A Bottom-Up LRIC Model for Mobile Networks in Romania

Documentation of the Model

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Version Control

This section sets out key changes between document versions.

Version No	Date	Changes	Initials
Version 1.0	22 March 2006	Alignment with model version 1.32	DAR/KXI
Version 1.1	27 March 2006	Alignment with model version 1.33	DAR
Version 1.2	27 March 2006	Alignment with model version 1.34	DAR/KXI
Version 1.3	28 March 2006	Alignment with model version 1.35	DAR/KXI
Version 1.4	29 March 2006	Alignment with model version 1.35	DAR/KXI
Version 1.5	30 March 2006	Alignment with model version 1.35	DAR/KXI
Version 1.6	04 April 2006	Alignment with model version 1.38	

1 Introduction

1.1 Purpose of document

This Manual is an operations handbook for the Romanian bottom-up mobile LRIC model (Version 1.38) developed by Ovum on behalf of the ANRC. The purpose of the Manual is to:

- Provide background on the modelling approach, including the costing methodologies and concepts that support the model
- Explain the workings and structure of the model
- Provide guidance to facilitate operation of the model

2 Purpose of the Model

2.1 Cost of call mobile termination in Romania

The purpose of the model is to illustrate the costs of operating a GSM mobile network in Romania – and provide a prediction of these costs to the end of 2009. The modelled network assumes that voice and data services are provided, and has been built specifically to calculate the cost of call termination in Romania. It is important to note that:

- the source data is based upon the information supplied by Mobifon and Orange Romania that were supplied as part of the data gathering process to populate the model. Where no published data was available, Ovum has used its experience of mobile costing work to make suitable estimates.
- the costs of call termination cannot be modelled in isolation of other services because a large number of network components are used by more than one service (e.g. a basestation transceiver is used to carry voice, SMS and GPRS data services). We have therefore included a comprehensive set of services in the model.
- the bottom-up model provides a simulation of the actual mobile networks in Romania, but there is a limit to the number of network elements that can be reasonably modelled. We have therefore deliberately limited the model to the most relevant and distinguishable network components rather than attempt to model every single component of a mobile network. Other costs are included by way of mark-ups, e.g. for indirect capital expenditure and operating costs, and for common costs.
- the model has been reconciled as far as possible with the mobile operator's assets (using data for the end of 2003 as provided by the operators) and their financial accounts (using published statements for 2004).
- separate versions of the model have been prepared for Mobifon and Orange, based on their different subscriber and traffic profiles, and their different network implementations. However, many of the input assumptions in the model (e.g. costs, equipment utilisation, depreciation periods) are taken as an average of the two networks benchmarked against international best practice.

The rates derived from the model are designed appropriately to compensate the mobile service provider for the economic costs of the services involved. The rates must satisfy a number of conditions to be effective, including:

- They must reflect accurately the economic costs of the service
- They must not involve the subsidisation of the costs of the service provider by the payments from the service seeker, nor vice versa
- They must emulate, to the greatest extent practicable, the charges that would result in a fully competitive market for the interconnection services.

It follows that regulated interconnection charges will not necessarily reflect the actual costs being incurred by the interconnection service provider, because these may include unacceptable levels of inefficiency that it would be inappropriate to pass on to the service seeker. Instead, the charges should provide an incentive for the service provider to achieve best practice levels of operational efficiency upon which the model is based.

2.2 The nature of the Bottom-up model

Bottom-up cost models seek to determine the costs that an efficient operator using forward looking network technologies would incur in the provision of the various network services. In the present case the primary interest is in determining the costs that such an operator would incur in addressing the levels of both overall traffic and interconnect traffic assumed.

The bottom-up mobile cost model:

- is designed to provide estimates of mobile network costs for the financial years 2002-2009
- is based upon an efficient network design under a scorched node approach
- includes the ability to model voice, SMS, GPRS, and EDGE traffic (which we equate to equivalent call minutes of voice traffic)
- is capable of illustrating both a GSM900 only network, and a dual band GSM900/1800 mobile network
- estimates the unit costs of call termination services in Euro cents.

3 Model Principles

3.1 Capital charges

The bottom-up model assumes that the network is a modern network every year. We have assumed this so that:

- the development profile of the network does not affect the calculation of the capital charge
- replacements of network assets do not need to be calculated or explicitly included, because the network assets are assumed always to be in its first year of operation.

The model uses Modern Equivalent Asset pricing to ensure that the assets represent the purchasing of an efficient operator. The model is capable of illustrating some of the most common approaches to calculating the capital charges (i.e. Depreciation + Return on Capital Employed) in line with economic depreciation principles:

- straight line
- tilted straight line
- annuity
- tilted annuity.

Economic depreciation is a method for determining a cost recovery that is economically rational in that it:

- reflects the underlying costs of production
- reflects the output of network elements over their lifetime.

The principle behind economic depreciation is that all efficiently incurred costs should be recovered in an economically rational way.

In the base case scenario, tilted annuity depreciation is used. An annuity is an approach in which the annual capital charge, the sum of depreciation and return on capital employed, is the same in each year of the defined asset life. This is especially important in bottom-up modelling which assumes that the network is a modern network every year. In contrast the straight-line depreciation approaches result in capital charges that decline year-on-year, and thus a bottom-up model that relies on first year depreciation under straight-line methods will tend to exaggerate capital costs.

The advantage of an annuity calculation is that it takes account of the discount rate (cost of capital) which generally suggests that it is rational to delay depreciation payments to some extent. However, this creates a "back-loaded" depreciation profile (i.e. more depreciation later in the asset life). This may be considered inappropriate for telecommunications assets because real prices tend to be declining, which means that future entrants will be able to purchase cheaper assets and so incumbents will typically wish to "front-load" unit cost recovery. Tilted annuities are designed to alleviate the problem of "back-loading" to the extent justified by the annual reduction in asset values. With this methodology, the sum of the depreciation charge and the return on capital employed declines over time consistent with the reduction in the replacement value of the asset.

In summary, tilted annuity depreciation:

- recovers both the depreciation charge and the cost of capital
- revalues assets at their modern equivalent, which is consistent with an economically efficient network
- is consistent with the preferred approach by a number of regulators (e.g. ComCom in New Zealand, PTS in Sweden, Telestyrelsen in Denmark).

The specification of each depreciation method is outlined in the following sections.

3.1.1 Straight line

Straight line depreciation divides the asset's price by the asset's life to produce an annual depreciation charge. To calculate the annualisation charge, a capital charge is added. The straight-line annualisation factor used in the model is:

$$\frac{V\,[1+r]}{n}$$

where:

- r is the rate of return on capital employed
- n is the economic life in years
- V is the current replacement cost of the asset.

