Model documentation for ARCEP

Bottom-up mobile LRIC model for ARCEP (Release 5): Model Documentation

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analysys mason

Contents

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1 Introduction

Analysys Mason has been commissioned by ARCEP to update the existing model of the long-run incremental cost (LRIC) of voice and SMS termination delivered by 2G and 3G mobile network operators in France.

This documentation is an update of the documentation previously created in 2007 during the initial creation of the LRIC model. The documentation update includes new content for new features of the model as well as removing obsolete content.

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
Annex B: describes the functioning of the pure LRIC macro

2 Model overview

2.1 Scope of model

The primary objective of the model is to assess on a pure LRIC basis the network costs of delivering incoming voice on 2G and 3G mobile networks. However, data and SMS services are also included in the scope of the model in order to take account of economies of scope. The model is based on the use of four 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
- FDD UMTS using 5 MHz paired spectrum in the 900 MHz band.

We have also built into the model the flexibility to assess the impact on voice and SMS termination costs of deploying HSPA and Femtocells.

The model explicitly calculates 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 is capable of calculating the costs of several network operators by allowing 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
- 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. It explicitly calculates the network costs for the period 1990–2016.

The model then calculates the pure long-run average incremental cost (LRIC) cost of voice termination delivered by mobile network operators in France. As part of the calculation process to work-out pure LRIC costs, the average long-run incremental cost (LRAIC) of all main services is calculated as well 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 four depreciation methods:

- straight-line depreciation (SLD)
- current costs accounting with operating capital maintenance (CCA-OCM)
- current costs accounting with financial capital maintenance (CCA-FCM)
- current costs with tilted annuities (CCTA)

2.2 Model structure

The mobile LRIC model comprises four distinct modules, as shown in Figure 2.1.

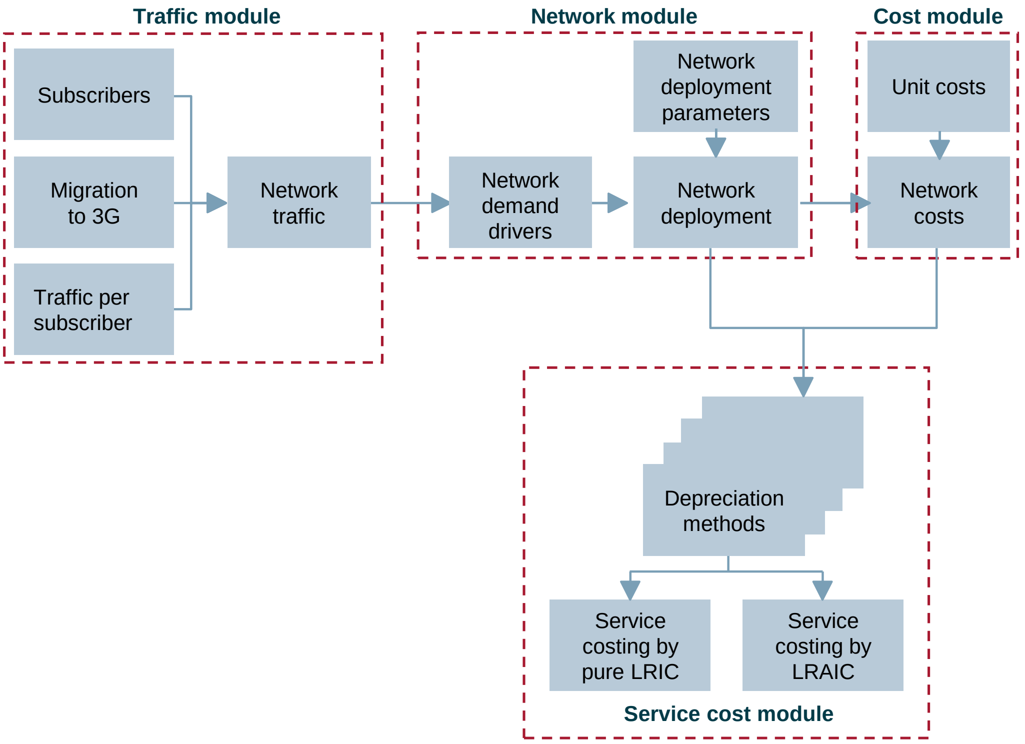

Figure 2.1: Model structure [Source: Analysys Mason]

- The **traffic module** produces network demand forecasts by projecting the number of subscribers, traffic per subscriber and market share 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** output service costs under the pure LRIC methodology, based on SLD, CCA-OCM, CCA-FCM or CCTA. Service cost by LRAIC is also worked out as part of the calculation process.

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 Figure 2.2.

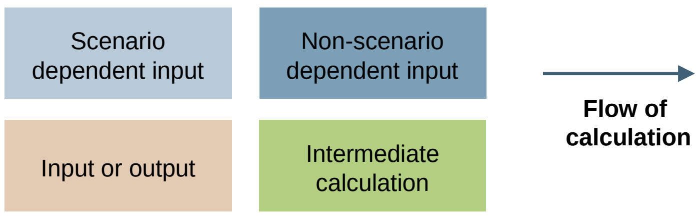

Figure 2.2: Key to calculation flow diagrams [Source: Analysys Mason]

2.3 Model inputs

Parameters in the model are based on data provided by operators, ARCEP's accounting data, INSEE, and market research databases (Analysys Mason Research and WCIS). Where no specific data sources are available we have provided estimates based on our own judgement.

2.4 Model results

The model results are calculated as the incremental cost of terminating voice services to mobile network operators ('pure LRIC' methodology). Results base their output on the four depreciation methods SLD, CCA-OCM, CCA-FCM and CCTA. The results are presented in nominal 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 Figure 3.1.

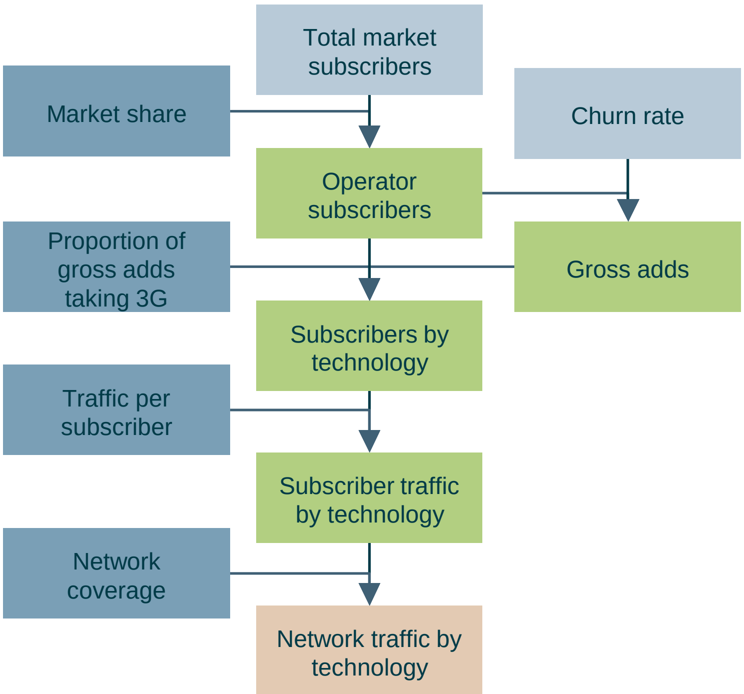

Figure 3.1: Traffic module calculation flow [Source: Analysys Mason]

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.

Five broad categories of subscribers are modelled:

- 2G subscribers
- 3G subscribers
- 3G datacards users (datacards are a new type of mobile subscriber that generate only, but large amount of, mobile broadband data)
- Machine to Machine users
- Femtocell subscribers

The migration of subscribers from 2G to 3G is forecast based on an assumed handset churn rate and an assumption about the number of churning subscribers that take 3G handsets in each year. 3G datacard market evolution is modelled based on its population penetration. Machine to machine users is modelled as a proportion of the total mobile subscribers, while Femtocell subscribers is modelled as a proportion of the 3G subscribers.

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.

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 traffic migration curves for voice, SMS and data. In addition a traffic migration curve is used to re-balance the traffic between R.99 and HSPA.

The traffic model is also able to model a 3G-only operator by assuming that all traffic is carried by the 3G network.

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

Demand parameters

- 2G coverage
- 3G coverage
- Proportion of gross additions taking 3G
- Market shares evolution (affects subscriber market share, machine 2 machine market share and datacards market share)

Traffic parameters

- Average voice traffic per subscriber
- Ratio of 3G voice use over 2G voice use as a proxy for usage patterns of early adopters
- Messages per average handset subscriber
- Ratio of 3G message use over 2G message use as a proxy for usage patterns of early adopters
- Messages per average Machine2Machine subscriber
- 2G data usage per subscriber
- 3G data usage per subscriber
- 3G data usage per datacard
- Voice migration profile (share of traffic on 3G network)
- SMS migration profile (share of traffic on 3G network)
- Handset data migration profile (share of traffic on 3G network)
- Datacard data migration profile (share of traffic on 3G network)
- Data migration profile (share of 3G data traffic on HSPA network)

Operator type parameters

- Modelled operator is 2G and 3G
- Traffic share per geotype inputs in sheet 'Geotypes' are based on 2G coverage

Femtocells

- Modelled operator deploys Femtocells

Network module parameters

- Direct tunnelling option
- 2G and 3G white zones deployment option
- Spectrum reallocation options
- 900MHz refarming options
- HSPA options
- Backhaul options
- UMTS 2100 carrier deployment options

3.3 Running a 3G only operator

This section contains a description of how to run a 3G-only operator.

