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Telecom Network Planning for evolving Network Architectures

Reference Manual

Draft version 5.1

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Reference Manual on the Telecom Network Planning for evolving Network Architectures

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Chapter 8 – Data gathering

Network planning, especially performed with NP tools, requires collection of numerous data.

Main input data are:

8.1. Geographical information for the studied area

Geographical Information Systems (GIS) are nowadays one of the most import tools for network planning, maintenance and monitoring. GIS applications try to build a model of the world inside a computer, allowing displaying and analyzing complex geographical correlations and details. The computer model of the world, which is the basis for all analyses, consists of geographical information.
Geographical information is the combination of geometrical, locatable details and collected information. Their coordinates as geometrical detail and their length or name as collected information, e.g. describe roads.

8.1.1. Vector and Raster data

There exist various types of geographical information mainly stored in 2 formats: raster or vector. Both formats have their justification inside the GIS world. Each format has its advantages and is intended for specific tasks. This chapter will explain both formats for the storage of geographical information and give an overview of the use and advantages of each format.

8.1.1.1. Vector data

Vector data has its name from the method by which the geometry is collected, starting with a point a vector with a certain length and direction points to the second location where another vector directs to a next location and so on.
Geometrical objects of a vector can be:

- Points
- Lines: two points connected by a line
- Poly lines: several connected points in a row, e.g. roads
- Polygons: several connected points in a row, the last and first points are connected. Polygons are closed poly lines and are used to surround areas, e.g. country borders

Figure 8.1: Real World

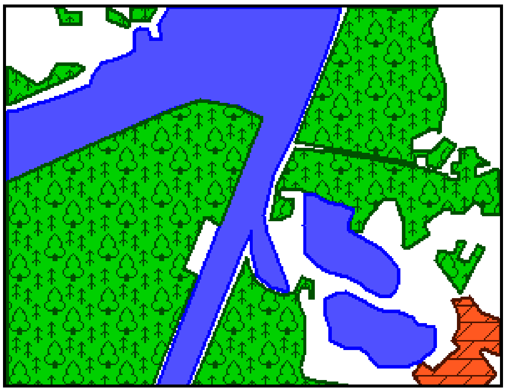


Figure 8.2: Vector model or the Real World

The geometry indicates points or follows lines that go along or surround objects of one and the same kind. Lines of the same type can be roads, rivers or microwave links. Closed polygons can surround areas like political districts, city contours, coverage areas, etc. Besides the geometry of vectors, collected information about these objects can be attached. Each vector object can have a lot of different information stored. The collected information for a country border could be for example: the country name, country size, number of inhabitants, inhabitants divided by male / female, income, etc.

8.1.1.2. Raster data

The second format in which geographical information is stored is the raster or grid format. The area of interest is divided into a regular grid of equally spaced small rectangular regions. One region of the raster computer model is called a pixel. Each pixel stores one (1) information about the surrounded area. This can be the mean height above sea level, the number of inhabitants living there, the field strength, etc. If more than one (1) information of the same type is available in a pixel area, a decision has to be made, which information will represent this area. A sub-classification of pixels is not possible because each pixel can indicate only one (1) information about its area content. In case the stored information should be more detailed, the pixel resolution, the area size of one (1) pixel, has to be reduced.

Figure 8.3: Real World

Figure 8.4: Raster model of the Real World

A collection of pixels containing the same information type is called a layer. Therefore one (1) layer can only store one type of information. If more than one information about a pixel object is required, several layers with different contents have to be created.

8.1.1.3. Comparison

Vector and raster format have different advantages and disadvantages. The table below gives an overview of the most significant differences.

	Vector format	Raster format
Available information	Several information types available per vector object	1 information value per raster pixel 1 information type per raster layer
Memory size	Low Memory size dependent on complexity of terrain	High Fixed memory size for terrain data area 1 full layer for each information type
Zooming Range	Flexible zooming of geometrical information	Zooming in multiples of pixel resolution
Zooming in > 100%	Possible, contents limited by accuracy of geometry	Zooming in leads to enlarging of pixel size on screen
Data access	Slow, valid information for specific point must be detected out of all vector objects	Fast, valid information at specific point detected from nearest pixel

Table 8.1: Comparison of geographical information formats

The table above points out that vector data has the great advantage of low memory consumption and the multiple availability of information regarding geometrical objects compared to raster data. Therefore it is predetermined for displaying purposes and the analysis of complex correlations of geographically large objects. If fast access to information at a certain point is needed or the terrain is very complex in terms of changes, the raster format is preferable. This is the reason why GIS applications which perform field strength calculations use raster format for the storage of most of the terrain data layer, like elevation-, land-use-, population-data or calculation results. Terrain data in vector format are usually used by these application for displaying political maps, roadmaps or networks, or the specification of areas for computer analyses.

8.1.2. Background Maps for Display and Visualization

Radio network planning with GIS applications allows the easy geo-correct overlay of sites, links or planning results over maps. Therefore overview and detailed maps are required.

