network controller.

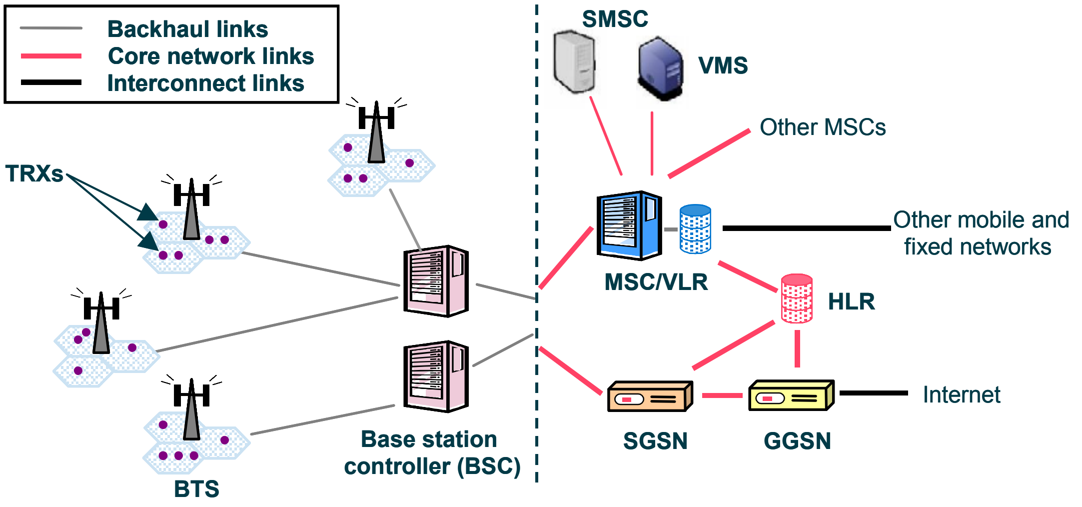


Exhibit 7: Simplified GSM network diagram

- Base station sites, transceivers (TRXs), BTSs, BSCs and backhaul links form the radio access network. A base station site includes at least one BTS and one TRX for each sector. Sites can be deployed with a variety of sector configurations (omni-sector, bi-sector, tri-sector, etc.) and frequency bands (900, 1800, dual 1800/900MHz). The average number of BTSs per site may vary by geotype and over time. The amount of spectrum in use at each site is determined by the physical constraints on the number of TRXs per sector and the total amount of spectrum available in the year.

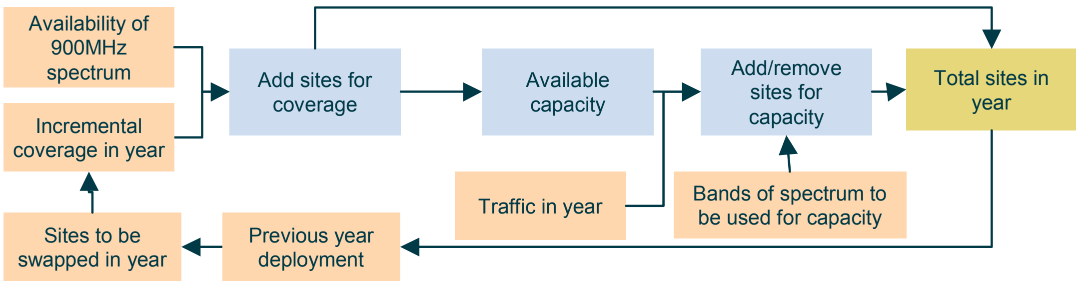
- The circuit-switched core network includes MSCs and SMSCs; calls may pass through several MSCs before being delivered to other networks.

- The packet-switched core network includes both SGSNs and GGSNs (Gateway GPRS Support Nodes). GGSNs connect to the Internet.

- HLRs (Home Location Registers) and VMSs (Voicemail Servers) also sit in the core network.

- Core network links are illustrated in Exhibit 7 in red. Interconnect links are shown in black, but are outside the scope of the LRIC model.

The algorithm that calculates the number of required base station sites uses an incremental approach, as illustrated in Exhibit 8. An incremental approach is adopted as several of the key parameters which govern the network deployment (e.g. maximum cell radius, amount of available spectrum) have been configured so that they may change over time and the network design must adapt to account for these changes without exhibiting unusual behaviour.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 8: *Calculation of the number of required sites*

- The input to the calculation is the number of sites deployed in the previous year, the traffic and information on the spectrum band to be used for coverage and capacity in year.

- The incremental coverage requirement is based on the area covered by the total number of sites from the previous year's deployment and the maximum cell radius in year. The model now also takes into account the number of 1800MHz sites rolled out for coverage that may be later swapped to 900MHz sites if this spectrum becomes available. If 900MHz spectrum is available, the model assumes that 900MHz cell sites only will be deployed for coverage since these have a greater cell radius.

- Next, the model calculates the total capacity provided, based on incremental sites deployed for coverage added to the existing sites from the previous year. The aim is to work out the additional capacity required to support the level of demand in that year. If the available capacity is greater than demand, the model will remove sites from those deployed for capacity in previous years. Look-aheads are applied to demand to allow for anticipated roll-out of sites.