Setting the scenario control parameters

- Set 2G coverage to ‘spare’
- Set 3G coverage to appropriate value (there are 5 ‘spare’ values that can be used)
- Set Proportion of gross additions taking 3G to ‘3G only operator’
- Set Market shares evolution to appropriate value (there are 3 ‘spare’ values that can be used)
- Set the voice migration, SMS migration, handset data migration and datacard migration profile to ‘3G only operator’
- Set Modelled operator is 2G and 3G to FALSE
- Set Model 2G white zones deployment to FALSE
- Set Date to return 900MHz spectrum to 2017

Checking consistency

- Consistency checks in column E of the ‘Scenario sheet’ give an alert if the selected profiles are not consistent e.g. a 3G coverage which is too late for assumed market entry date.
- Make sure they are all set to Ok

Setting the other model parameters

- If reusing an existing profile e.g. the 'generic operator' one, check that the assumed values for that profile correspond to the operator you want to model.
- If creating a separate profile in the spare one, set values for all operator-dependent parameters.

Other model parameters to pay attention to

- A value must be set for the 2G MSC CPU capacity as that value is used when estimating the number of main switch buildings

3.4 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.

Compared with the 2007 model, the list of scenario parameters has been expanded to control the new functionalities.

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.

In addition to the inputs that were in the 2007 model, 2G/3G traffic migration profiles and Femtocell penetration inputs are also included. On the other hand the EDGE coverage has been removed. Given the progress of technology EDGE is not as important as it was before and removing it allows to reduce the complexity of the model.

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.

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 Figure 3.2 below. The rural communes are also identified as either mountainous on non-mountainous.

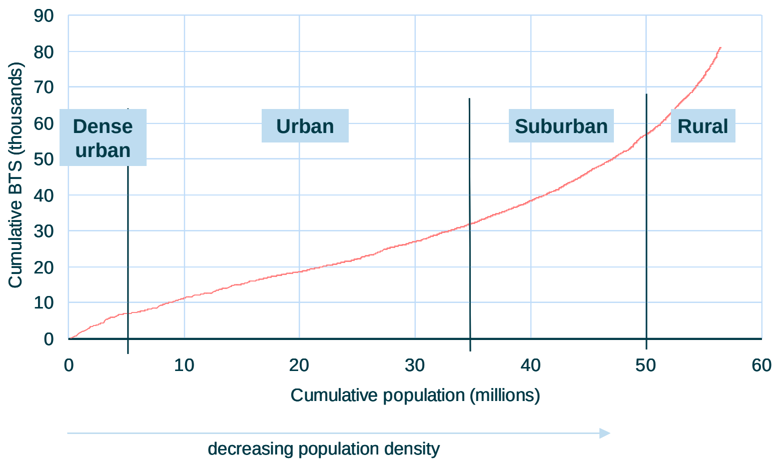

Figure 3.2: Cut-offs for geotypes (cumulative population and cumulative base stations Source: Analysys Mason]

Subscribers

This sheet produces a forecast of the number of subscribers by technology for the modelled operator. Five broad categories of subscribers are modelled as described in section 3.1.

3G datacard users, machine to machine users and Femtocell subscribers are additional market segments included in the current model to reflect the increase influence of these emerging technologies.

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.

The population penetration of 3G dongles is forecast using a s-curve, based on the historical penetration. 3G datacard market outlook is obtained by combining this penetration with the population forecast. Total machine to machine market is modelled as a proportion of the total mobile subscribers. Finally operator market share profiles are applied to these two services to arrive at the operator-specific subscriber numbers. Femtocell subscribers is modelled simply as a proportion of the selected operator’s 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 traffic, 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 traffic to different types of destination; and incoming traffic as a proportion of outgoing traffic to each of those destinations. Voicemail traffic is defined as a proportion of incoming calls. Subscriber traffic is then converted into network traffic based on the mix of 2G and 3G subscribers and 2G/3G traffic migration profiles.

This is a substantial simplification when compared with traffic rebalancing algorithms used in the 2007 model. This modification was performed in response to operators' comments following the release of the 2007 model. This implementation allows for greater transparency in forecasts and the ability to take into account of new usage profiles.

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 Figure 4.1. The input of the module, taken from the traffic module, is the service demand on the 2G and 3G networks. The output of the module is the network deployment.

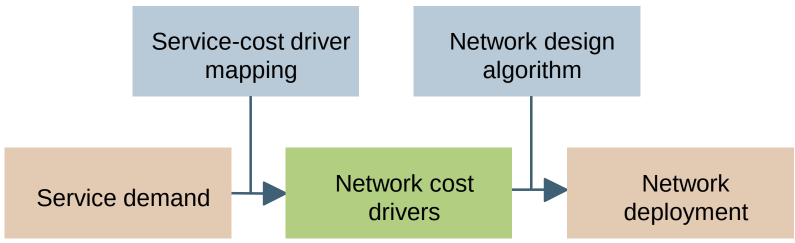

Figure 4.1: Network module flow of calculation [Source: Analysys Mason]

The 2007 model assumes only one type of 3G carrier. In response to operators' requests, the current model incorporates the capability to simulate two different types of 3G carriers which can have different functionalities. They are denominated as "type 1" and "type 2" carriers. By varying the traffic mix (namely R99 voice, R99 data and HSPA data traffic) on these two types of carriers, different scenarios can be considered:

- Deployment of dedicated HSPA carrier: Type 1 carriers carry R99 voice, R99 data and HSPA data traffic, hence act as a shared carrier, whilst Type 2 carriers are dedicated to carrying only HSPA data traffic
- Deployment of dedicated voice and data carrier: Type 1 carriers carry only R99 voice traffic while Type 2 carriers carry only R99 data and HSPA data traffic
- Deployment of dedicated voice carrier and a shared voice/data carrier: Type 1 carriers carry only R99 voice traffic, and type 2 carriers can carry all three kinds of traffics

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 (service demand, coverage, subscriber numbers as well as operator-specific network design options).

3G_Carrier_dep

This sheet contains the parameters and macros used in the network design algorithm to calibrate the deployment dates of the UMTS2100 carriers. These has been implemented in order to model the use of additional 2.1GHz spectrum for UMTS in a dynamic way.

The calibration process may be run as part of the pure LRIC macro, which can be triggered by pressing the button "*Run LRIC calculations*" in the sheet *results* of the workbook *4 – service cost.xls*. Alternatively, the user can initiate the calibration process independently by pressing the button "*Force Re-calibration*" in this sheet.

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.

The current model implements the reduction of GSM900 spectrum holdings. The freed up spectrum is then available to be awarded to the new entrant to the French mobile market. Provisions have also been made to reduce GSM900 spectrum holdings in rural and rural mountain geotypes in the future to account for spectrum refarming for UMTS900 use.

Other new parameters include:

- proportion of traffic processed by 2G MSCs; the remaining traffic is processed by combined 2G/3G MSCs and MGWs
- percentage of newly established sites that are 2G white zone sites

Params – 3G

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

Several new parameters have been implemented in the current model:

- HSPA site upgrade schedule
- Parameters to dimension type 1 and type 2 carriers:
  - Percentage of R99 voice traffic on the type 2 carriers

  - Percentage of R99 data traffic on the type 2 carriers
  - Percentage of HSPA traffic on the type 2 carriers
- Direct tunnelling activation date (is activated or deactivated by setting the activation date - a date of 2017 is equivalent to deactivating)
- HSPA site upgrade impact on backhaul
- Percentage of newly established sites that are 3G white zone sites
- Percentage of 3G white zone sites that are upgraded from 2G white zone sites

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.

- New parameters have been implemented to model a more versatile 3G network:3G spectrum availability dates, by carrier type[1] and by spectrum type[2]
- The maximum number of 3G 2100 MHz carriers available to operators have been increased from 3 to 5
- Cell radii by spectrum type

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.

The current model includes several additions:

- Option and parameters to model the IP-MPLS optic fibre core transmission technology in addition to existing leased lines and SDH optic fibre
- Proportion of new backhaul technologies:
  - DSL backhaul
  - Fibre backhaul
- Threshold for migration to Ethernet of existing TDM backhaul technologies:
  - Leased line backhaul
  - Microwave backhaul

1 Type 1 and Type 2

2 2100MHz and 900MHz

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.

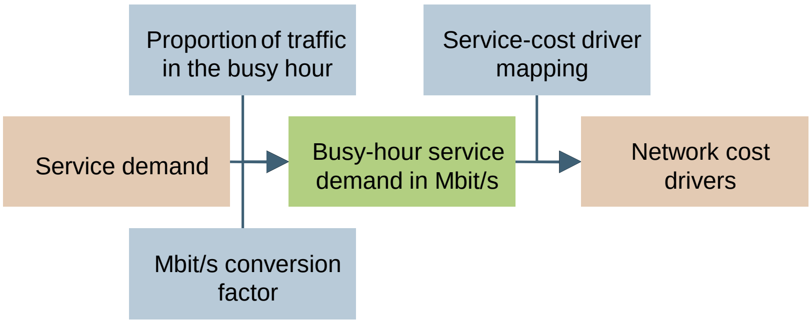

Figure 4.2: Cost driver calculation flow [Source: Analysys Mason]

The typical calculation flow is shown in Figure 4.2, 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.

The 3G radio interface traffic is further split between the Type 1 and Type 2 carriers, according to the assumptions specified in the sheet "*Params – 3G*"

The cost drivers do not include the use of dedicated signalling channels or radio channels reserved for GPRS since these are accounted for separately. However, this sheet does output 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[3], look-ahead periods and headroom drivers.