3.1.2 Tilted straight line

Tilted straight line depreciation takes account of the expected price changes for assets. It will results in a steeper depreciation profile when prices are falling than unadjusted straight line depreciation. The tilted straight-line annualisation factor used in the model is:

$$\frac{V\,[1+r-a]}{n}$$

where:

- r is the rate of return on capital employed
- a is the rate of change of the replacement cost of the asset
- n is the economic life in years
- V is the current replacement cost of the asset.

3.1.3 Annuity

A standard annuity calculates the charge that after discounting recovers the asset's purchase price and financing costs in equal annual sums. In the beginning of an assets lifetime the annualisation payment will consist more of capital charges and less of depreciation charges; this reverses over time resulting in an upward sloping depreciation schedule. The annuity function used is outlined below:

$\underline{V\,[1+a\,]^{t-1}\,[r]}$

$1 - [1/(1+r)]^n$

where:

- r is the rate of return on capital employed
- a is the rate of change of the replacement cost of the asset
- n is the economic life in years
- V is the current replacement cost of the asset
- T is the age (in years) of the asset.

3.1.4 Tilted annuity

The tilted annuity approach bundles depreciation and the return on capital into a single amount. It adjusts the capital costs over time in line with the rate of increase or decrease of the replacement cost of the capital equipment.

Under a tilted annuity the capital cost in each year is given by:

$$\frac{V\,[1+a]^{t-1}\,[r-a]}{1 - [(1+a)/(1+r)]^n}$$

where:

- r is the rate of return on capital employed
- a is the rate of change of the replacement cost of the asset
- n is the economic life in years
- V is the current replacement cost of the asset
- T is the age (in years) of the asset.

3.2 Weighted Average Cost of Capital

Figures 3.1 contains the level of the Weighted Average Cost of Capital (WACC). Its level is set to be consistent with the ANRC's current guidelines.

Figure 3.1: Pre-tax rate of WACC

Pre-tax rate of WACC (Mobifon)	17.52%
Pre-tax rate of WACC (Orange)	16.88%

Source: ANRC

3.3 Mark-ups

The determination of service costs for interconnection charging purposes needs to include not only the LRIC for such services, but also that share of common and overhead costs that may be reasonably attributed to the provision of the services in question.

The recognised way of doing this is to determine the extent of the costs involved and then to express those costs as a mark-up on all of the operations involved. The enterprise may have other business operations that are distinct and separate from the operation being modelled. Common and overhead costs therefore must be shared across all of these businesses. In the present context, typical other businesses that might be involved are:

- Retail service business (we are here concerned with interconnection costs, not retail business costs)
- Overseas subsidiaries

The approach that we have adopted in this model is to examine various mark-ups (expressed as a percentage) based on the actual costs of the operators. We then compare this with a range of benchmarks from other operators. The resulting allowable mark-ups are as shown in Figure 3.2.

Figure 3.2: Mark-ups used in the model

Network Capex (Direct) Calculated in the model	**Network Opex (Direct)** 11.2% of Direct Capex	**Retail Capex** 10% of network Capex
Network Capex (Indirect) 10% of Direct Capex	**Network Opex (Indirect)** 22.5% of Direct Opex	**Retail Opex** 17 Euro per connection; 33 Euro per subscriber p.a.
Common Costs 6% mark-up		

3.4 Summary of model principles

The model calculates LRICs for relevant services:

- Using LRIC
- Using separate increments for subscribers and traffic, taken across the network as a whole.
- Using a bottom up modelling approach
- Using a scorched node approach
- Valuing assets at current prices on a Modern Equivalent Asset (MEA) basis

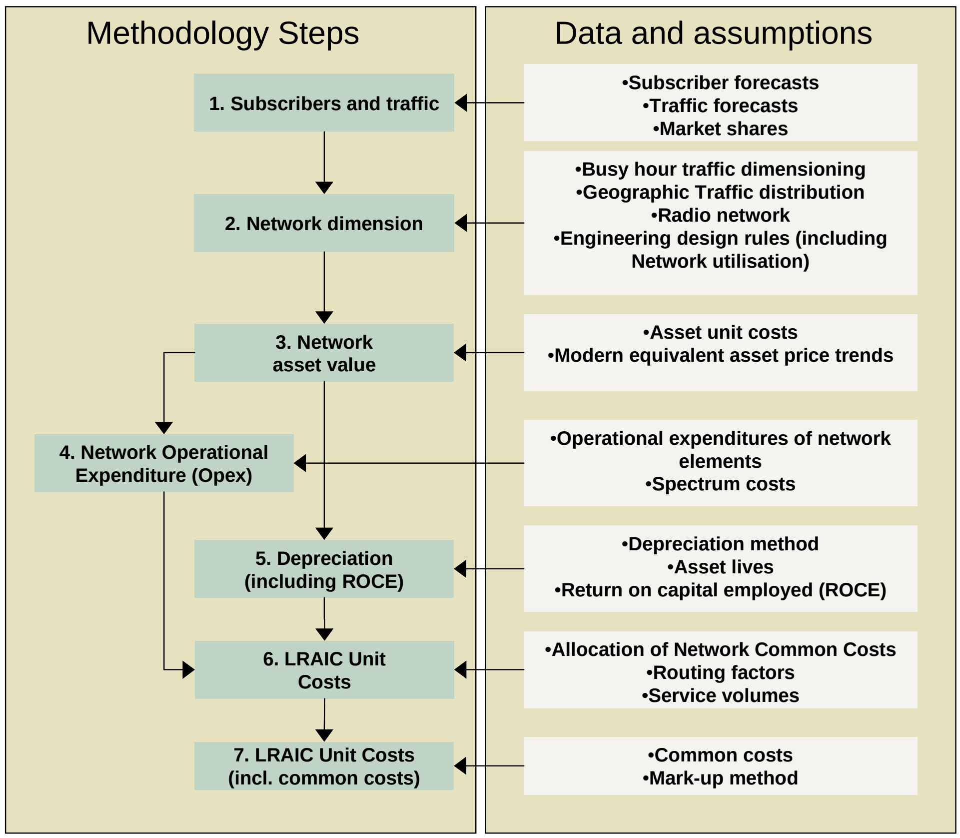
- Allocating network element costs to services using Service Routing Factors
- Applying mark-ups for fixed common and joint costs on an equi-proportionate basis.

4 Model Design

4.1 Model Schematic

The bottom-up methodology consists of the seven steps outlined in Figure 4.1.