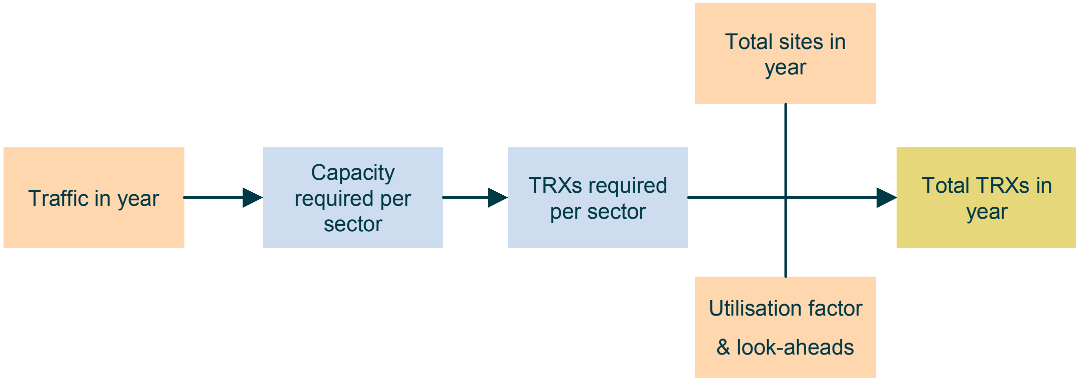
- The type of cells deployed for capacity is based on the traffic split by cell type and the proportion of spectrum of each band to be used for capacity, both specified in the *Params – 2G* sheet.

- The model then calculates the total number of sites in year by adding the incremental numbers of sites required for capacity and coverage to existing ones.

We note that the radio network demand calculation excludes demand for signalling or GPRS. Signalling is assumed to require a fixed number of dedicated channels per TRX (one in the base case) and GPRS is assumed to require a fixed number of dedicated channels per sector (one in the base case). In calculating the potential traffic capacity provided by a base station, these channels are first removed so that the demand and capacity calculations are consistent.

To upgrade a GSM network to EDGE involves a change only to the radio network, in particular the TRX and BSC assets. Older networks usually require complete replacement of this equipment, while newer networks may be able to deploy EDGE using a software upgrade to existing equipment. We have assumed that complete replacement is necessary and model this as an early replacement of TRX and BSC assets within the cost module. We also account in the network module for a reduction in maximum cell radii possible in areas in which EDGE is launched.

The total number of **TRXs** is based on the capacity required per sector, derived from the total number of sites, and the traffic in year, with an allowance for utilisation, as illustrated in Exhibit 9. The algorithm first calculates the number of TRXs required per sector and outputs the total number of TRXs by cell size and by geotype to be used in the cost module.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 9: *Calculation of the number of required TRXs*

The number of **BTSs** required is worked out from the total number of sites and the average number of BTSs per site, both of which may vary over time and by geotype.

The **backhaul** requirement per site, in terms of required 2Mbit/s links per site, is calculated based on the assumed traffic per site. This is used as input to the shared backhaul algorithm on the *Network design – other* sheet.

BSCs are dimensioned based on the number of TRXs in the radio network and a maximum area covered per BSC to ensure a more distributed roll-out.

BSCs have both **BTS-facing ports** and **core-facing ports**. The quantity of BTS-facing ports is equal to the total number of 2Mbit/s links required for BTS backhaul, with an allowance for utilisation. A **concentrator** asset is deployed based on the average number of concentrators per NodeB-facing port. The number of core-facing ports is calculated as the number required to carry all of the traffic in the radio network divided by an assumed capacity, with an allowance for utilisation.

A BSC may be located remotely and as such require microwave or leased line backhaul to reach the core network. We assume that **BSC backhaul** design follows a ring structure. A parameter setting the average number of BSCs per ring specifies the number of BSC per ring, each ring we assume to be connected to an MSC. The total number and size of links required for BSC backhaul is calculated based on the traffic per BSC, an assumption regarding the number of BSCs per ring, and an assumption regarding the proportion of BSCs which require backhaul, with an additional allowance for utilisation.

The **MSC** handles subscriber-related processing functions, including location updates, and call-related processing functions. The cost driver for the MSC includes demand based on 2G subscriber numbers (to capture the impact of location update processing), demand linked to incoming, outgoing and on-net call attempts, and a maximum number of BSCs per MSC to ensure a more distributed roll-out. The total number of MSCs is calculated by dividing the total processing demand by the processing capacity of a single MSC, with an allowance for utilisation. Additionally, it is assumed for the generic operator that a minimum of seven MSCs is required for redundancy.

MSCs have both **BSC-facing ports** and **core-facing ports**. The number of BSC-facing ports is driven by the total number of BSCs and the MSCs' processing capacity and utilisation. Core-facing ports required are driven by total circuit-switched traffic including traffic that travels between switches within the mobile operator's network, and traffic which travels across interconnect links. Their dimensioning includes an allowance for utilisation and an overhead for signalling purposes.

Packet-switched traffic is passed from the BSCs to an **SGSN** and then to a **GGSN**. The GSNs are dimensioned based on both the number of active data sessions and the total throughput of data. The number of active data sessions is estimated based on the total packet-switched traffic and an assumed average throughput per session. This is cross-checked against the implied number of active sessions in the busy hour as a proportion of all subscribers. The total number of SGSNs and GGSNs required is the greater of the number required to support the calculated quantity of busy hour sessions and busy hour traffic, with an allowance for utilisation. It is assumed that a minimum of ten SGSNs and two GGSNs will be deployed for redundancy and geographic coverage.

SMSCs are dimensioned based on the number of messages in the busy hour, which is calculated based on an assumed average message size, with an allowance for utilisation. It is assumed that a minimum of three SMSCs will be deployed for redundancy.

The **core transmission** network is dimensioned within the *Network design – other* sheet.

The number of **SIM cards** required in each year is equal to the number of 2G subscribers in that year.

A **licence fee** asset is deployed in the calendar year in which traffic starts on the 2G network. This year is 1993 for the generic operator.

Network design – 3G

This sheet contains the network design algorithms that create the asset demand projections for assets used in the 3G network. Exhibit 10 below provides a simplified representation of some of the network elements included in the 3G network design algorithm.