[3] "The deployment of a scorched node network is captured explicitly by the use of additional utilisation parameters. These indicate the degree to which equipment is unable to reach the level of utilisation that would be achieved in a scorched earth deployment, as a direct result of adhering to the scorched node constraint. A scorched-node deployment is one that evolves over time and is constrained by the history of deployments. Conversely, a scorched-earth deployment is one which has no historic constraints, and can be deployed in an optimal fashion" [Source: The LRIC model of UK mobile network costs, developed for Oftel by Analysys, September 2001]

Network design – 2G

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

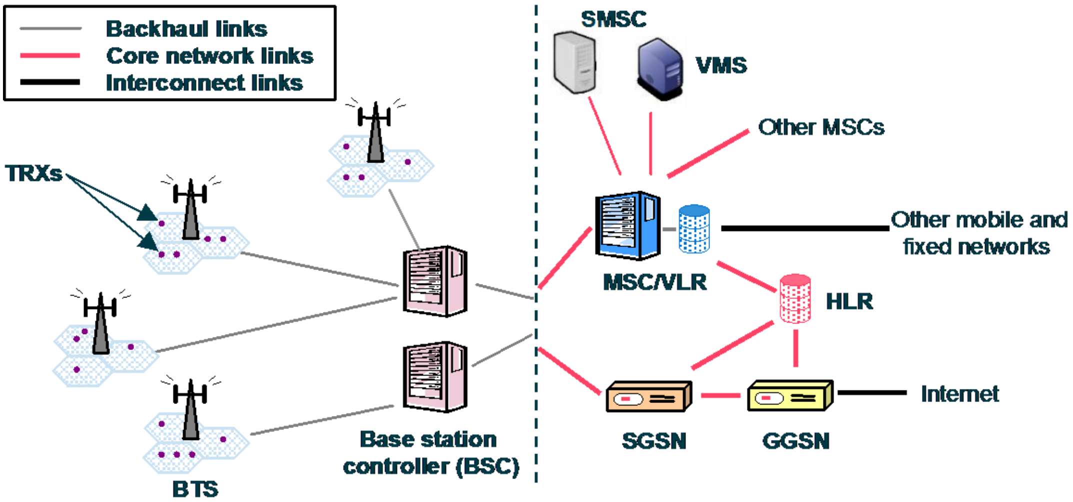

Figure 4.3: Simplified GSM network diagram [Source: Analysys Mason]

- Base station sites, transceivers (TRXs), BTSs, base station controllers (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 SGSNs (Serving GPRS Support Nodes) and GGSNs (Gateway GPRS Support Nodes) which connect to the Internet.
- A Home Location Register and a Voicemail Server also sit in the core network.
- Core network links are illustrated in Figure 4.3 in red. Interconnect links are shown in black, but are outside the scope of the LRIC model.

The algorithm which calculates the number of required **base station sites** uses an incremental approach, as illustrated in Figure 4.4. 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.

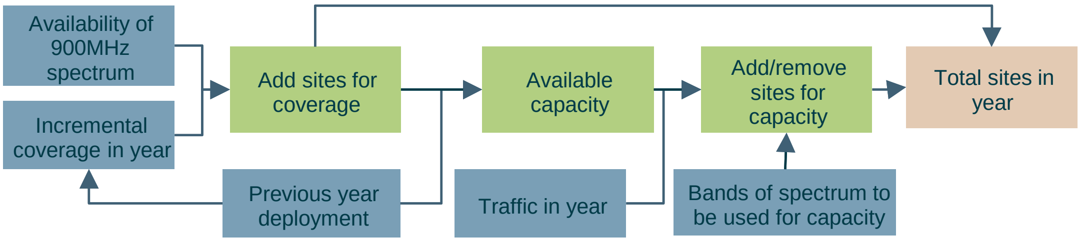

Figure 4.4: Calculation of the number of required sites [Source: Analysys Mason]

- 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. 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.
- The model calculates separately the number of incremental 2G white zone sites as a percentage of the incremental coverage sites. This is described in more detail in Figure 4.11 at the end of the 'Network design – 3G' section
- 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 and GPRS is assumed to require a fixed number of dedicated channels per sector. 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.

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 Figure 4.5. 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.

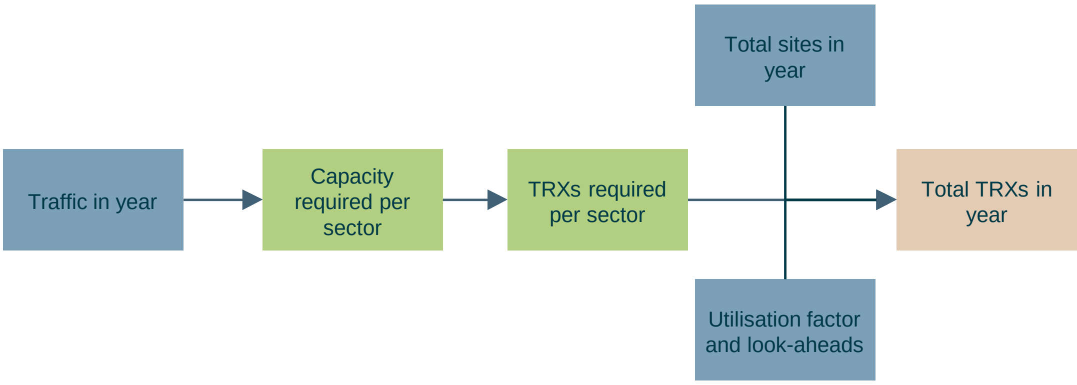

Figure 4.5: Calculation of the number of required TRXs [Source: Analysys Mason]

The number of **BTSs** required is worked out from the total number of sites and the average number of BTSs per site 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.

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. **BSC backhaul** design follows a ring structure. 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 migration profile from 2G MSCs to combined 2G/3G MGW and MSCS, and demand linked to incoming, outgoing and on-net call attempts. 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 that a minimum of two 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 which 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 two SGSNs and GGSNs will be deployed for redundancy.

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 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.

An **intelligent network** (including billing systems, prepaid platforms and other service platforms) is deployed in the first year of operation of the network.

A **licence fee** asset is deployed at the beginning of 2G network operations.

As described above, the current model assumes a migration over time to a layered architecture for circuit switched layer, as opposed to the monolithic 2G MSC implementation in the 2007 model. A demand migration profile from 2G MSCs to combined 2G/3G MGW and MSCS is applied to the BSC traffic, as illustrated in Figure 4.6 below:

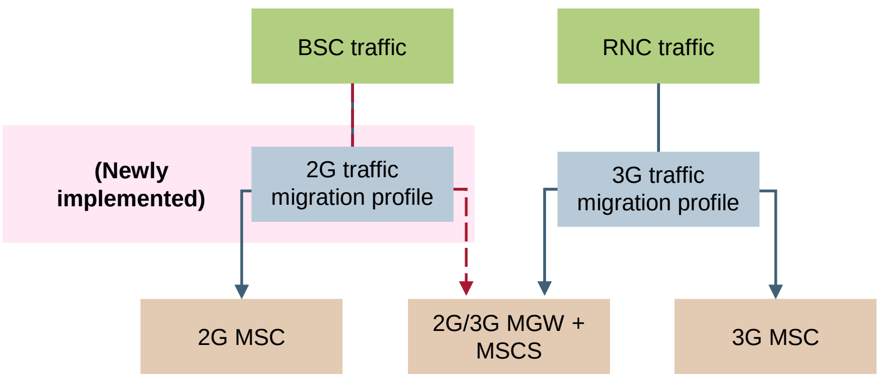

Figure 4.6: A layered architecture for the CS layer [Source: Analysys Mason]

Network design – 3G

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

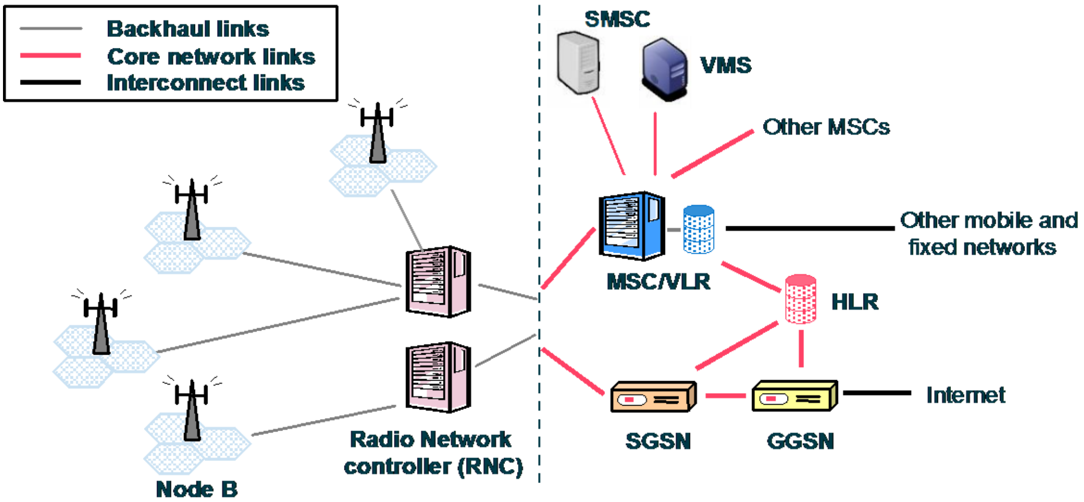

Figure 4.7: Simplified UMTS network diagram [Source: Analysys Mason]

- 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 SGSNs (Serving GPRS Support Nodes) and GGSNs (Gateway GPRS Support Nodes) which connect to the Internet.
- A Home Location Register (HLR) and a Voicemail Server also sit in the core network.
- Core network links are illustrated in Figure 4.7 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.