Figure 4.1: Bottom-up methodology



The methodology consists of the following steps:

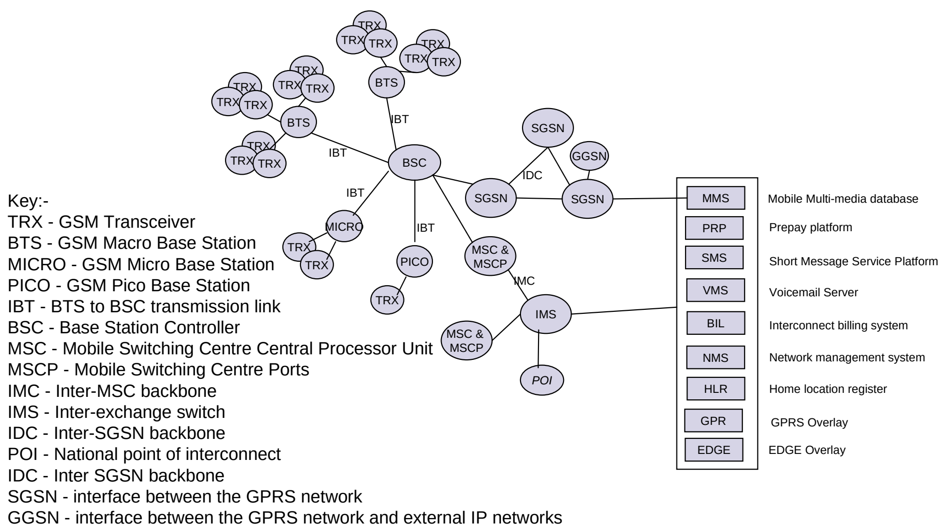
1. **Subscribers and traffic** - forecast the number of subscribers and traffic
2. **Network dimension** – estimate the volumes of network assets using coverage requirement, traffic distribution, quality of service etc.
3. **Network asset costs** – apply modern equivalent asset price trends and asset unit costs to estimate the total value of the network assets
4. **Network operational expenditure (Opex)** – estimate the cost of operating the network from its size and value
5. **Depreciation** – annualise the cost of network assets and include a return on capital employed

6. **LRAIC unit costs before mark-ups** – estimate the costs of providing each service and then unitise these costs using routing factors
7. **LRAIC units costs, after mark-ups** – apply mark-ups to allow for common costs.

4.2 Network elements modelled

Figure 4.2 illustrates the topology of the mobile network, and the network elements that the bottom-up model contains.

Figure 4.2: Network topology



The network dimensioning converts the traffic and subscribers volumes into the required number of network elements using:

- busy hour traffic dimensioning
- geographic traffic distribution
- network dimensioning (including transceiver characteristics, spectrum usage and availability, quality of service, network utilisation, and other engineering design rules).

We have assumed that BSCs and MSCs are co-located in the same premises.

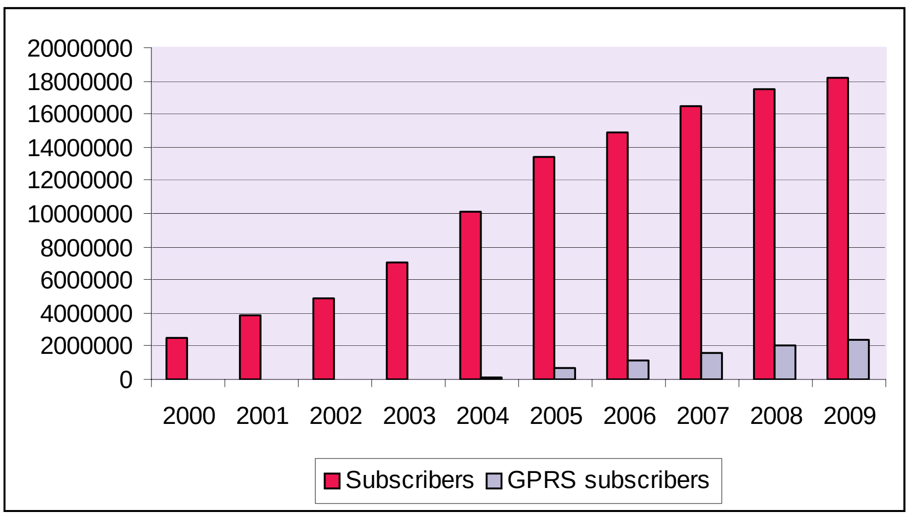
5 Model Operation

5.1 Subscriber and traffic forecasts

5.1.1 Mobile subscribers

The number of mobile and GPRS subscribers in Romania are shown in Figure 5.1. We have used the operators' actual data for the year to 2003 - 2005 and then projected forwards using Ovum's standard forecasting methodology to estimate the number of subscribers. This involves estimating the number of subscribers in the longer term, and using a Gompertz curve to project forward from the existing base and growth rate.

Figure 5.1: Subscribers (year-end)



Source: Ovum analysis, 2004

Figure 5.1 illustrates that the growth in subscriber volumes has been particularly rapid over 2003 -2005, and that this growth looks set to continue.

The number of GPRS subscribers are based on independent studies Ovum has produced. In the base case, the model assumes no EDGE deployment.

5.1.2 Subscriber market shares

The market shares in 2003- 2005 of each operator are based on data supplied by the operators.

Beyond 2005, the base case assumes that the market shares of Orange and Mobifon will each fall to 40% by the end of 2009 for GSM services and will reach 40% for GPRS services. The model assumes a fall in market share as new players enter the market.

5.1.3 Traffic forecasts

Traffic information was based upon operator traffic submissions made to the ANRC. As no estimate of Orange's GPRS traffic was provided, we made a suitable estimate of the GRPS traffic levels.

The forecasted growth rates applied to both Mobifon and Orange are based upon Ovum market analysis in Romania and are shown in Figure 5.2. For most services we have assumed that traffic per subscriber will remain constant.

Figure 5.2: Per subscriber traffic growth

	2006	2007	2008	2009
Voice Traffic	0%	0%	0%	0%
HSCSD Data	0%	0%	0%	0%
SMS	9%	8%	7%	6%
GPRS	0%	0%	0%	0%
MMS	0%	0%	0%	0%
EDGE	0%	0%	0%	0%

Source: Ovum analysis

We have based the mix of traffic for each service upon the operator submissions and further information gathered from discussion with Mobifon and Orange Romania. We have assumed no change in the traffic mix over the period 2006-2009.

The model also:

- For simplicity, sets all service volumes other than voice, MMS, SMS and GPRS as zero. Both Mobifon and Orange submitted no results on the volumes of other services
- As Mobifon did not submit any roaming minutes and to ensure consistency between operators, both incoming and outgoing roaming minutes have been excluded from the traffic estimates
- No traffic mix was submitted for GPRS traffic by either operator, so we have based the traffic split on the voice splits
- Because HSCSD, and EDGE traffic is not implemented in the bottom-up model, the HSCSD and EDGE traffic splits have been set to zero.