8.1.2.1. Overview maps

Overview maps are needed to display countrywide or large area coverage or even multinational networks for international coordination. The maps can be in vector as well in raster format. The maps in raster format are most of the time scanned paper maps, which are post processed in order to display the scanned information at the geographically correct

places. The scanned paper maps have the advantage that they have a higher recognition factor than vector maps. Vector maps do usually not show so many details and their representation strongly depends on the visualization functionality of the CIS tool.
Overview maps should show only the necessary details, like political borders, main cities, rivers, lakes, and roads that are needed to identify known locations at the first view. Map scales from 1:500,000 to 1:4,000,000 are suggested depending on the area of interest.

8.1.2.2. Medium scale maps

Medium scale maps at a scale between 1:50,000 and 1:250,000 are needed for more detailed network investigations in rural areas or the presentation of locally restricted networks. Like the overview maps they can be in vectors or in raster format. Again scanned raster maps have the advantage of a higher recognition factor, which makes it easier to present planning results to spectators that are not familiar with vector based maps. On the other hand vector based maps are often more up-to-date than raster maps which have an update circle of 5 or more years. Vector based maps are often generated out of most recent data collected for route planning software.

8.1.2.3. Detailed maps

Detailed maps of a scale of 1:30,000 and lower are used for detailed network-, micro-cell- and PMP planning in rural and urban areas. They can be in raster and vector format. Scanned and geo-corrected city maps are a very good and cheap source for detailed maps of the most important cities around the world. For a lot of countries paper maps at a scale of 1:10,000 to 1:25,000 are available. Unfortunately, they are often more than 10 years old or restricted by military. Therefore the usage of these maps is very often limited.
A second very useful source for detailed maps is a combination of most recent orthorectified images and precise vector data. The images are created from satellite imagery or aerial photography. The orthorectification changes the point of view from one (1) point camera lens perspective towards parallel top view perspective. This mechanism allows looking at every point of the image right down onto the top of the building instead of viewing it from the side. The vectors overlaying the images mark well known points of interest, highlight rivers and important streets or display names of cities, streets and house numbers. The available details in the images depend on the source of the maps. Aerial photography usually has a pixel resolution of 0.1 m to 2 m. A pixel resolution of 0.64 m to 5m for optical satellites is available on the market for nearly every area in the world.

Figure 8.5: IRS 1C/D satellite image

8.1.3. Elevation data

Elevation data can be divided into 3 categories:

- DTM (Digital Terrain Model)
- DEM (Digital Elevation Model)
- DBM (Digital Building Model)

Elevation data is most of the time stored in raster format. Only DBM data is often stored in vector format. The advantage of raster format for elevation data is that a preprocessed height value is easily detectable for every point of planning area. The exact height can be detected by the next neighboring pixel or bilinear interpolated by the four neighboring pixel. Elevation data in vector format would require a detection of all neighboring elevation contours needed to interpolate the exact height at that position.

The most important and most used elevation type is the DTM. There is no standardization for these names. A digital Terrain Model is often called DEM or simply Elevation Model. It represents the height of the surface of the earth above sea level.

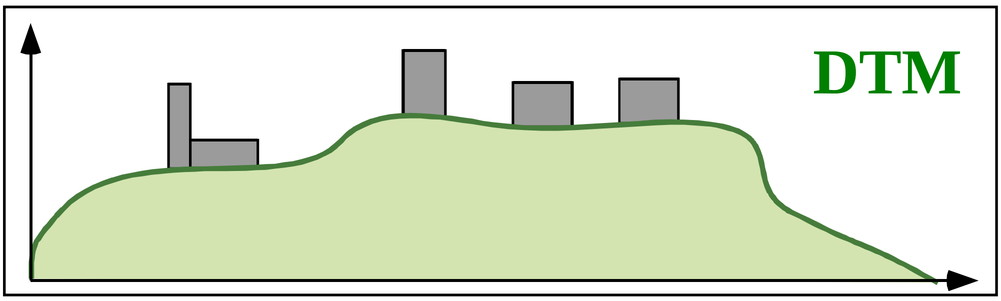


Figure 8.6: Digital Terrain Model – Surface height above sea level

The DTM in combination with land-use data is the most used source for field-strength calculations. For GSM and microwave link planning a pixel resolution of 50 m for rural areas and of 20m – 25m for urban areas is suggested.

Digital Elevation Model (DEM) is often called Digital Surface Model (DSM) or Digital Building Model (DBM). A DEM is most of the time stored in raster format. Each pixel of the DEM represents the height of the surface of the earth above sea level plus the rooftop height, where buildings are.