Two types of 3G carriers, namely Type 1 and Type 2, are modelled in the current model to incorporate the capability to investigate various carrier deployment options:

- Deploy dedicated HSPA data carrier
- Deploy dedicated voice and data carriers
- Deploy dedicated voice carrier and shared voice/data carrier

The calculations span two sheets. The sheet *Network design – 3G* calculates the number of carriers/sectors/sites required for coverage. The capacity carriers/sectors/sites calculations then branch off into two sheets:

- The number of Type 1 carriers/sectors/sites required for capacity are calculated within the same worksheet
- The number of Type 2 carriers/sectors/sites required for capacity are calculated in a new sheet called *Network design – type 2 carriers*

These two streams of calculations then converge back to the sheet *Network design – 3G* which completes the 3G carriers/sectors/sites deployment profile modelling.

The calculation flows are illustrated in Figure 4.8 below:

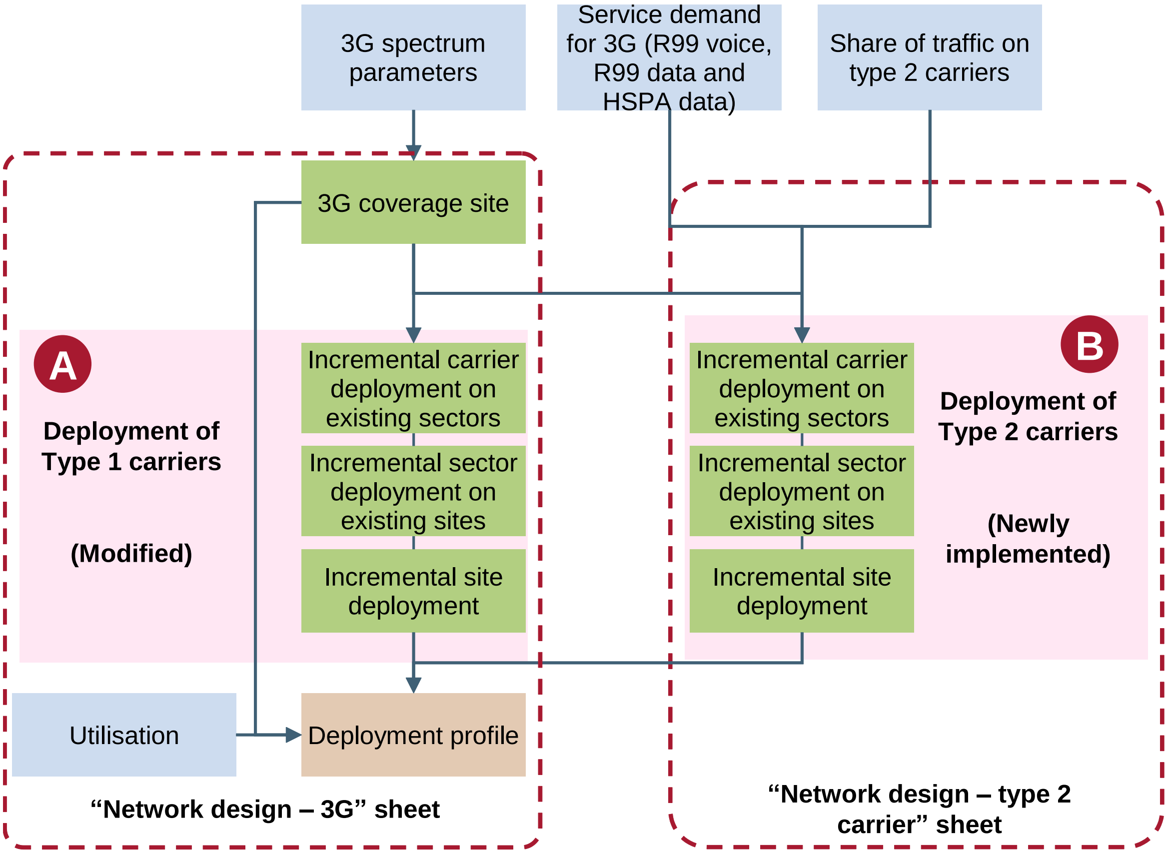

Figure 4.8: Type 1 and Type 2 carrier / sector / site deployment [Source: Analysys Mason]

The algorithm which calculates the number of required carriers, sectors and sites uses an incremental approach. This is represented by Ⓐ and Ⓑ in Figure 4.8, and is described in more detail in Figure 4.9. 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 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.

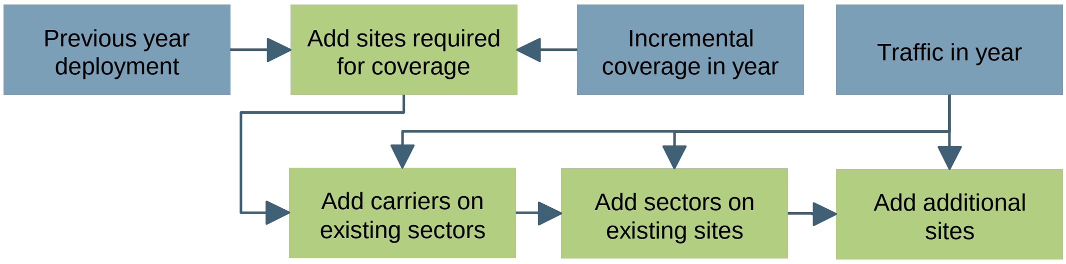

Figure 4.9: Calculation of the number of required carriers, sectors and sites [Source: Analysys Mason]

- The input to the calculation is the carrier, sector and site deployments of the previous year.
- The number of sites required to support the increase in coverage which occurs during the year is calculated based on the assumed maximum cell radius, and these sites are added to the deployment from the previous year.
- The model calculates separately the number of incremental 3G white zone sites as a percentage of the incremental coverage sites. This is described in more detail in Figure 4.11 at the end of this section
- Next, the model calculates the number of carriers (deployed on a sector on a site) required to support the assumed level of demand in the year. If this is greater than the number of carriers currently deployed, the model will add additional carriers on existing sectors until it reaches the limit of the spectrum available.
- 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 is deployed per sector. If this is greater than the number of existing deployed sectors, additional sectors (and associated carriers) will be deployed as long as there is capacity available on existing sites.
- As a final step, the model calculates the number of sites (with maximum deployment of carriers and sectors) which would be required to support the level of the demand in the year. If the number required is greater than the number of existing sites, new sites (and associated carriers and sectors) are deployed.
- The number of additional carriers, sectors and sites required are added to the previous year's deployment to calculate the total deployment in the current year. This is 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.

We note that (unlike in the 2G network deployment algorithm) the radio network demand calculation includes demand for SMS and data services. 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 either on the assumed traffic per site or based on the version of HSPA activated on the site. This is used as input to the shared backhaul algorithm on the 'Network design – other' sheet.

RNCs are dimensioned based on 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.

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. 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 which 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 section *Network design – other* below.

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 3G subscriber numbers (to capture the impact of location update processing), demand migration profile from 3G MSCs to combined 2G/3G MGW and MSCS, and demand linked to incoming, outgoing and on-net call attempts. 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 that a minimum of two MSCs is required for redundancy.

MSCs have both **RNC-facing ports** and **core-facing ports**. The number of RNC-facing ports is driven by the total number of BSCs and the RNCs' processing capacity and utilisation. Core-facing ports required are driven by total circuit-switched traffic including traffic which 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 RNCs to GGSNs in two ways:

- via an **SGSN** and then to a **GGSN**
- bypass the SGSN through a RNC-based direct tunnelling process

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 two SGSNs and GGSNs will be deployed for redundancy. This is illustrated in Figure 4.10 below

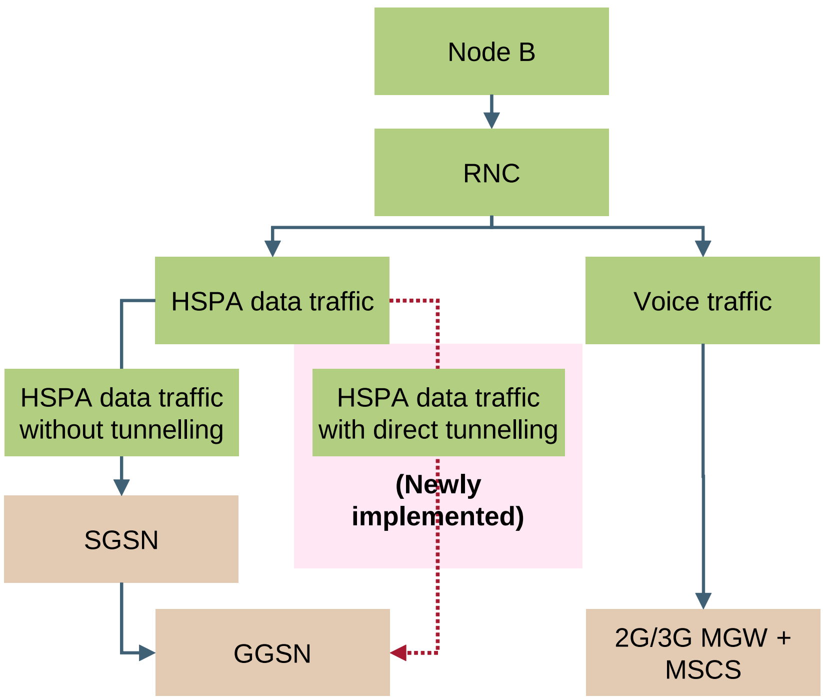

Figure 4.10: Implementation of direct tunnelling [Source: Analysys Mason]

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.