5.2 Network Dimension

5.2.1 Introduction

The network is dimensioned in response to one of the three drivers set out below:

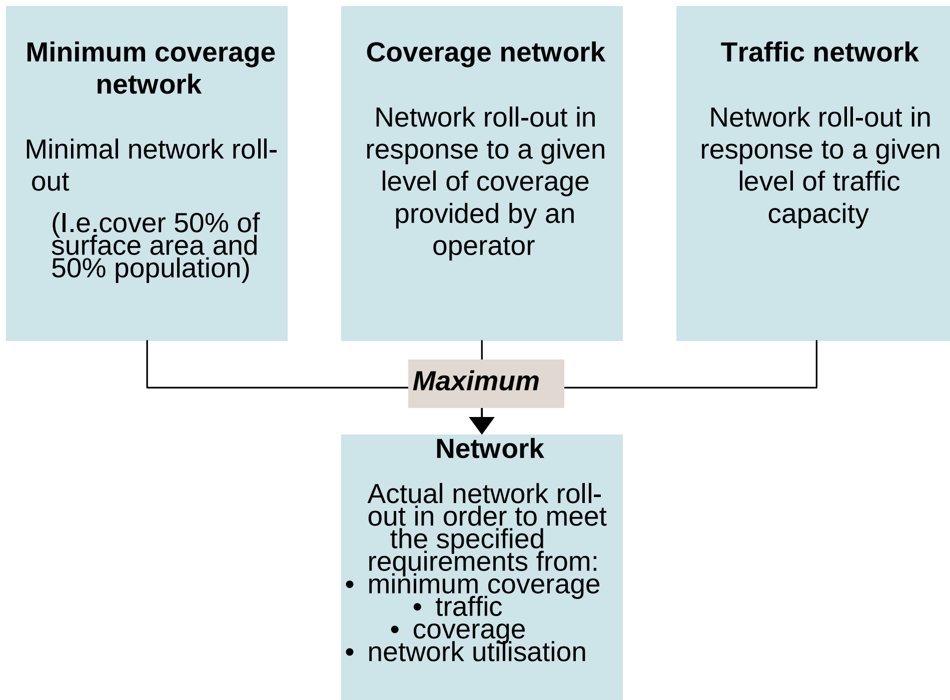
- coverage obligation contained in the licence
- coverage network to provide a given level of coverage (in excess of the licence obligation)
- traffic network to provide a given level of traffic capacity for a given level of utilisation.

To dimension the radio network we assume:

- GSM900 network is rolled out initially to provide the minimum coverage
- the minimum transceiver configuration of a macro basestation is 1 transceiver per sector
- transceivers are added to each basestation in response to traffic demand until each basestation is fully configured
- in the dual band GSM900/1800 network, GSM900 and GSM1800 transceivers are collocated on the same basestations, and GSM1800 transceivers are added to provide additional traffic capacity
- once each basestation is fully configured with both GSM900 and GSM1800 transceivers, additional basestations are added to provide additional traffic capacity
- the upper limit on the number of transceivers per basestation is determined by either
    - the physical limit of the number of transceivers per sector, which is a maximum of 6 transceivers per sector
    - the number of transceivers per sector that the spectrum will allow – this is outlined in the traffic network section.
- that each basestation in the minimum coverage network contains one transceiver

The number of basestations in the urban, suburban and rural coverage areas are based on the asset information Mobifon and Orange Romania submitted.

Figure 5.3: Radio network rollout



5.2.2 Minimum coverage network

The minimum coverage network is defined as the network topology in which both Orange and Mobifon provide minimum coverage such that:

- 50% of the country area is covered
- 50% of the population is covered
- there is at least one basestation in each municipality
- traffic network requirements are set to carry one minute of traffic
- 'Coverage Network' requirements (see below) are ignored.

The model assumes that network operators will roll-out to more densely populated areas, and by covering 50% of Romania's land area, they will automatically cover 50% of the population and provide a basestation in each municipality.

The model assumes that the minimum coverage is achieved through the GSM900 network. This is because fewer GSM900 transceivers are required to provide a minimum level of coverage than if GSM1800 transceivers were used to cover the same area.

The minimum number of basestations that are required for a given level of coverage network is based upon the maximum radius that each transceiver can operate - see

Figure 5.4. We assume that each basestation contains just one transceiver dimensioned in one sector (i.e. the minimum number of transceivers per sector).

Figure 5.4: Maximum GSM 900 Transceiver radius (Km)

	Maximum Transceiver radii (Km)
Urban	1.5
Suburban	3
Rural	11.6

Source: Ovum analysis

5.2.3 Coverage network

The coverage network is the network that is deployed by each operator to attain the given level of coverage achieved in practice. It is higher than the minimum coverage network. We assume that this coverage:

- is higher in more densely populated areas
- grows through the forecast horizon.

We assume that the geographic coverage of each operator increases to 90% by the end of 2009.

5.2.4 Traffic network

In the deployment of the traffic network, the model assumes that pico or micro basestations are only deployed in urban areas. The model assumes the pico and micro basestations carry a constant proportion amount of traffic in urban areas throughout the years. The set proportion match the number of picocells and microcells currently present in Mobifon's and Orange's network and the level of traffic carried on each network by these basestations.

Pico and micro basestations differ from macro basestations (BTS) in that pico basestations are usually positioned indoors and provide in-building coverage, while micro basestations are assumed to work outside but have very limited coverage.

The model assumes that:

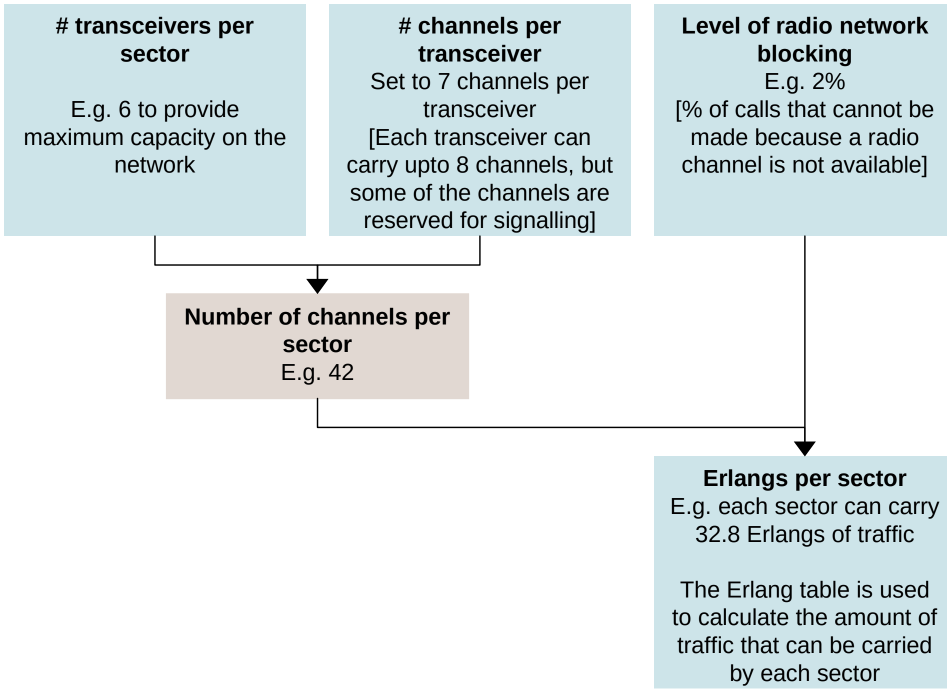
- pico basestations are configured with one TRX in and one sector per site
- micro basestations are configured with two TRXs and one sector per site.