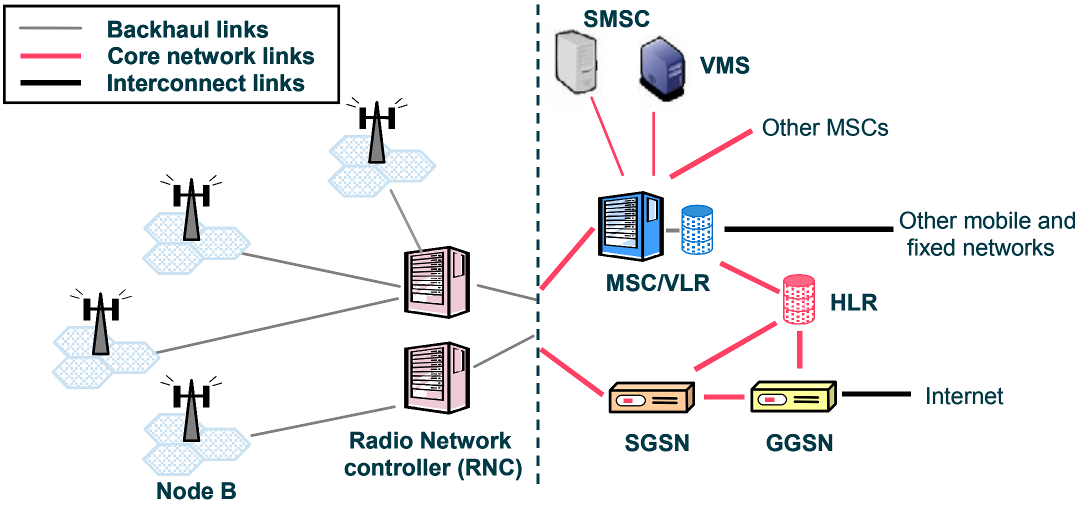


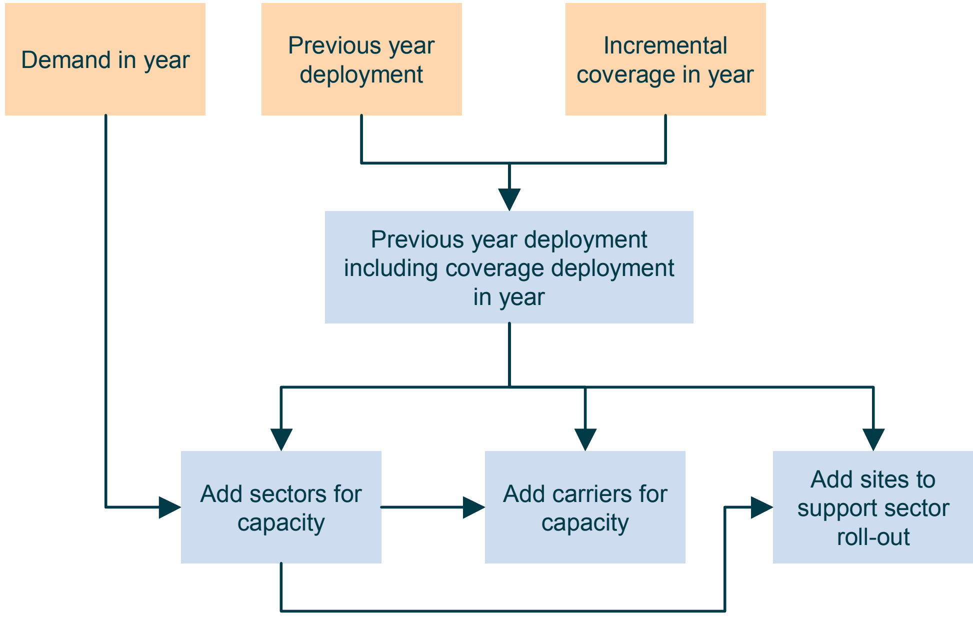
Exhibit 10: *Simplified UMTS network diagram*

- NodeBs, radio network controllers and backhaul links form the radio access network.
- The circuit-switched core network includes MSCs, which are subdivided into an MSC Server, used for call and subscriber processing, a Media Gateway (MGW), used for switching traffic and a Visitor Location Register (VLR), which contains a record of all active subscribers on the network. Calls may pass through several MSCs before being delivered to other networks.

- The packet-switched core network includes both SGSNs and GGSNs. GGSNs connect to the Internet.
- A Home Location Register (HLR) and a VMS also sit in the core network.
- Core network links are illustrated in the Exhibit 10 in red. Interconnect links are shown in black, but are outside the scope of the LRIC model.

There is a single **NodeB** per **base station site**. A NodeB can be deployed with a variety of **sector** configurations (omni-sector, bi-sector, tri-sector, etc.), similar to a 2G site. While in a 2G site the amount of spectrum in use is determined by the number of TRXs per sector, in a 3G NodeB, spectrum usage is determined by the number of **carriers** deployed in a given sector. Each additional carrier uses an additional 2×5MHz of spectrum and adds to the traffic capacity of the cell. We assume that sufficient channel elements are deployed with each carrier to carry the traffic associated with that carrier and that these costs are included in the cost of the carrier asset.

The algorithm that calculates the number of required carriers, sectors and sites uses an incremental approach, as illustrated in Exhibit 11. An incremental approach is adopted as several of the key parameters which govern the network deployment (e.g. maximum cell radius, number of available carriers) have been configured so that they may change over time and the network design must adapt to account for these changes without exhibiting unusual behaviour. We have not explicitly accounted for signalling in the deployment of the 3G radio network as there is no dedicated resource reserved for signalling in the 3G radio network. However, the capacity parameters used in the radio network are lower than might otherwise be the case in order to represent only the traffic-carrying capacity of equipment.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 11: *Calculation of the number of required carriers, sectors and sites*

- The number of carriers, sectors and sites required to support the increase in coverage that occurs during the year is calculated based on the assumed maximum cell radius and the minimum site configuration.