An **intelligent network** (including billing systems, prepaid platforms and other service platforms) is deployed in the first year of operation of the network.

A **licence fee** asset is deployed at the beginning of 3G network operations..

In addition, the current model also explores the white zone sites deployments. 3G coverage is increased as a result of white zone sites deployment (in the same way as 2G coverage is assumed to have been achieved through white zone site deployment from 2003). These are modelled in the following way:

- From 2003 to 2011, a portion of the new suburban, rural and rural mountain 2G sites are white zone sites
- From 2011 to 2013, a portion of the new suburban, rural and rural mountain 3G sites are white zone sites
- A portion of the 3G white zone sites are assumed to be upgraded from the 2G white zone sites

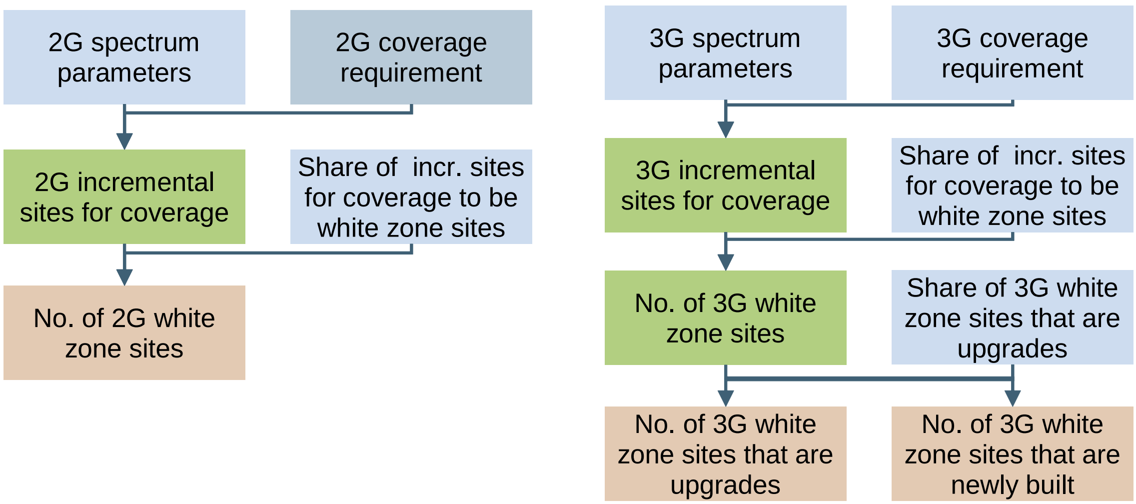

Figure 4.11: 2G and 3G white zone sites deployment [Source: Analysys Mason]

Furthermore, the current model also added the option to use Femtocell for 3G subscribers added, with the use of a new geotype "indoor Femtocells". When this option is activated, a percentage of all 3G traffic (of 3G subscribers with Femtocells) is offloaded to Femtocells. It is currently (implicitly) considered that Femtocells use unlicensed spectrum (e.g. not 2.1GHz), thus no impact on the use of 3G carriers have been implemented when Femtocells are used. The calculations outputs two new assets: Femtocell Customer Premises Equipment (CPEs) and Femtocell gateways.

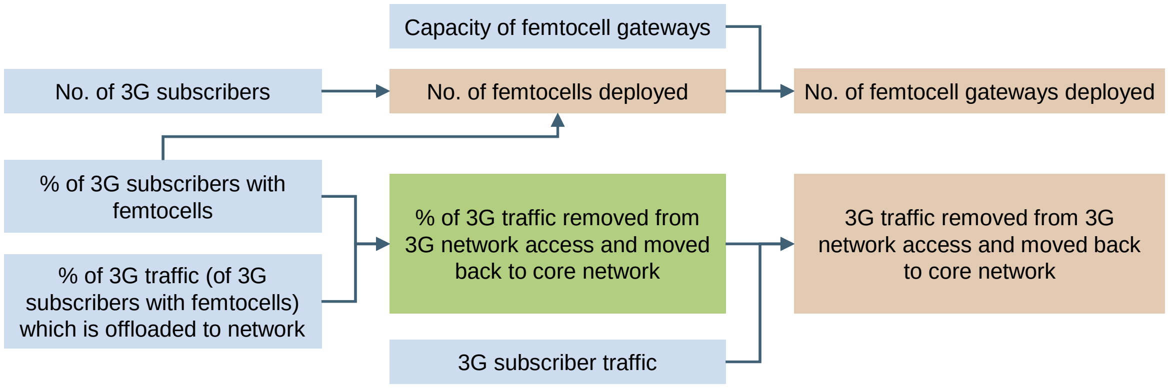

Figure 4.12: Femtocell modelling [Source: Analysys Mason]

Network design – type 2 carriers

This sheet contains the network design algorithms which calculates the number of required Type 2 carriers, sectors and sites uses an incremental approach. This is represented by B in Figure 4.8, and is illustrated in more detail in Figure 4.9.

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 which will be shared with 2G sites (if available) is assumed as an input to the calculation. The algorithm then outputs the number of required sites which 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. Backhaul is then deployed to accommodate the implied average traffic per site. The configuration of the backhaul network is assumed to be a mix of four backhaul technologies parameter set in the 'Params – others' sheet.:

- Leased lines (already in previous versions of the model)
- Microwaves (already in previous versions of the model)
- DSL (added to the new version of the model)
- Fibre (added to the new version of the model)

In addition the legacy TDM backhaul technologies (leased lines and microwave) are migrated to **Ethernet backhaul** on a geotype by geotype basis over a specified duration (currently set at 3 years) from the time the following two conditions are fulfilled:

- Ethernet backhaul is available

- The average number of E1 links per site is greater than a threshold representing the point at which it is more cost-effective to migrate to Ethernet backhaul

HLRs and **VMSs** are driven by the number of active subscribers. It is assumed that 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. They are driven by whichever is the greatest number of assets in the following four asset classes – MSCs in the 2G network, 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.

The total number of **core network** transmission requirements is driven by all core traffic, including all 2G and 3G packet-switch and circuit-switched traffic. This transmission requirements is then supported by one of three transmission architecture

- A number of E1 leased line links
- A mix of dark fibre and wavelengths optic fibre infrastructure with SDH ADMs (Add and Drop Multiplexers)
- A mix of dark fibre and wavelengths optic fibre infrastructure with IP ADMs (Add and Drop Multiplexers)

The transmission architecture can change over time which allows to reflect an operator migrating from for instance leased lines to its own IP core transmission backbone.

The modern equivalent of a 2G or 3G MSC is an **MSC Server (MSC-S)** and **Media Gateway** (MGW). 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 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 Server, with an allowance for utilisation. Additionally, it is assumed that a minimum number of MSC Servers is required for redundancy and for managing MGWs.

The MGW is assumed to be driven by the number of ports required to accommodate the traffic received from the BSCs and/or 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.

Over time a migration curve migrates the 2G and 3G traffic to the combined 2G/3G MSC-S and MGWs.

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 SLD, CCA-OCM, CCA-FCM or CCTA. 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.

A special calibration factor is included to scale the HSPA data traffic in order to account for the more efficient HSPA network elements. This is not the case for R.99 data as the cost drivers already take into account the difference in efficiency between R.99 voice and R.99 data.

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 Figure 4.13 below.

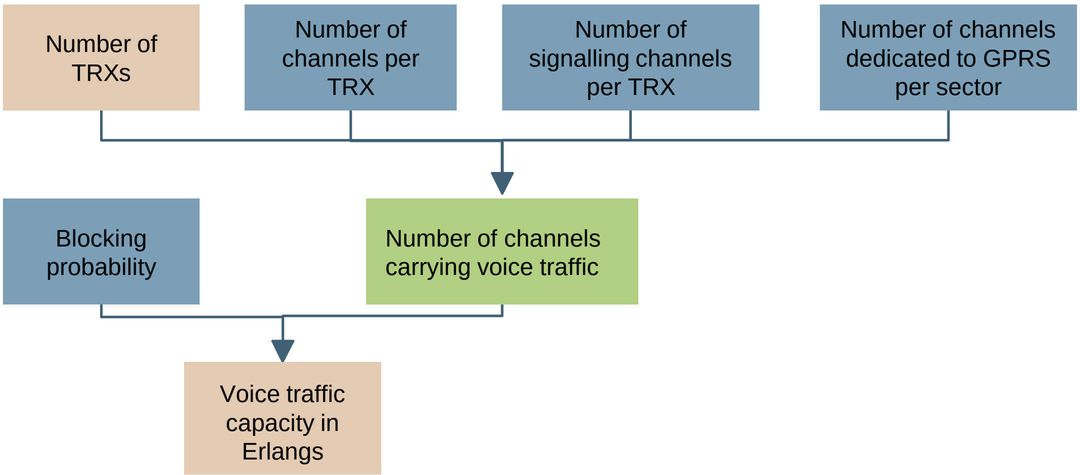

Figure 4.13: Erlang table accounting for signalling and GPRS overheads [Source: Analysys Mason]

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 expense required to roll out the network deployment. The cost module takes as input the forecasts of assets produced by the network module.