The traffic capacity of the network is calculated for each basestation sector using an Erlang table.

As shown in Figure 5.5, the drivers of capacity are:

- The number of transceivers deployed in each basestation sector
- The number of traffic channels per transceiver
- The level of call blocking in the radio network, we assume a 2% blocking factor consistent with the operators licences.

Figure 5.5: Example traffic dimensioning calculation



The number of transceivers per sector is estimated using:

- the level of traffic capacity required
- the traffic capacity provided by the coverage network
- the caps on the number of transceivers per basestation from either the spectrum or the physical capacity per sector (which is 6 TRX per sector).

5.2.5 Busy hour traffic dimensioning

Ovum estimates the volume of erlangs from the traffic volumes. Erlangs are a measure of the number of channels required in the busiest hour on the busiest day of the year. Erlangs are a commonly used means of dimensioning the amount of capacity required in a network. Each traffic type is converted into this common unit, which allows the dimensioning of various traffic driven network elements to be performed using this common driver. To calculate the Erlangs in the radio network, we double the calculated number of traffic Erlangs used to carry on-net traffic because:

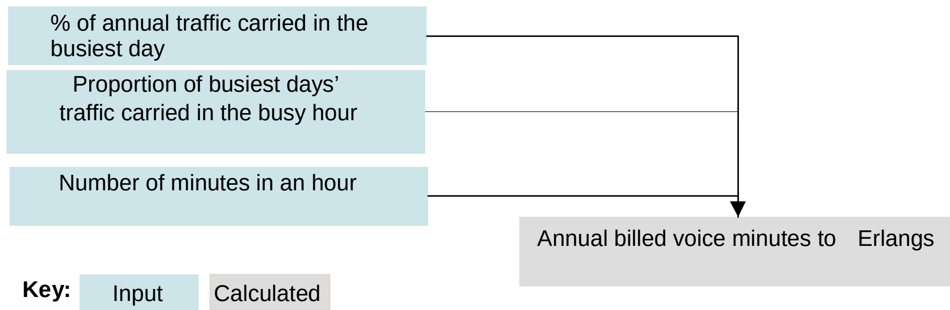
- two radio channels are used for on-net traffic
- only one radio channel is used to carry incoming and outgoing traffic.

The conversion of each traffic type into Erlangs is explained below. The source of each assumption is Ovum's previous traffic modelling and network analysis.

Voice

Figure 5.6 illustrates the voice conversion factors to convert the number of minutes of network traffic in a year into Erlangs. The parameters are based upon data provided by the operators and Ovum's experience.

Figure 5.6: Voice minutes to erlang conversion factor



Source: Ovum analysis

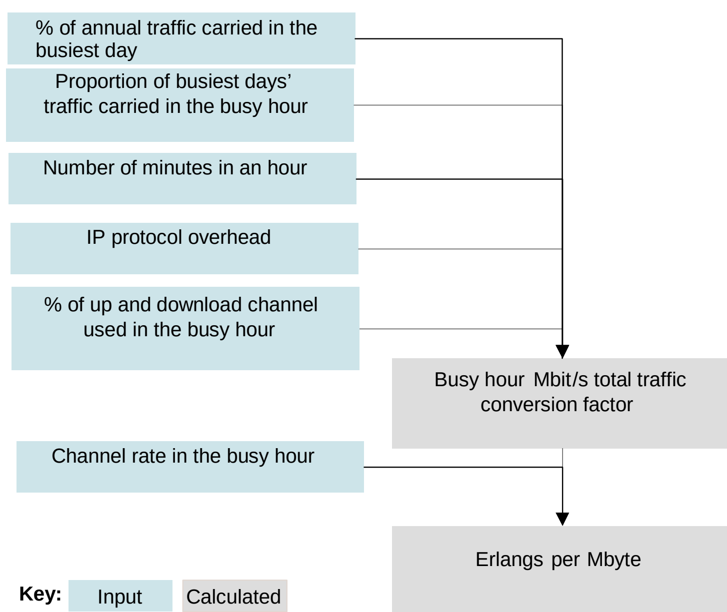
SMS

The SMS conversion factor is taken as 144 SMS per voice minute (source Ofcom).

MMS

Figure 5.7 illustrates the MMS conversion factors, which are based upon data provided by the operators and Ovum's experience.

Figure 5.7: MMS erlang conversion factors



Source: Ovum analysis

GPRS & EDGE data

The GPRS and EDGE conversion factors, which are based upon data provided by the operators and Ovum's experience, are calculated as follows: GPRS/ EDGE Erlang per Mbyte = (Annual voice minutes to Erlangs conversion factor) divided by (GPRS MB per voice minute). The GPRS MB per voice minute is set at 0.07 (source: Ofcom).

5.2.6 Geographic traffic distribution

To capture the varied nature of the rollout of the network to meet demand in different areas, Mobifon and Orange have classified their networks according to traffic density in three different geo-types: Urban, Suburban and Rural. From this data we have estimated the average Geographic size of each geo-type and the % of voice traffic generated. The model has based the traffic distribution and geotypes upon the 2004 voice traffic and geotype submissions made by Mobifon and Orange.

5.2.7 Network utilisation

The model has set the network utilisation parameters to represent what an operator might reasonably achieve in practice. The estimates are based upon Ovum's experience of working with mobile operators.

The utilisation factors dimension the network according to how it might be used in practice. The following relationship defines the utilisation of network components in the model:

Number of items provisioned = Number of items required / (reasonable growth utilisation x Scorched node allowance x design utilisation)

The utilisation parameter is used to reflect the three 'under-utilisation' effects:

- **Reasonable growth utilisation:** equipment is deployed in advance of expected demand (measured in months), which depends upon the amount of time it takes to plan, order, deliver, and install new network components. The model explicitly determines the level of under-utilisation in the network as a function of equipment planning periods and expected demand.
- **Scorched node allowance**: This represents the proportion of the currently deployed network elements, which an efficient network would require. .
- **Design utilisation:** The design utilisation parameter ensures that the equipment in the network can provide sufficient capacity to operate to allow for breakdown and repair of equipment, as well as providing additional capacity for unpredictable surges in demand.

We have set the utilisation parameters so that they provide sufficient additional capacity to operate the network and provide sufficient resource for a growing network.