- The incremental deployment for coverage in year is added up to the total carrier, sector and site deployments of the previous year. The resulting numbers of carriers, sectors and sites are used as an input to the calculation of the capacity deployment.

- Demand is adjusted to account for the fact that traffic is not homogeneous across sites and not homogeneous across sectors within a cell site, we assume that on average each site needs to be dimensioned to be able to carry extra traffic equivalent to the capacity of 1 carrier on 1.5 sectors.

- The model then calculates the number of sectors required to support the level of demand in that year assuming that the maximum number of carriers could be deployed per sector. If this is greater than the number of existing deployed sectors, additional sectors will be deployed.

- Next, the model calculates the number of carriers required to support the assumed level of demand in the year, based on the total number of sectors required in year. If this is greater than the number of carriers deployed, the model will add additional carriers.

- As a final step, the model calculates the number of sites that would be required to support the total number of sectors deployed. If the number required is greater than the number of existing sites, new sites are deployed.

- The total deployment in the current year is then divided by the overall utilisation of the assets calculated on the *Reasonable growth inputs* sheet to give the actual number of assets deployed, allowing for future growth.

- Additionally, the scenario modelling an aggressive HSDPA deployment creates a virtual HSDPA-enabled macrocell asset for each macrocell in a geotype where HSDPA was launched. These assets correspond to a non-renewable capex in the cost module accounting for the one-off costs related to HSDPA roll-out. The launch of HSDPA also causes a decrease of 20% of the average 3G cell site radii in geotype.

- The radio network demand calculation includes demand for SMS and data services (unlike in the 2G network deployment algorithm). This is because channels are dynamically allocated in 3G and there is no need to reserve dedicated signalling or data channels. The call setup, handover and location management functions that are necessarily carried out in the 2G network's dedicated signalling channels are accounted for in the 3G network by virtue of the 3G capacity utilisation factors.

The **backhaul** requirement per site, in terms of required 2Mbit/s links per site, is calculated based on the assumed traffic per site. This is used as input to the shared backhaul algorithm on the *Network design – other* sheet.

RNCs are dimensioned based on the number of NodeBs per RNC and the total circuit-switched and packet-switched traffic in the radio network. It is assumed that an RNC will have a different capacity limit for circuit-switched and packet-switched traffic and therefore the number of RNCs required for each type of traffic is calculated separately. The number of RNCs deployed is the sum of those needed to support both circuit-switched and packet-switched traffic and also accounts for a maximum number of NodeBs per RNC to ensure a more distributed geographical roll-out.

RNCs have both **NodeB-facing ports** and **core-facing ports**. The quantity of NodeB-facing ports is equal to the total number of 2Mbit/s links required for NodeB backhaul, with an allowance for utilisation. A **concentrator** asset is deployed based on the average number of concentrators per NodeB-facing port. The number of core-facing ports is calculated as the number required to carry all of the traffic in the radio network divided by an assumed capacity, and with an allowance for utilisation.

An RNC may be located remotely and as such require microwave or leased line backhaul to reach the edge of the core network. **RNC backhaul** design follows a ring structure relying on a parameter setting the average number of RNCs per MSC-ring. This parameter specifies the number of RNCs per ring, each ring we assume to be connected to an MSC. The total number of links required for RNC backhaul is calculated based on the traffic per RNC, the number of ring nodes required and an assumption regarding the proportion of RNCs that require backhaul, with an additional allowance for utilisation. Links are then distributed between microwave and leased lines accordingly to a parameter set on the *Params – 3G* sheet. Available backhaul options are identical for RNC backhaul and core network transmission links and are described in the sub-section *Network design – other* below.

3G call processing is now based on two generations of MSCs, including **3G MSCs** and **MSCSs** plus **MGW**. The proportion of each type of asset to be deployed is based on a parameter evolving over time. 3G MSCs are deployed in the same way as 2G MSCs. The MSC Server handles subscriber-related processing functions, including location updates, and call-related processing functions. The cost driver for the MSC Server includes demand based on 3G subscriber numbers (to capture the impact of location update processing), and demand linked to incoming, outgoing and on-net call attempts. The total number of MSC Servers is calculated by dividing the total processing demand by the processing capacity of a single MSC, with an allowance for utilisation. Additionally, it is assumed that a minimum of two MSCs and MSC Servers are required for redundancy. The MGW is assumed to be driven by the number of ports required to accommodate the traffic received from the RNCs (total circuit-switched traffic), traffic which travels between switches within the mobile operator’s network, and traffic which travels across interconnect links. The number of

MGWs required is the total number of ports divided by the assumed port capacity of each MGW, with an allowance for utilisation.

Packet-switched traffic is passed from the RNCs to an **SGSN** and then to a **GGSN**. The GSNs are dimensioned based on both the number of active data sessions and the total throughput of data. The number of active data sessions is estimated based on the total packet-switched traffic and an assumed average throughput per session. This is cross-checked against the implied number of active sessions in the busy hour as a proportion of all subscribers. The total number of SGSNs and GGSNs required is the greater of the number required to support the calculated quantity of busy hour sessions and busy hour traffic, with an allowance for utilisation. For the generic operator, it is assumed that a minimum of four SGSNs and one GGSNs will be deployed initially.

SMSCs are dimensioned based on the number of messages in the busy hour, which is calculated based on an assumed average message size, with an allowance for utilisation. It is assumed that a minimum of two SMSC will be deployed for redundancy.

The **core transmission** network is dimensioned within the *Network design – other* sheet.

The number of **SIM cards** required in each year is equal to the number of 3G subscribers in that year.

A **licence fee** asset is deployed in calendar year in which spectrum was bought by the operator. This year is assumed to be 2001 for the generic operator.

Network design – other

The site requirements output by the 2G and 3G network models are adjusted in this sheet to account for **site sharing**. The proportion of incremental 3G sites that will be shared with 2G sites is set on the *Params – other* sheet, based on assumptions made from data provided by the French operators. The algorithm then outputs the number of required sites that will be standalone 2G, standalone 3G, and shared.