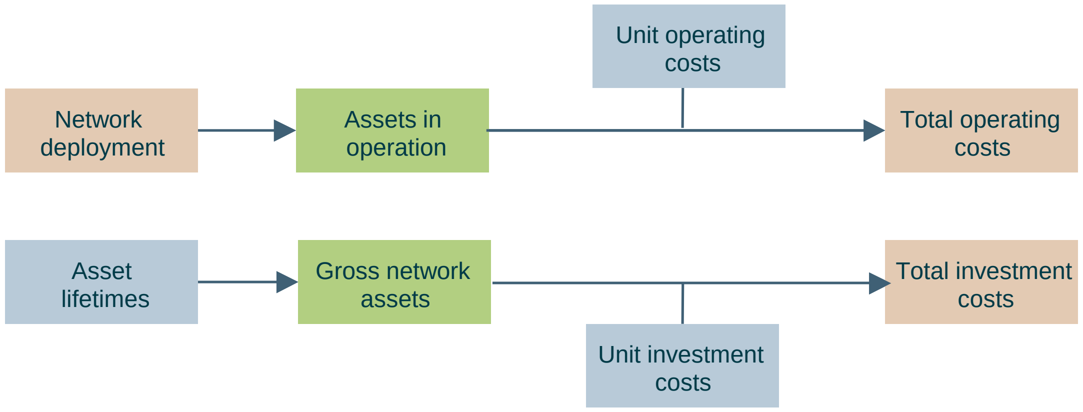

Figure 5.1: Cost module flow of calculation [Source: Analysys Mason]

5.2 Detailed description of module contents

This section provide 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, asset lifetime and discount rate.

Parameters

This sheet contains the inflation assumptions and discount rates assumptions It calculates discounting factors used in the model. It also contains a list of asset lifetimes. Compared with the 2007 model, the current model includes lifetime for several new assets (please refer to Figure 5.2 for a list of new assets).

Group	Subgroup	Name
Sites	Cell sites	White zone sites: site acquisition and preparation and lease
3G radio network	3G cell site equipment	White zone sites: RAN sharing equipment
Backhaul	Backhaul	Ethernet microwave link
Backhaul	Backhaul	TDM microwave link (8 Mbit/s)
Backhaul	Backhaul	DSL backhaul
Backhaul	Backhaul	Ethernet leased line
Backhaul	Backhaul	TDM leased line (2 Mbit/s)
Backhaul	Backhaul	Fibre backhaul
3G radio network	3G Femtocells	Femtocell: site acquisition and preparation and lease
3G radio network	3G FMGs	Femtocell gateway
Shared core network	Core transmission	Fibre-based ADM
3G radio network	HSPA upgrades	HSPA 1.8/3.6 site upgrade
3G radio network	HSPA upgrades	HSPA 7.2 site upgrade
3G radio network	HSPA upgrades	HSPA 14.4 site upgrade
3G radio network	HSPA upgrades	HSPA site upgrade spare
Shared core network	Core transmission	IP-MPLS access points 1GbE

Figure 5.2: List of new assets [Source: Analysys Mason]

Compared with the 2007 model, the current model also includes new asset-specific parameters:

- Delay in decommissioning (for assets that are not required anymore) used to reflect the fact that operators do not decommission some assets such as cell sites
- Number of years of opex lagging to reflect decommissioning (this parameter used to be the same value of 2 years for all assets but this did not really make sense for assets such as leased lines that can be easily decommissioned given enough notice)

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.

Unit investment

The current Modern Equivalent Asset (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.

Compared with the 2007 model, the current model includes capex requirements for several new assets (please refer to Figure 5.2 for a list of new assets).

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 is then calculated.

Compared with the 2007 model, the current model includes opex requirements for several new assets (please refer to Figure 5.2 for a list of new assets).

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 simple economic depreciation methods, and produces a service costing on this basis.

Two service costing methodologies, pure LRIC and LRAIC, are used. Both require the following inputs: service demand, network element output, element lifetimes, network investment, expenses, and discount rate. The outputs are the service costs for incoming voice traffic and incoming SMS on the basis of SLD, CCA-OCM, CCA-FCM or CCTA.

6.1.1 Pure LRIC

When the model calculates *Pure* LRIC results, a macro automatically runs through the steps shown in Figure 6.1 and described thereafter.

- It runs the model, using the corresponding UMTS2100 carrier deployment dates, and calculates annualised costs for the operator's complete network, *with* the increment of wholesale terminated traffic from other networks
- It runs the model, using the corresponding UMTS2100 carrier deployment dates, and calculates annualised costs for the operator's complete network, *without* the increment of wholesale terminated traffic from other networks
- It calculates the difference in annualised costs for these two situations
- It divides the difference in annualised costs by the number of wholesale terminated minutes to result in the per-minute incremental cost.

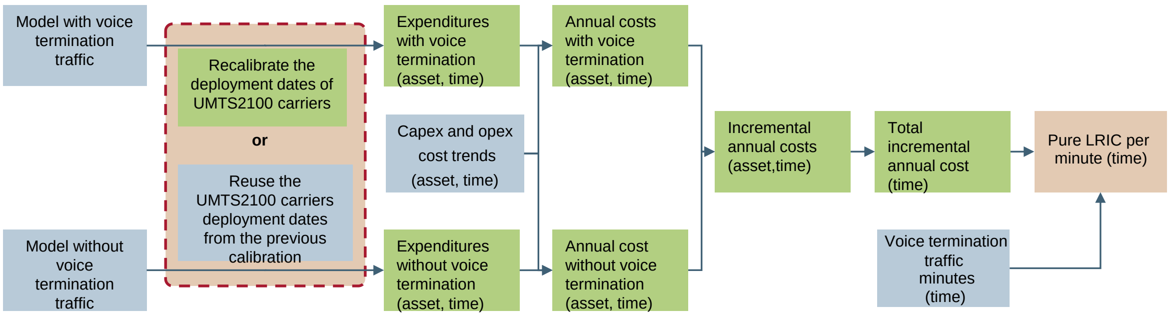

Figure 6.1: Calculation steps performed by the macro to calculate the Pure LRIC results [Source: Analysys Mason]

6.1.2 LRAIC

The model is also able to work out service costing according to a LRAIC methodology, following the steps outlined in Figure 6.2 below. Having found the required assets for the network, it depreciates them over their lifetimes by one of the four depreciation methods SLD, CCA-FCM, CCA-OCM or CCTA. Subsequently, the calculated costs are allocated to their appropriate service using the routing factors.

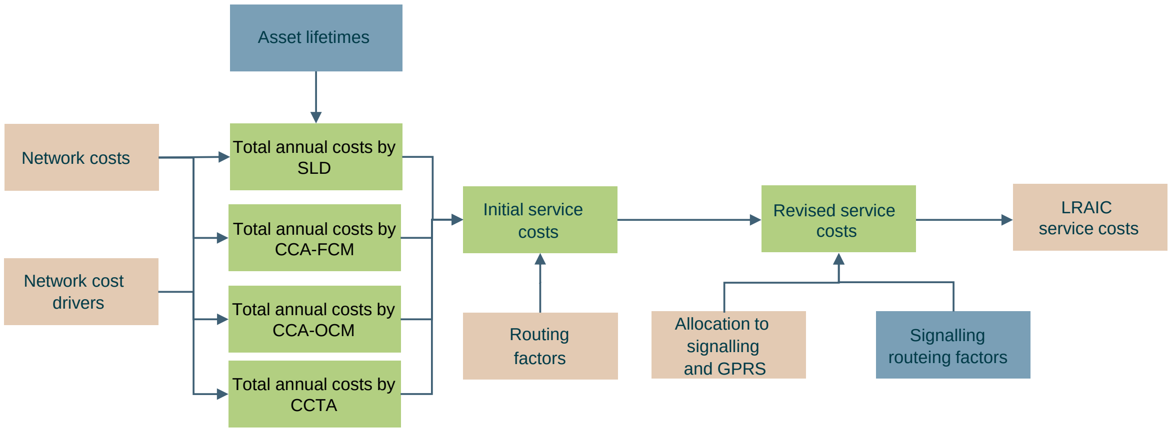

Figure 6.2: Service cost module flow of calculation [Source: Analysys Mason]

The LRAIC 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 as outlined in Figure 6.3.