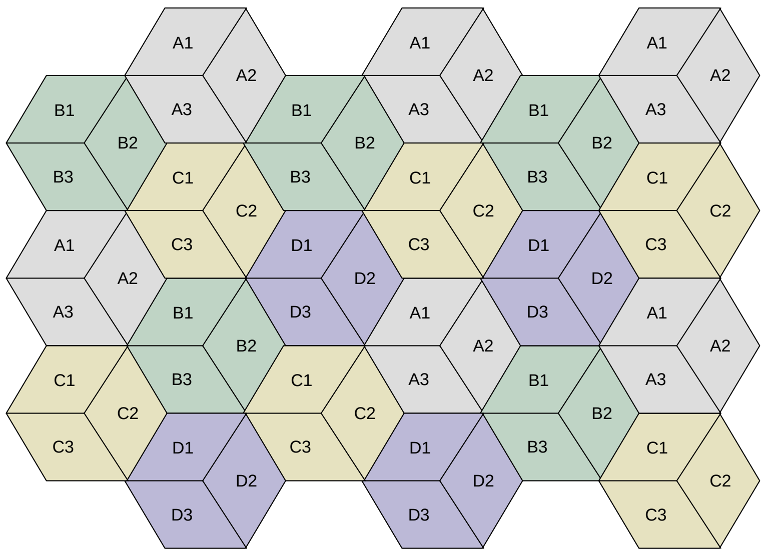
5.2.8 Spectrum

For frequency and basestation planning purposes the coverage is divided into hexagons – this produces a coverage area equal to 2.6 x $radius^2$. We assume that:

- the frequency re-use pattern is 12, which is equivalent to a basestation frequency re-use of 4, see Figure 5.8. This puts an upper limit on the number of transceivers that a basestation sector can operate for a given amount of spectrum
- each transceiver requires 200kHz of paired spectrum, and provides eight 25kHz-communication channels.

Figure 5.8: Frequency re-use pattern

Frequency re-use of 12
Basestation frequency re-use of 4
Note: Each hexagon represents a different basestation



Source: Ovum analysis

Figures 5.9 and 5.10 contain the spectrum estimates made for each operator.

Figure 5.9: GSM900 spectrum (paired, MHz)

	Urban	Suburban	Rural
Mobifon	12.4	12.4	12.4
Orange	12.4	12.4	12.4

Source: Ovum analysis

We assume that the GSM1800 will be used in urban areas, where there is likely to be the greatest need due to a high traffic density.

Figure 5.10: GSM 1800 spectrum (paired, MHz)

	Urban	Suburban	Rural
Mobifon	2.4	0	0
Orange	3.6	0	0

Source: Ovum analysis

5.2.9 Engineering design rules

Base Station to Base Station Controller transmission link (IBT)

The models assume that:

- 2Mbit/s links are deployed to carry the traffic from the Base Station (BTS) to the Base Station Controllers (BSC)
- a 2Mit/s link has 32 channels: 30 of these channels can carry traffic, 2 channels are reserved for signalling
- 60% of base station to BSC links require more than one microwave link – which leads to a multihop factor of 1.6.

Base Station Controller (BSC)

The number of transceivers (TRXs) each BSC can support determines the number of BSCs required. The model assumes:

- A BSC can control up to 512 GSM TRXs
- BSCs are co-located with MSCs

Mobile Switching Centre (MSC)

The number of MSC Central Processing Units is determined by the busy hour call attempts. Voice and High Speed Circuit Switched Data traffic is the only traffic that we assume that needs to be switched by the MSC. The model assumes:

- an average call duration of 0.8 minutes
- 80% of calls are switched by two MSCs via an inter-MSC switch
- there is a 10% uplift in capacity to cover signalling and legal interception.

Mobile Switching Centre Ports (MSCP)

The number of MSC ports is determined by the busy hour erlangs that are required to be switched, and the proportion of traffic that is switched through 2 MSCs. The model assumes that:

- 80% of calls are switched by two MSCs via an inter-MSC switch
- there are two ports on each MSC, one BSC-facing and one MSC-facing.

Inter-MSC backbone (IMC)

The level of capacity redundancy that is provisioned between the MSCs is set to 150% so that if a link fails, then back up is provided. Redundancy is required to ensure voice circuit availability in case a link fails. We assume a backbone network links the MSCs together and the amount of switching capacity required on the backbone is estimated using the traffic that is switched through more than 1 MSC. The capacity of each voice channel is an input parameter.

The length of each IMC link is estimated by approximating the average area each MSC needs to serve, the calculation is set out below:

Average length of each IMC (Km) = Sqrt[(# MSCs / Covered area) / 3.14] x 2

Point of interconnect for national traffic (POI)

The model assumes:

- the capacity required for each voice channel is set to 64Kbit/s – the size of a voice channel in the fixed network
- each POI is dimensioned in units of 155 Mbit/s (or STM-1)
- to calculate the cost of the POI, that each points of interconnect links is on average 10Km in length

Inter SGSN backbone (IDC)

Redundancy is required to ensure data circuit availability in case a link fails. The level of redundancy on these links is set to 150%.

The length of each IDC link is estimated by approximating the average area each IDC needs to serve, the calculation is set out below:

Average length of each IDC (Km) = Sqrt[(# SGSN's / Covered area) / 3.14] x 2

SGSN

The SGSN conversion factor is based upon data provided by the operators and Ovum's experience. The SGSN conversion rate is calculated as follows: SGSN Erlang per Mbyte = (Annual voice minutes to Erlangs conversion factor) divided by (GPRS MB per voice minute). The SGSN MB per voice minute is set at 0.07 (Source Ofcom).

GGSN

The GGSN conversion factor is based upon data provided by the operators and Ovum's experience. The GGSN conversion rate is calculated as follows: GGSN Erlang per Mbyte = (Annual voice minutes to Erlangs conversion factor) divided by (GPRS MB per voice minute). The GGSN MB per voice minute is set at 0.07 (Source Ofcom).

Mobile multi-media databases (MMS)

The model estimates of the approximate number of MMS's provisioned. The model assumes that the number of MMS required in dimensioned around the number of transceivers in the network.

Pre-pay platform (PRP)

The model assumes that each PRP platform can support 200,000 per-pay subscribers.

Short Messaging Service Platform (SMS)

The SMS platform is dimensioned around the number of SMS carried in the busy hour. The model assumes that the capacity unit of each SMS platform is 500 Busy hour SMS per second.

Voicemail service platform (VMS)

The number of VMS platforms provisioned are dimensioned around the total number of mobile subscribers.

Interconnect billing system (BIL)

The size of the interconnect billing system is dimensioning around the size of the points of interconnect (POI) with other operators.

Network Management System (NMS)

The network management system is dimensioned around the number of transceivers in the network.

Home Location Register (HLR)

The HLR is dimensioned around the number of mobile subscribers.

GPRS Overlay (GPR)

The number of GPRS overlay platforms is dimensioned around the number of transceivers that are in the network.

Transit Switch (IMS)

The number of transit switches is dimensioned around the number of busy hour call attempts that it processes.