In order to model the effects of BTS and Node-B **backhaul sharing**, the sheet calculates the total backhaul capacity required in a geotype for the 2G and 3G network and the number of sites that will be deployed (including standalone 2G, standalone 3G, and shared sites). Backhaul is then deployed to accommodate the implied average traffic per site. The configuration of the backhaul network is linear with the number of sites : the total number of backhaul links is thus directly obtained from the number of sites, with a difference made between standalone sites (2G or 3G) and shared sites (which are assumed to need more backhaul links per site).

The **Intelligent Network (IN), HLRs** and **VMSs** are driven by the number of active subscribers. It is assumed that the IN, HLRs and VMSs are shared between the 2G and 3G networks, and as such they are dimensioned based on total 2G and 3G subscribers.

It is assumed that **switch sites** are shared between the 2G and 3G networks. Since switch sites are required for a variety of switch assets, they are driven by whichever is the greatest number of assets in the following four asset classes – MSCs in the 2G network, MSCs and MSC Servers in the 3G network, and SGSNs in both networks. An assumed number of switches per site is used to calculate the number of sites required, along with an assumed maximum and minimum number of switch sites.

There are now two options available to model core network transmission links, either based on leased lines or fibre optic. If the leased line solution is chosen, the total number of 2Mbit/s leased lines required is driven by all core traffic, including all 2G and 3G packet-switched and circuit-switched traffic. The fibre optic solution includes links with high capacity requirements using dark fibre and links with lower capacity requirements using optical wavelengths. We have modelled this on the basis of an estimate of the length of core transmission network required for each type of link. Both options include an allowance for utilisation and an overhead accounting for signalling set in the *Params – other* sheet. This overhead is set equal to 1/28 in the base case on the basis that we assume 1 channel in 8 is a signalling channel and that each of the other 7 channels is upgraded from 16kbit/s to 64kbit/s in the core network, while the signalling channel continues to require 16kbit/s in the core network. 1/28 is calculated as 16/(64×7).

The **Service Integration Infrastructure** is associated with push SMS and corresponds to the additional infrastructure required to offer this service.

The **Network Management System (NMS)** is also driven by all core traffic and is assumed to be shared between the 2G and the 3G network.

Asset demand for costs

This sheet summarises the total number of assets required to support the projected network deployment used in the cost module.

Element output

This sheet calculates the output of each element based on the service demand and a table of routing factors. For each group of assets, a cost driver is specified over which the costs of the asset should be recovered following either historic cost or economic depreciation. The model then selects the appropriate routing factors to calculate the each elements output.

Further re-allocation of costs from signalling and from radio channels reserved for GPRS is carried out in the service costing module.

Lists

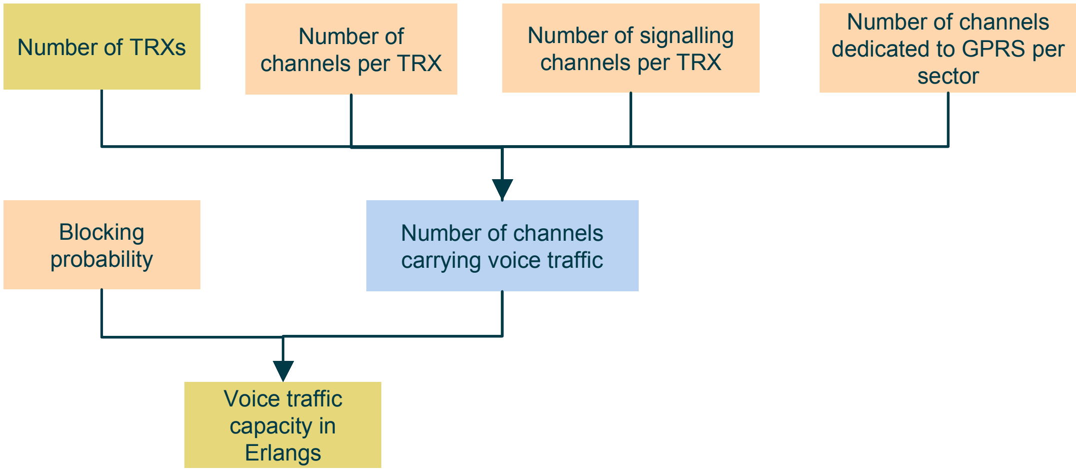
This sheet contains several lists used for reference elsewhere in the model.

Erlang B

This sheet contains two lookup tables respectively used by the *2G* and *3G Network design* sheets to perform the Erlang-B transformation.

The table used in the *3G Network design* sheet corresponds to a classic Erlang B table working out the number of channels required to deliver a certain amount of traffic for a given blocking probability.

The table used for the 2G radio network accounts for a number of dedicated channels per TRX for signalling and a number of dedicated channels per sector for GPRS. It calculates the total number of channels required (including the dedicated channels) to deliver a certain amount of voice traffic for a given blocking probability. The algorithm used to derive this table is illustrated in Exhibit 12 below.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