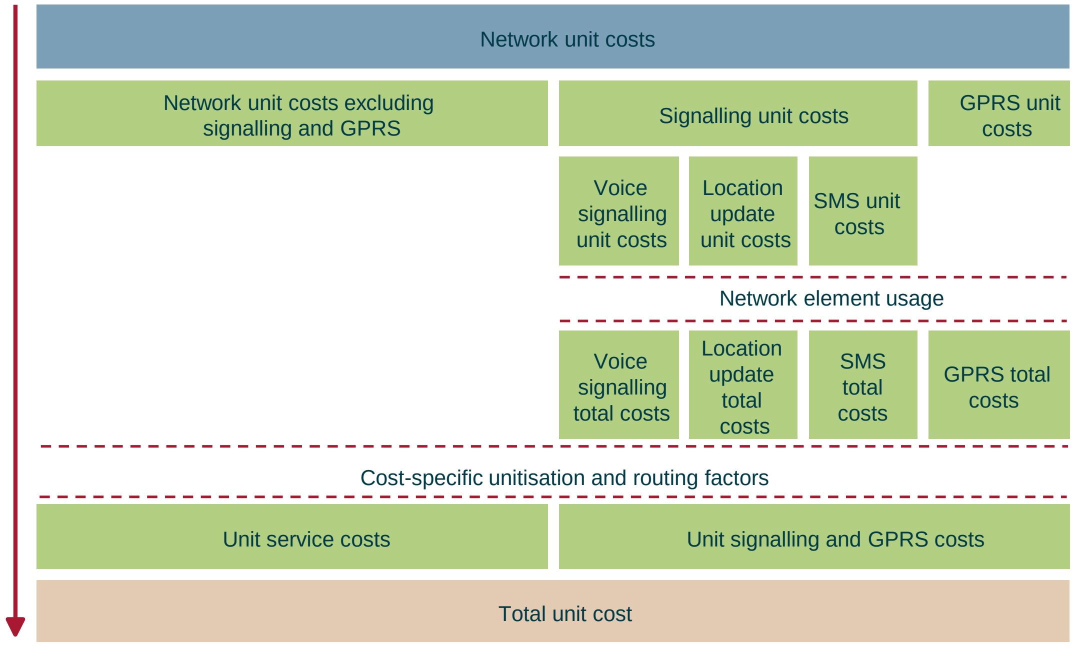

Figure 6.3: LRAIC Service unit cost calculation flow [Source: Analysys Mason]

Signalling costs are further split into voice signalling, location update and SMS. These costs are worked out separately for 2G and 3G. The cost allocations used are detailed in Annex A.2.

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

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

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 cost calculations: service demand, service routing factors, 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.

VAL.1

This sheet calculates the SLD, CCA-OCM and CCA-FCM annual costs of the network.

The major steps in the calculations are the following:

- The investment is converted from real 2009 to nominal
- The SLD annual depreciation and cost of capital employed charges are calculated based on the Gross Book Value (GBV) and Net Book Value (NBV)
- The CCA-OCM annual depreciation and cost of capital employed charges are calculated based on the Gross Replacement Cost (GRC)
- The CCA-FCM annual depreciation and cost of capital employed charges are calculated by adding the adjustment for holding losses (gains) to the CCA-OCM calculations

The annual capex charges are linked to the relevant sections of the calculations dependent on the chosen depreciation method. The annual opex charges are then converted from real 2009 to nominal and added to the capex charges to give the total annual costs. Those costs are the ones used in the Service or Result sheet to calculate either the LRAIC or the pure LRIC.

VAL.2

This sheet calculates the CCTA annual costs of the network. Those costs are then fed through to VAL.1 to offer a single interface to the following sheets.

The major steps in the calculations are the following:

- A composite discount rate is calculated that mixes the inflation rate and the MEA price trends
- Then for each asset in the model, two matrices (investment year vs. cost recovery year) are used to calculate the 'net accounting value' and the annuity
- A summary table is then created and fed back through to VAL.1

Service

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

Results

This sheet presents the 2G/3G aggregated network cost per unit for incoming voice calculated under pure LRIC.

The button to initiate the pure LRIC macro is also located on this sheet.

Lists

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

Annex A: Treatment of signalling costs

The treatment of signalling costs in the mobile cost 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. This treatment is done under the LRAIC methodology.

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). In the calibrated versions of the model we will carry out off-line calculations to ensure that this provides sufficient capacity to deliver SMS services.

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).[4] 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)
- 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)

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

Signalling in the 3G radio network

The 3G radio network allocates capacity dynamically; we therefore account for SMS traffic on the basis of the loading on the radio network in Mbit/s. Capacity of radio network equipment is parameterised in terms of traffic capacity in Mbit/s and assets are driven by the traffic capacity demand in Mbit/s (including voice, data and SMS traffic). Overheads for handovers, call signalling and location updates are therefore accounted for via the parameterisation of assets in terms of traffic capacity.

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 network management system, 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. Figure A.1 contains the cost allocation routing factors used for this purpose. 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 initial parameters will be adjusted following analysis of the quantitative data to be 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 by parameters.

- 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, it is assumed that these account for a fixed proportion of the radio network costs, initially assumed to be 5%. These costs are allocated between call signalling and location updates in proportions set by parameters.

- 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 by parameters.

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:

- backhaul costs are allocated on the basis of the number of 2Mbit/s links required by each of the 2G and 3G networks across all geotypes
- costs for cell sites 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.

Asset type	*Initial routing factor*	*Further allocation to GPRS based on…*	*Further allocation to signalling based on…*
2G SIM cards	2G subscribers		
2G cell site equipment	2G radio traffic	proportion of radio channels reserved 1/8	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 1/29	proportion of radio channels reserved
2G MSCs	2G MSC processing		
2G MSC ports – BSC-facing	2G CS traffic	proportion of radio channels reserved 1/8	proportion of radio channels reserved
2G MSC ports – Interconnect facing	2G interconnect CS traffic	1/29	core network signalling overhead
2G MSC ports – Interswitch facing	2G inter-switch CS traffic	5%	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 1/29	proportion of radio channels reserved
3G SIM cards	3G subscribers	1/8 of 2G costs to 2G signalling	
3G cell site equipment	3G radio interface traffic	"1/8 of 2G costs to 2G signalling	radio traffic signalling overhead
3G site upgrade	3G radio interface traffic		radio traffic signalling overhead
3G RNCs	3G core traffic	1/29	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	1/8	core network signalling overhead
3G MSC ports – Interswitch facing	3G Inter-switch CS traffic		core network signalling overhead
3G NMS	3G core traffic	1/29	core network signalling overhead
3G GSN	3G PS core traffic		
3G licence fees	3G radio interface traffic	5%	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 and proportion of radio traffic that is 2G

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 and proportion of radio traffic that is 2G
Backhaul	All radio traffic	proportion of 2G radio channels reserved and proportion of backhaul used for 2G 1/29	proportion of 2G radio channels reserved / 3G radio traffic signalling overhead and proportion of backhaul used for 2G / 3G
Transit switches	All MSC processing		core network signalling overhead
HLRs	All subscribers	1/29	
IN and other service platforms	All subscribers	1/29	
2G/3G SMSC	2G/3G SMS	1/8	
Main switch sites	All core traffic	1/8 of 2G costs to 2G signalling	core network signalling overhead
Core transmission	All core transmission traffic	"1/8 of 2G costs to 2G signalling	core network signalling overhead
BSC/RNC to MSC links	All radio traffic		
VMS	VMS		
Service Integration Infrastructure	Push SMS		
3G FMGs	3G core traffic		
3G Femtocells	3G SIM cards		
HSPA upgrades	HSPA traffic		

Figure A.1: Cost allocation routing factors [Source: Analysys Mason]

Annex B: Macro documentation

Visual Basic (VB) codes has been developed, using Microsoft Excel, by Analysys Mason to automate certain routine calculations or operations in the ARCEP's long-run incremental cost (LRIC) model.

This annex presents an overview of major groups of macros implemented. It outlines the structures and functions of each macro and, where appropriate, their interactions with other macros. Instructions of how to use each macro are provided, as are the key steps that should be followed in order to maintain the integrity of the codes should the user wish to make modifications to the model.

The remainder of this annex is laid out as follows:

- Section B.1describes the pure LRIC macro
- Section B.2 describes the UMTS2100 carrier calibration macros

B.1 The pure LRIC macro

How the macro works

The European Commission's *Recommendation on the Regulatory Treatment of Fixed and Mobile termination rates in the EU* defines a "pure" LRIC approach to calculating mobile termination. On the other hand, the *Plus* LRIC approach is consistent with the prevailing approach in fixed voice termination costing in Europe and ARCEP's previous mobile LRIC approach. Therefore the model calculates both *Pure* and *Plus* LRIC forms of incremental cost in order that ARCEP has available the range of results it may consider in its eventual regulatory decision.

The calculations needed for pure LRIC require the model to be run twice, and is automated by a macro. When the model calculates *Pure* LRIC results, the macro automatically runs through the following steps:

- runs the model, using the corresponding UMTS2100 carrier deployment dates[5], and calculates annualised costs for the operator's complete network, *with* the increment of wholesale terminated traffic from other networks
- runs the model, using the corresponding UMTS2100 carrier deployment dates, and calculates annualised costs for the network, *without* the increment of wholesale terminated traffic incoming from other networks

5 These dates are either obtained in situ by a recalibration process, or are read in from a previous calibration. The calibration macro is described in section B.2.

- calculates the difference in annualised costs for these two situations
- divides the difference in annualised costs by the number of wholesale terminated minutes to result in the per-minute incremental cost.

The macro automates the process shown in Figure B.1 below.

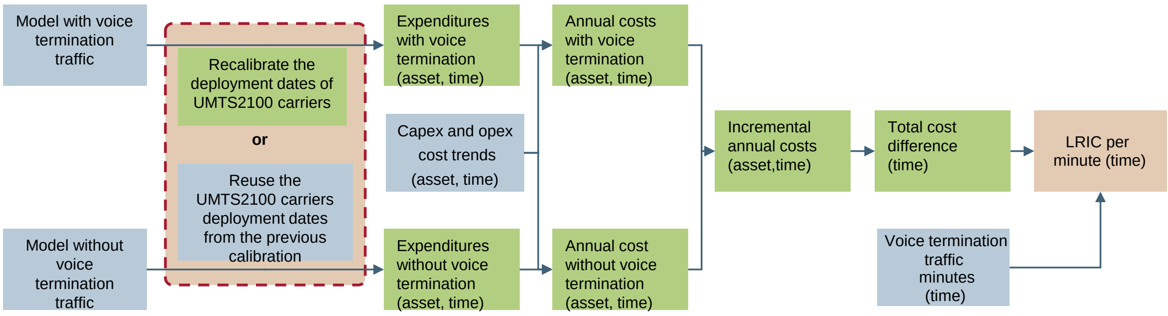

Figure B.1: *Calculation steps performed by the macro to calculate the Pure LRIC results [Source: Analysys Mason]*

Using the macro

In order for the pure LRIC macro to function properly, all four workbooks must be open.