EDGE (EDGE)

We have deliberately set the number of EDGE overlay platforms required to zero because of the dimensions of the technology have not been provided by mobile operators, and in the base line case no EDGE traffic is assumed.

Authentication centre (AUC)

The number of AUC platforms provisioned are dimensioned around the total number of mobile subscribers. This database allows authentication of request for service and the communication coding using algorithms. AUC communicates with:

- HLR;
- The SIM card of the mobile station;
- The mobile station;
- BTS

Interactive voice response (IVR)

The number of IVR platforms provisioned are dimensioned around the total number of mobile subscribers. IVR is a telephony technology in which someone uses a touch-tone telephone to interact with a database to acquire information from or enter data into the database. IVR technology does not require human interaction over the telephone as the user's interaction with the database is predetermined by what the IVR system will allow the user access to.

5.3 Network Asset Values

The model examines the following network asset values:

- TRX
- BTS
- IBT
- BSC
- MSC
- MSCP
- IMC
- POI
- IDC
- SGSN
- GGSN
- MMS
- PRP
- SMS
- VMS
- BIL
- NMS
- HLR
- GPR
- MICRO
- PICO
- IMS
- EDGE
- AUC
- IVR

In addition the model estimates the "COMMON" cost (i.e. Common costs between the operator network and retail costs), as the well the operator's retail costs.

The unit cost estimates have been derived from data provided by Mobifon, cross-checked against data from earlier Ovum cost modelling assignments. Orange did not submit any unit cost information.

Modern Equivalent Asset price trend

No Modern Equivalent Asset price trend information was submitted by either Mobifon or Orange. In its absence, we believe that a sensible range for most network components lies between 0 and –5% per annum. We have set the MEA trends to reflect the following:

- there is unlikely to be any significant cost reductions for BTS (basestations), MICRO and PICO, as a lot of these costs are building and site related
- there is going to be cost reductions for most items of network equipment such as TRX, IBT, BSC, MSC, MSCP, SMS, BIL, HLR, IMS. We believe that this could average –5% per annum over the forecast horizon
- GPRS, EDGE, COM are unlikely to change as they represent the fixed costs of operating a mobile network.

Asset lives

From Ovum's previous experience, mobile network equipment generally has an asset life of 10 years. The exceptions are NMS and BIL which are both network components that have a large software component to them and should therefore have a shorter life of 5 years. This is also the rationale for the 5 year asset life for the retail systems, that we believe would have a large software component. IVR has also 5 years asset live.

We have set the:

- network common asset life to 10 years, in line with other network elements, and,
- network / retail common cost lifetimes to be 15 years which is in line with the fee for the licence.

5.4 Network operational expenditure

Network

The operational expenditure is included in the model as a proportion of the cost of network assets. We exclude the licence fees from the value of network operational expenditure as these are calculated separately in the next section. These estimates have been derived from data provided by Mobifon, cross-checked against data from earlier Ovum cost modelling assignments.

Because network operational expenditure is difficult to estimate theoretically, our assumption is based upon Mobifon's reported network operational expenditure in 2003 expressed as a proportion of the estimated Gross Replacement Cost of its network assets at the end of 2003. This proportion is then assumed to remain constant throughout the forecast period, when applied to the Gross Replacement Cost in 2003 prices. We excluded licence fees from the operational expenditure, as these are costs are dealt with separately in the model as a common cost.

Orange did not submit any operational expenditure data.

Spectrum costs

We have added the cost of GSM spectrum to the operational expenditures outlined above. The spectrum that Orange and Mobifon require is charged on an annual basis.

Retail

The retail costs of providing services to customers are contained in Figure 5.11. They are defined as those costs, which are caused by, or provide benefit to, mobile subscribers. They consist of:

- Marketing
- Advertising
- Distribution and subscriber acquisition
- Retail billing.

The retail costs are based upon data submitted by the mobile operators.

Figure 5.11: Retail operational expenditure assumptions (Euro)

	2002	2003	2004	2005	2006	2007	2008	2009
Retail opex per new connection	17	17	17	17	17	17	17	17
Retail opex per sub	33	33	33	33	33	33	33	33

Source: Ovum analysis

5.5 LRAIC Unit costs

5.5.1 Routing factors

Routing factors are used to allocate costs amongst different services. The base case uses Ovum's routing factors, which are based upon Ovum's experience of similar studies, and the network configuration illustrated in Figure 4.2. We have used the erlang equivalent of each service to allocate the traffic driven costs. We set out the rules of thumb used to derive our routing factors:

- On-net calls make twice as much usage of transceivers, basestations, and transmission links as outgoing off-net calls and incoming calls
- 144 SMS is equivalent to 1 voice minute and that on-net SMS make twice as much usage of transceivers, basestations, and transmission links as outgoing off-net SMS and incoming SMS.
- On-net calls make 80% more use of the MSC and incoming calls 20% more use of the MSC than outgoing calls.
- Any equipment that is dedicated to provide a given service should be allocated to that service. For example, the SMSC is allocated to SMS services, GPRS costs to GPRS services.
- As no voicemail minutes were used in the model, voicemail costs were allocated to subscribers
- POI links were allocated to outgoing off-net calls and SMS, and to incoming calls and SMS

- Network common costs such as BIL, NMS, and COM have already been allocated amongst network elements, and so do not need to be allocated via the routing factors.

Ideally routing factors should be developed by undertaking a detailed analysis of the proportion of usage that each service makes of each network component during the busiest hour. Both Mobifon and Orange submitted routing factors, but no supporting rationale (traffic study) on which their routing factors had been derived.

5.5.2 Service volumes

The billed service volumes are used to unitise the costs allocated to each service. For voice traffic billed minutes are taken to be 30% less than network minutes.

5.6 Mark ups

An operator in an efficient market will ensure that common costs are recovered through the services that are provided. The mark-ups included in the model are shown in Figure 3.2.

There are two principal ways in which common costs can be factored into the service costs that an operator can charge:

- Equi-proportionate mark-up (EPMU)
- Ramsey pricing mark-up.

The model uses equi-proportionate mark-ups to recover the common costs. This is in line with all regulators that have adopted a LRAIC approach so far.

Ramsey-pricing was not implemented as:

- it requires uncertain assumptions, and
- there is no industry consensus as to the appropriate application of the theory.

Treatment of Inflation

To avoid the uncertainty of inflation, we produce all the cost results in 2003 real Euro.

6 Results

6.1 Call termination

6.1.1 LRAIC

We have set up a base line case under each operators subscriber traffic profile, traffic distribution and spectrum allocation which assumes the following:

- a dual band GSM 900/1800 rollout, no EDGE rollout is assumed
- a 40% market share of subscribers by 2009
- 90% geographic network coverage by 2009
- 2% of voice calls are blocked
- network operational expenditure set to 14% of the network capex
- the minimum coverage network is not separated out and treated as a common cost, but is implicitly included in the network costs
- common cost mark up of 6%
- tilted annuity depreciation.