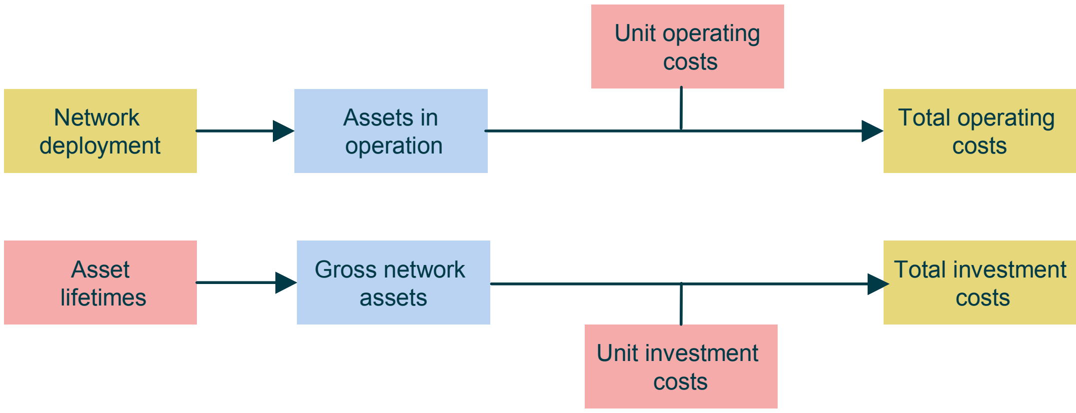
Exhibit 12: *Erlang table accounting for signalling and GPRS overheads*

The number of channels, signalling channels and GPRS channels per TRX and the blocking probability are parameters set in the *Params – 2G* sheet.

5 Cost module

5.1 Introduction

The cost module calculates the total investment and operational expenditure required to roll out the network deployment. The cost module takes as input the network deployment (i.e. the forecasts of assets) produced by the network module. It multiplies the assets in operation by the unit operating cost over time in order to generate the total operating costs. It uses asset lifetimes to calculate replacement cycles and hence the gross network asset required in each year, and multiplies these by unit investment costs to generate the total investment costs.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 13: *Cost module flow of calculation*

5.2 Detailed description of module contents

This section provides a sheet-by-sheet description of the contents of the module.

Linked inputs

This sheet links to the outputs of the network module: the number of assets, operator choice and EDGE coverage.

A switch allows the user to select an operator manually, otherwise the choice of operator is linked to the network module.

Parameters

On this sheet parameters for discount rates, asset lifetimes and operating expenditure ratios can be entered.

The lifetimes entered in this sheet are assumed to be economic lifetimes rather than accounting lifetimes. Economic lifetimes refer to the period after which it is economically efficient to replace an asset and to incur capex rather than to continue incurring opex to maintain the asset for longer.

Asset demand for costs

This sheet smoothes the rate of asset deployment to avoid spikes in supply. Typically, the rate of deployment of an asset climbs to a peak before declining. The smoothing algorithm ensures that before the peak, asset numbers always increase (or remain constant), while after the peak, asset numbers always decrease or remain constant.

The number of assets incurring operating expenses is calculated on this sheet. Where asset numbers are decreasing (due to decommissioning), it is assumed that there will be a lag between when the asset is no longer required in the network and when it will no longer incur operating expenses.

The number of assets purchased is calculated as the number of incremental assets required plus the number of assets required to replace assets whose lifetime has expired.

An adjustment to model EDGE roll-out is also made in this sheet. The algorithm forces advanced replacement of TRXs and BSCs in the years following launch of EDGE in a given geotype.

Unit investment

The current MEA price of each asset and the MEA price trend over time are input on this sheet. The resulting MEA price over time is then calculated.

Total investment

Total investment is calculated as unit investment (MEA prices) multiplied by the number of assets purchased. The result is used as input to the service cost module.

Unit expenses

The current MEA expenses of each asset and the MEA expenses trend over time are input on this sheet. The resulting MEA expenses per unit over time are then calculated.

Total expenses

Total expenses are calculated as unit investment (MEA prices) multiplied by the number of assets in operation. The result is used as input to the service cost module.

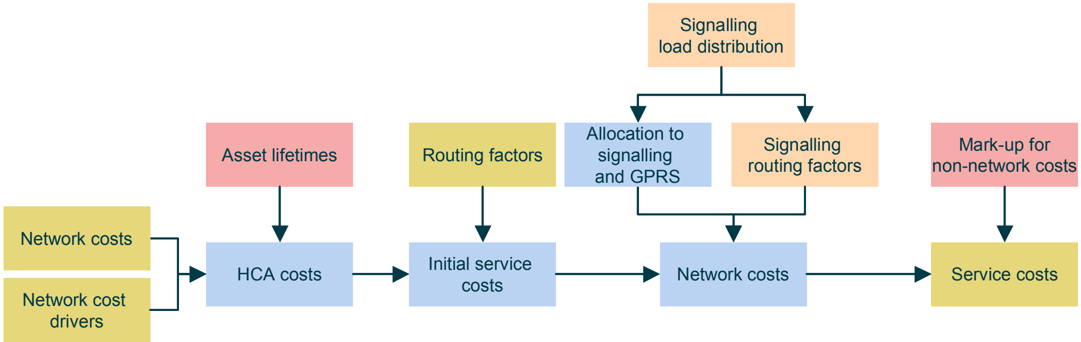
Lists

This sheet contains several lists used for reference elsewhere in the model.

6 Service cost module

6.1 Introduction

The service cost module implements historic cost accounting and produces a service costing on this basis. The key inputs to the module are the service routing factors, network costs and cost drivers. The model generates costs on a HCA basis on the basis of the asset lifetimes, and makes an initial allocation of these costs to services on the basis of the routing factors. It then considers the radio network load due to signalling and GPRS in order to conduct a secondary allocation of network costs to services requiring these functions. Finally it adds a mark-up for non-network costs in order to derive the final service costs. The outputs are the service costs for incoming voice traffic and incoming SMS on the basis of HCA.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 14: *Service cost module flow of calculation]*

The cost allocation method is designed to be consistent with the cost drivers used to determine network deployment. Cost allocation is primarily based on routing factors defined in the *Network* module; certain costs are then re-allocated to signalling or GPRS channels, and in turn via a second set of routing factors to SMS messages, incoming calls and GPRS.

The cost allocations used are detailed in Exhibit 15 below.