The main parameters for the model can be found in the *scenario* sheet of the *1 – traffic.xls* workbook. These include key model parameters, traffic module parameters, network module parameters, and function parameters.

The pure LRIC macro is called "*update*", and it can be initiated by pressing the "Run LRIC calculations" macro-button on the *Results* sheet of the *4 – service cost.xls* workbook. When this is done, the following window would appear, giving the user the option to re-calibrate the UMTS2100 carrier deployment dates. Some major changes to the model parameters or inputs, such as operator choice, coverage inputs, traffic assumptions, may affect the rollout speed, and hence the deployment dates of the UMTS2100 carriers. As a result he/she should proceed with the recalibration. If the user is confident that no such changes were made, skipping the recalibration process would significantly speed up the pure LRIC macro.

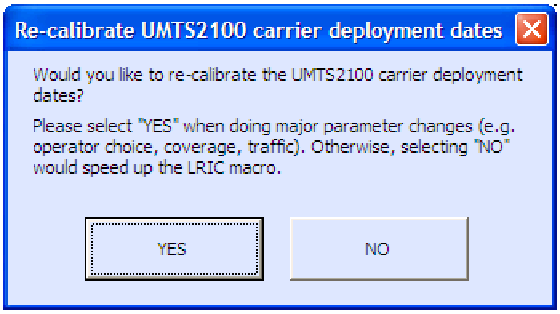

Figure B.2: Recalibration choice window [Source: Analysys Mason]

The macro should take a few minutes to run. Upon completion another window would appear, letting the user know how long it took for the entire process. Please note the length would vary when running the model on different machines or using versions of Excel.

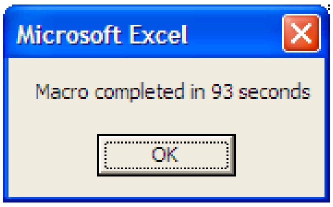

Figure B.3: An example of the window shown upon the pure LRIC macro's completion [Source: Analysys Mason]

B.2 The UMTS2100 carrier calibration macros

How the macros work

The current model implements a series of macros such that the use of additional 2.1GHz spectrum for UMTS can be model in a dynamic way.

These macros are used as part of the pure LRIC macro "*update*", whose overview has been provided in section B.1. The following flow chart outlines the interactions between "*update*" and various macros and user forms related to UMTS2100 carrier calibration.

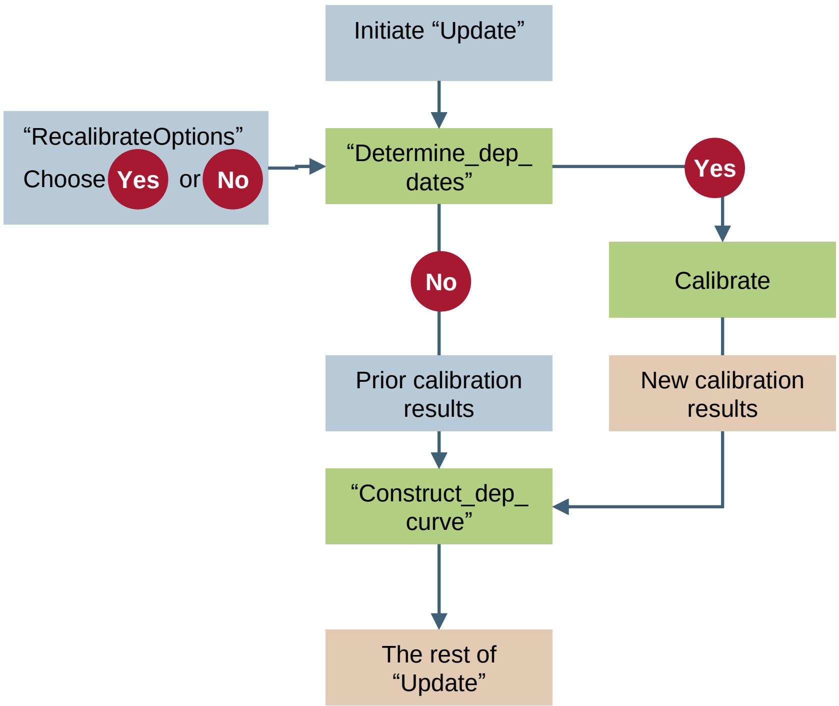

Figure B.4: The relationship between "update" and various carrier calibration macros [Source: Analysys Mason]

RecalibrateOptions This user form prompt the user to choose whether or not to run the recalibration within the macro "*Determine_dep_dates*".

Determine_dep_dates If the user chooses "Yes" in response to the user form "*RecalibrateOptions*", this macro initiates "*Calibrate*" followed by "*Construct_dep_curve*". Otherwise, the macro skips "*Calibrate*" and only initiates "*Construct_dep_curve*" (i.e. it uses outputs of a previous calibration).

Calibrate This is the core macro which performs the actual calibration process. The flow chart Figure B.5 outlines the major steps taking place. At the end of the macro, the calibration results are recorded into the following name ranges: *"startyear.2nd.UMTS2100.carrier_1", "startyear.3rd.UMTS2100.carrier_1", "startyear.4th.UMTS2100.carrier_1", "startyear.2nd.UMTS2100.carrier_2", "startyear.3rd.UMTS2100.carrier_2", "startyear.4th.UMTS2100.carrier_2".*

Construct_dep_curve This macro copies the calibration results from the sheet *3G_Carriers_dep* and pastes them to the sheet *Params – 3G spectrum* of the *workbook 2 – network.xls*. This macro makes sure the calibration results are being

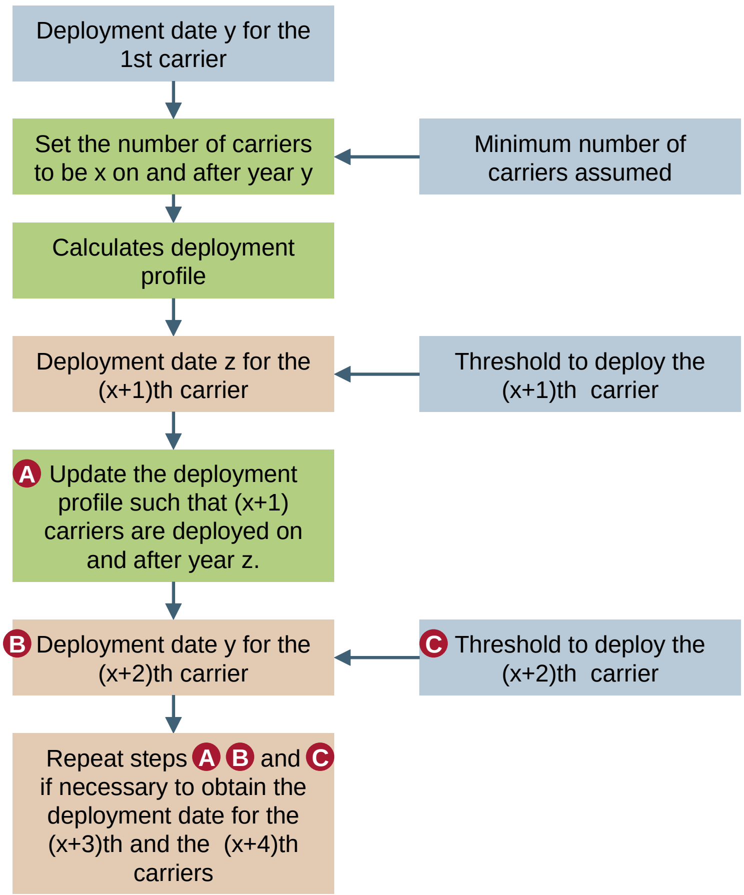

Figure B.5: Calculation flow for the macro "calibrate" [Source: Analysys Mason]

The model also allows a user to recalibration the carrier deployment dates without having to invoke the pure LRIC macro "*update*". This is achieved via the use of a separate macro called "*recalibrate*". This macro triggers the macros "*calibrate*" and "*Construct_dep_curve*". It enables a user to run quick sensitivity tests relating to carrier deployment dates without having to run the full model.

Using the macros

The main parameters relating to the macro are the "minimum number of carriers assumed" and the "thresholds" found in the sheet "*3G_Carrier_dep*" in the workbook "*2 - networks.xls*". Note that the "minimum number of carrier assumed" overwrites the "thresholds". In other words, if *x* carriers are assumed, they would be deployed at the same time as the 1st carrier. As a result the thresholds assumed for the *x*th, (*x*-1)th, (*x*-2)th and (*x*-3)th carriers, if applicable, would have no effects on the macro.

Running "*recalibrate*" is much faster than running "update" since only 2 workbooks need to be open: the "*1 - traffic.xls*" workbook and the "*2 - networks.xls*" workbook. It can be initiated by pressing the button "force re-calibration" in the sheet "*3G_Carrier_dep*" in the workbook "*2 - networks.xls*".

The details of using the macro "*update*" can be found in section B.1.

Key things to remember

Before running "*recalibrate*", make sure only the "*1 - traffic.xls*" workbook and the "*2 - networks.xls*" workbook are open. Having all the four modules open would significantly slow down the calculation process.