Figure 6.1 indicates the level of call termination for the base case.

Figure 6.1: LRAIC call termination cost (Euro cents per minute)

	2002	2003	2004	2005	2006	2007	2008	2009
Mobifon	8.17	7.10	6.73	5.63	5.17	4.92	4.71	4.58
Orange	8.60	7.29	6.17	5.20	4.63	4.42	4.24	4.19
Average	8.39	7.20	6.45	5.41	4.90	4.67	4.47	4.39

7 Comparison

To confirm the accuracy of the bottom-up model, we have compared its outcomes against information provided by the mobile operators. The detailed information is confidential but the overall results are as follows:

- **Subscribers.** Subscriber numbers have been reconciled against the data provided by Mobifon and Orange for 2003-2004.
- **Traffic.** Traffic volumes for all services have been reconciled against the data provided by Mobifon and Orange for 2003-2004
- **Asset lives.** The asset lives used in the model closely match those supplied by the operators. For a few assets the operators have quoted a range of asset lives, whereas we have taken a single figure, typically the midpoint of that range.
- **Asset volumes.** The equipment volumes estimated by the model have been compared with the actual volumes reported by the operators at the end of 2003. There is not a perfect reconciliation, as is to be expected of a bottom-up model, but the overall results are reasonable:
  - In the case of Orange, the model overstates BTS capacity by about 12%, overstates TRX capacity by around 68%, and IBT capacity by around 17%.
  - In the case of Mobifon, the model overstates BTS capacity by about 17%, overstates TRX capacity by around 30% and BHCA MSC capacity by 4%. On the other hand it underestimates IBT by 2% and IMC by 10%.
- **Asset values.** The analysis of operators' financial statements for 2004 has been compared with the results with the bottom-up model. It appears on this basis that the model overvalues Orange's assets at the end of 2004 by 35%, and it similarly overstates Mobifon's asset value by 42%.
- **Operating expenditure.** The analysis of the operators' financial statements for 2004 also indicates that the model overestimates Orange's operating expenditure in 2004 by 31%, and it similarly overstates Mobifon's operating expenditure by 14%.

On this basis it appears that the bottom-up model provides a reasonably accurate representation of the mobile operators' costs. If anything the model appears marginally to over-estimate costs, at least historically.

8 Glossary of abbreviations

8.1.1 *BIL* – Interconnect billing system

The interconnect billing system is a database that measures the interconnect traffic and payments.

8.1.2 *BTS* – GSM Base station site

The model estimates the number of GSM base stations sites which are the sites on which radio transmission equipment are placed. The basestation site houses the radio access equipment such as transceivers (TRX)– see the definition of a TRX below.

8.1.3 *BSC* - Base station controller

The function of the base station controller is to aggregate traffic from a number of base stations (BTS) and route it to the MSC.

8.1.4 *CAGR* - Compound Annual Growth Rate

This is a mathematical term that estimates the average annual growth rate.

8.1.5 Erlang

Erlang is a unit without dimension, accepted internationally for measuring the traffic intensity. This unit is defined as the aggregate of continuous occupation of a channel for one hour (3600 seconds). An intensity of one Erlang means the channel is continuously occupied.

8.1.6 *GGSN* - Gateway GPRS Support Node

The Gateway GPRS Support Node (GGSN) is a router that serves as the gateway between the wireless operator's GPRS core network and external Packet Data Networks such as the internet.

8.1.7 *GPR* – GPRS overlay

The GPRS overlay is the licence fee levied by GSM equipment manufacturer to operate a GPRS network.

8.1.8 *GPRS* - General Packet Radio Service

The General Packet Radio Service (GPRS) is a non-voice value added service that allows information to be sent and received across a GSM mobile telephone network. GPRS has a theoretical maximum speeds of up to 171.2 kilobits per second (kbit/s) are achievable with GPRS using all eight timeslots at the same time.

8.1.9 *GSM* - Global System for Mobile Communications

GSM is an open, non-proprietary system for mobile communications that is constantly evolving. GSM uses digital technology and time division multiple access transmission methods. Voice is digitally encoded via a unique encoder, which emulates the characteristics of human speech. This method of transmission permits a very efficient data rate/information content ratio.

8.1.10 *HLR* – Home Location Register

The HLR identifies whether the subscribers on the network are customers of the operator. This is one of the very few subscriber-driven network elements in the model.

8.1.11 *IBT* – BTS to BSC Transmission link

The model works out the number and capacity of the transmission links between BTS and BSC, and their average distance.

8.1.12 *IDC* – SGSN to SGSN Transmission link

The model works out the number and capacity of the transmission links between SGSNs, and their average distance.

8.1.13 *IMC* – MSC to MSC Transmission link

The model works out the number and capacity of the transmission links between MSCs, and their average distance.

8.1.14 *MEA* – Modern Equivalent Asset

This is an accounting term, that is used to describe a modern asset purchased to replace an asset.

8.1.15 *MMS* - multimedia messaging service

Multi Media Messaging Service allows mobile phone users to enhance their messages by incorporating sound, images, and other rich content, transforming it into a personalised visual and audio message.

8.1.16 *MSC* – Mobile Switching Centre

The mobile switching centres are the key switching nodes of the national mobile network.

8.1.17 *MSCP* – Mobile Switching Centre Ports

The mobile switching centre ports determine the capacity of the switching nodes of the national mobile network.

8.1.18 *NMS* – Network Management System

The network management system is used to monitor, supervise, maintain and operate the network.

8.1.19 *POI* – Point of Interconnect

This link handles inbound and outbound traffic between domestic operators.

8.1.20 *PRP* – Pre pay platform

The pre-paid platform ensures that the calls made by prepaid customers are covered by credit provided by those customers.

8.1.21 *RETAIL* –Customer management systems

The customer management system is a database of mobile subscribers, used to manage, track and monitor customer contact activities such as customer service, fault management and promotional campaigns.

8.1.22 *SGSN* - Serving GPRS Support Node

The Serving GPRS Support Node (SGSN) performs mobility and data session management for GPRS mobiles. In addition, the SGSN performs ciphering and compression of the data transmitted and the routing of IP Packets

8.1.23 *SMS* – Short Message Service platform

The SMS platform is dedicated to the acceptance, storage and archiving of SMS traffic.

8.1.24 *TRX* - Transceiver

The transceivers sit on the base stations and the aerials that are used to send and receive the radio signals from the base station to the mobile handset. They are the main traffic-driven component of the BTS. The number of TRXs per base station is a function of the traffic the BTS is required to support, and the spectrum available for that base station.

8.1.25 *VMS* – Voicemail Service platform

The VMS platform is dedicated to the acceptance, storage, archiving and retrieval of voicemail.