Asset type	*Initial routing factor*	*Further allocation to GPRS based on …*	*Further allocation to signalling based on …*
2G SIM cards	2G SIM cards		
2G cell site equipment	2G radio traffic	proportion of radio channels reserved	proportion of radio channels reserved
2G TRXs	2G radio traffic	proportion of radio channels reserved	proportion of radio channels reserved
2G BSCs	2G radio traffic	proportion of radio channels reserved	proportion of radio channels reserved
2G MSCs	2G MSC processing		
2G MSC ports – BSC-facing	2G CS radio traffic	proportion of radio channels reserved	proportion of radio channels reserved
2G MSC ports – Interconnect facing	2G interconnect CS traffic		core network signalling overhead
2G MSC ports – Interswitch facing	2G inter-switch CS traffic		core network signalling overhead
2G GSN	2G PS core traffic		
2G SMSC	2G SMS		
2G licence fees	2G radio traffic	proportion of radio channels reserved	proportion of radio channels reserved
3G SIM cards	3G SIM cards		
3G cell site equipment	3G radio interface traffic		radio traffic signalling overhead
3G site upgrade	3G radio interface traffic		radio traffic signalling overhead
3G RNCs	3G core traffic		radio traffic signalling overhead
3G MSCs	3G MSC processing		
3G MSC ports – RNC-facing	3G CS traffic		radio traffic signalling overhead
3G MSC ports – Interconnect facing	3G interconnect CS traffic		core network signalling overhead
3G MSC ports – Interswitch facing	3G Inter-switch CS traffic		core network signalling overhead
3G GSN	3G PS core traffic		
3G SMSC	3G SMS		
3G licence fees	3G radio interface traffic		radio traffic signalling overhead
Cell sites	All radio traffic	proportion of 2G radio channels reserved and proportion of radio traffic that is 2G	proportion of 2G radio channels reserved/ 3G radio traffic signalling overhead and proportion of radio traffic that is 2G/3G

Remote switching sites	All radio traffic	proportion of 2G radio channels reserved and proportion of radio traffic that is 2G	proportion of 2G radio channels reserved/ 3G radio traffic signalling overhead and proportion of radio traffic that is 2G/3G
Backhaul	All radio traffic	proportion of 2G radio channels reserved and proportion of radio traffic that is 2G	proportion of 2G radio channels reserved/3G radio traffic signalling overhead and proportion of radio traffic that is 2G/3G
BSC/RNC to MSC links	All radio traffic	proportion of 2G radio channels reserved and proportion of links used for 2G	proportion of 2G radio channels reserved/3G radio traffic signalling overhead and proportion of links used for 2G/3G
Transit switches	All MSC processing		core network signalling overhead and proportion of core traffic that is 2G/3G
HLRs	All calls		
Main switch sites	All core traffic		core network signalling overhead and proportion of core traffic that is 2G/3G
NMS	All core traffic		core network signalling overhead and proportion of core traffic that is 2G/3G
IN	All subscribers		
Core transmission	All core transmission traffic		core network signalling overhead and proportion of core traffic that is 2G/3G
VMS	Incoming voicemail and voicemail retrieval		
Service Integration Infrastructure	Push SMS		

Exhibit 15: *Cost allocations*

6.2 Detailed description of module contents

This section provides a sheet-by-sheet description of the contents of the module.

Linked inputs

This sheet lists the input to the HCA cost calculations: operator choice, service demand, service routing factors, average durations of calls, network element output, signalling and GPRS adjustments, MEA price trends, element lifetimes, network investment and expenses, and discount rate. All of the inputs are linked from the network and cost module.

Signalling

This sheet calculates on a bottom-up basis the signalling load on the 2G and 3G network over time. It also works out the corresponding routing factors for re-allocations of costs due to signalling.

The 2G network calculation takes as input the total busy hour traffic on the 2G network for all voice and SMS services and average channel occupation by voice call signalling, SMS carriage and location updates, based on information provided by operators. It outputs the resulting distribution of signalling channel occupation over time.

The 3G calculation works in a similar way, except that it considers only voice call signalling and location updates, since SMS carriage is already accounted for in the network module.

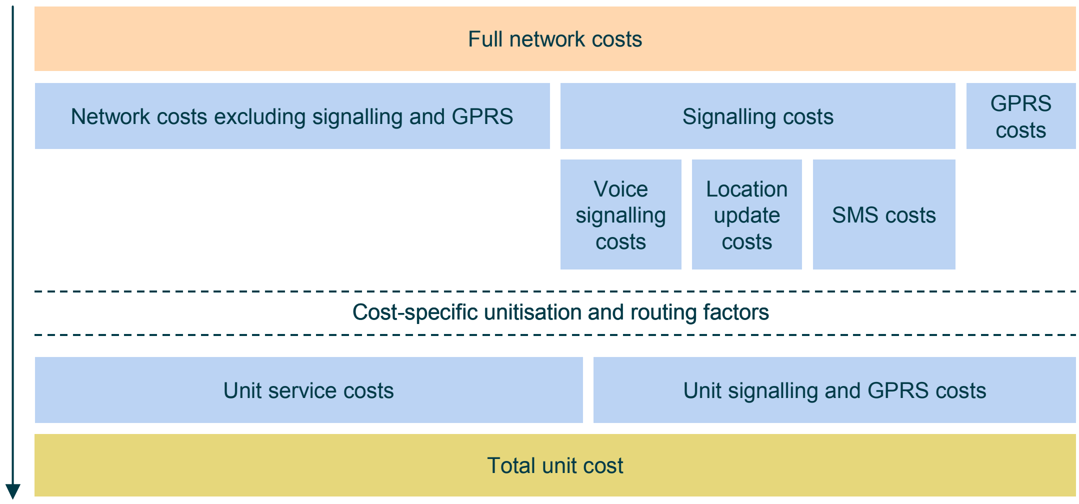
HCA

This sheet calculates the HCA annual cost of the network using historic cost accounting.

HCA Service

This sheet calculates the cost per unit volume of service based on the total annual HCA cost by network element.

The model first splits out from the full network costs a share of costs due to signalling and GPRS as illustrated below in Exhibit 16.



For a key to the colour conventions used in this diagram, see Exhibit 2 on page 6.

Exhibit 16: *HCA unit cost calculation flow*

Signalling costs are then further split into voice signalling, location update and SMS. These costs are worked out separately for 2G and 3G.

Unitisation of costs and routing factors are specific to each type of cost (all services, voice signalling, location update, SMS, and GPRS).

Finally the model outputs the cost per unit volume of service by summing the unit service, signalling and GPRS costs.

Results

This sheet presents the network cost per unit for incoming voice and incoming SMS services, both separately for 2G and 3G and aggregated. It also adds a mark-up for non-network costs. This sheet also shows total network costs, as well as the breakdown of HCA service costs over time.

Lists

This sheet contains several lists that are included for reference elsewhere in the module.

Annex A: Treatment of signalling costs

The treatment of signalling costs in the mobile LRIC model is intended both to capture the relevant network costs and also to allocate them between call signalling, location updates and SMS functions in a way consistent with ARCEP's determination.

A.1 Capture of relevant costs

Signalling in the 2G radio network

The 2G radio network relies on dedicated channels for signalling. We assume that the number of channels required is a fixed number per TRX (initially set as one signalling channel from the eight channels available on a TRX). We have confirmed using off-line checks not integral to the main model that this is more than sufficient to carry the forecast signalling traffic.

In order to account for the signalling channel in the network deployment algorithms, the voice traffic capacity of a TRX is adjusted (initially to seven rather than eight channels).[2] This adjusted TRX capacity is used to drive the deployment of both TRX and cell sites based on a cost driver of 2G voice traffic.

The deployment of other assets in the 2G radio network accounts for the signalling channel in the following way:

- BTS deployment is driven by cell sites, which already accounts for the signalling
- BSC deployment is in turn driven by BTS deployment, which already accounts for signalling
- the backhaul (BTS–BSC) deployment is driven by the capacity required for a full eight channels per TRX (which therefore includes the signalling channel)

[2] We note that an adjustment to TRX capacity is also made to account for the reservation of a GPRS channel.

- deployment of BTS-facing ports on BSCs is also driven by the capacity required for a full 8 channels per TRX
- deployment of MSC-facing ports on BSCs is driven by the capacity required for circuit-switched traffic, based on a required number of circuits, which accounts for the use of one in eight circuits for signalling
- deployment of BSC–MSC links for remote BSCs is driven by the total number of 2Mbit/s ports at the BSC which are either MSC-facing (which accounts for voice and signalling circuits) or SGSN-facing (which accounts for GPRS traffic)

Signalling in the 3G radio network

The 3G radio network allocates capacity dynamically between signalling and traffic channels. In order to account for the signalling channel in the network deployment algorithms, we rely on input parameters that define the traffic-carrying capacity of radio equipment. We account for SMS traffic within these algorithms on the basis that it is carried in the 3.4kbit/s signalling radio bearer (SRB) channel.

Signalling in the core network

MSC and SMSC network deployment algorithms account for call signalling, SMS and location updates using explicit cost drivers for each of these functions. Switch sites are in turn driven by the number of MSCs and GSNs.

Algorithms for the deployment of the core transmission network account for signalling by considering the extra capacity that must be provisioned in order to convey this channel. The extra capacity required is initially set at a mark-up of 1/28 on voice and data traffic on the basis that for each TRX in the radio network seven of the 16kbit/s channels are converted to 64kbit/s channels in the core network and there is an additional one signalling channel at 16kbit/s. We assume that the additional loading on 3G traffic is similar to that for 2G traffic.

In considering the NMS, which helps to support the signalling channels, we do not explicitly include signalling since we assume that a single network management system is deployed for each of the 2G and 3G networks.

A.2 Allocation of signalling costs

Network costs are first annualised for each asset and then allocated by the use of routing factors consistent with the cost drivers for that asset. For MSC and SMSC assets this allocates appropriate signalling costs directly to services. However, for other assets it is necessary to carry out a pre-allocation of costs to signalling functions and to allocate these signalling costs to services on the basis of a separate set of routing factors. This is designed to be done in a manner consistent with ARCEP's decision relating to the 2G radio network. The parameters used are based on the quantitative data provided by operators.

- In the 2G radio network, since signalling channels are initially assumed to account for one of the eight channels per TRX, 1/8 of all 2G radio network costs are pre-allocated to signalling costs. These signalling costs are allocated between call signalling, location updates and SMS functions in proportions set dynamically on a bottom-up basis in the signalling sheet.

- In the 3G radio network, costs relating to the SMS function (as measured in the loading in Mbit/s) are allocated directly to SMS services. For call signalling and location updates, a portion of the radio network costs is allocated to these functions based on proportions set dynamically on a bottom-up basis in the signalling sheet.

- In the core transmission network, since signalling channels are initially assumed to require a 1/28 mark-up on capacity required, 1/29 of all core transmission costs and switching costs other than those for MSCs and SMSCs are pre-allocated to signalling costs. These signalling costs are allocated between call signalling, location updates and SMS functions in proportions set dynamically on a bottom-up basis in the signalling sheet.

For some assets that are shared by 2G and 3G networks, it is also necessary to calculate the proportion of costs relevant to either 2G or 3G services before carrying out the allocation described above. In particular:

- costs for cell sites, backhaul and remote switching sites are allocated on the basis of the total radio traffic required (as measured in voice-equivalent Mbit/s) by each of the 2G and 3G networks across all geotypes
- costs for BSC/RNC to MSC links are allocated on the basis of the total number of links required by each of the 2G and 3G networks