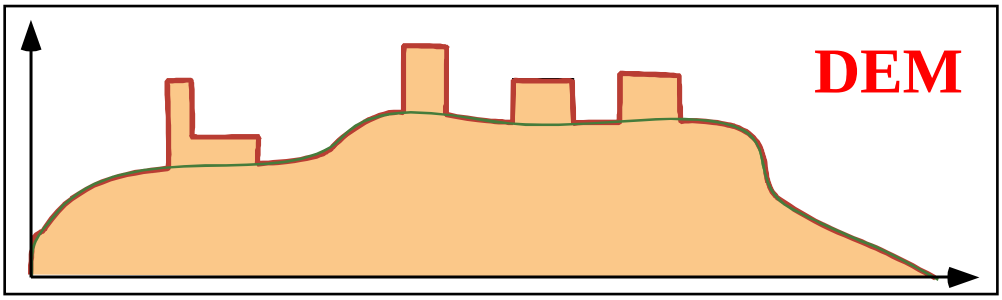


Figure 8.7: Digital Elevation Model – Surface height above sea level plus rooftop height

The recommended pixel resolution for DEM data is between 1 m and 5 m. A pixel resolution of 5m implies that a building represented by 1 pixel has a minimum size of 5 m x 5 m. Smaller buildings will not be detected and therefore not included into the DEM.

Digital Building Model (DBM) is available in raster as well as in vector format. The height given represents the rooftop height above sea level. All areas, which are not covered by buildings, are marked with a certain default value, which is most of the time –9999 or –999.

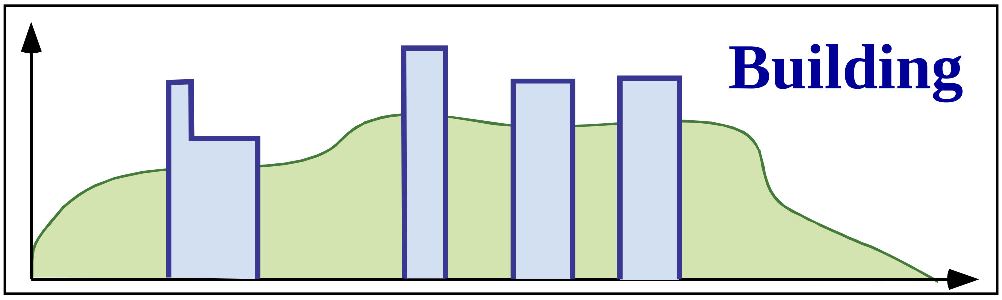


Figure 8.8: Digital Building Model – Rooftop height above sea

The recommended pixel resolution for DBM data is between 1 m and 5 m. A pixel resolution of 5m implies that a building represented by 1 pixel has a minimum size of 5 m x 5 m. Smaller buildings will not be detected and therefore not included into the DBM. Some new 3D propagation model for micro- and pico-cell planning are based on a DBM in vector format. Besides the rooftop height above sea level other information about that building is included. This additional information can be: rooftop height above ground, wall material parameter, roof type, etc. The geometry and file format for this DBM in vector format strongly depends on the software used and can be very complex, since there exists no industrial standard for 3D-building data yet.

	DTM	**DEM**	**DBM**
Given height	Ground height above sea level	Ground height or rooftop height above sea level	Roof-top height above sea level, else default value
Resolution for rural areas	50 m		
Resolution for urban areas	20m – 25 m	1m – 5 m	1m – 5 m
Sources	Topographical maps	Aerial photography Stereo high resolution satellite imagery	Aerial photography Stereo high resolution satellite imagery Aerial photography
Usage	Macro- cell and microwave link planning	Micro- and pico-cell planning, PMP	Micro- and pico-cell planning, PMP
Price indication	0.05 – 2 Euro / km^2	50 – 300 Euro / km^2	50 – 300 Euro / km^2

Table 8.2: Comparison of elevation data types

8.1.4. Clutter / Land-use data

Besides the DTM some propagation models take the land coverage into consideration for the calculation of the field-strength. Depending on the type how the earth is covered at a place, these models calculate complex correction coefficients to adopt the free-space field strength on measurements. There exist different synonyms for this kind of information:

- Land-use data
- Land-coverage data
- Clutter data
- Morpho data

Clutter data stores the information on how the earth is covered. The supported clutter classes are not standardized and therefore strongly depend on the software used and the propagation model supported. The most important clutter classes are listed below.

Clutter class	Classification
Sea	Tidal water
Inland water	Lakes, reservoirs, rivers, streams
Open wet areas	Areas liable to flooding usually situated beside rivers
Open	Agricultural land with sparse dwelling; uncultivated land
Forest	Woodlands; forest
Open in Urban	Open areas located within urban areas
Industrial areas	Factories, warehouses, surface quarries, docklands
Villages	Urban areas located approximately > 2 km from the urban fringe unless clearly separated by a feature such as a major river. Villages can be scattered throughout the image
Suburban Residential	Areas of housing mixed with wooded areas and streets. Often situated on the outskirts of urban areas
Urban	Medium density buildings or housing often mixed with areas of open.
Dense Urban	Dense buildings with narrow side streets, mostly found in city center areas.
Parks Recreational areas	Urban parks, sports stadiums, golf courses
Block Buildings	Groups of generally narrow buildings, parallel and separated by open space

Table 8.3: Most important clutter classes

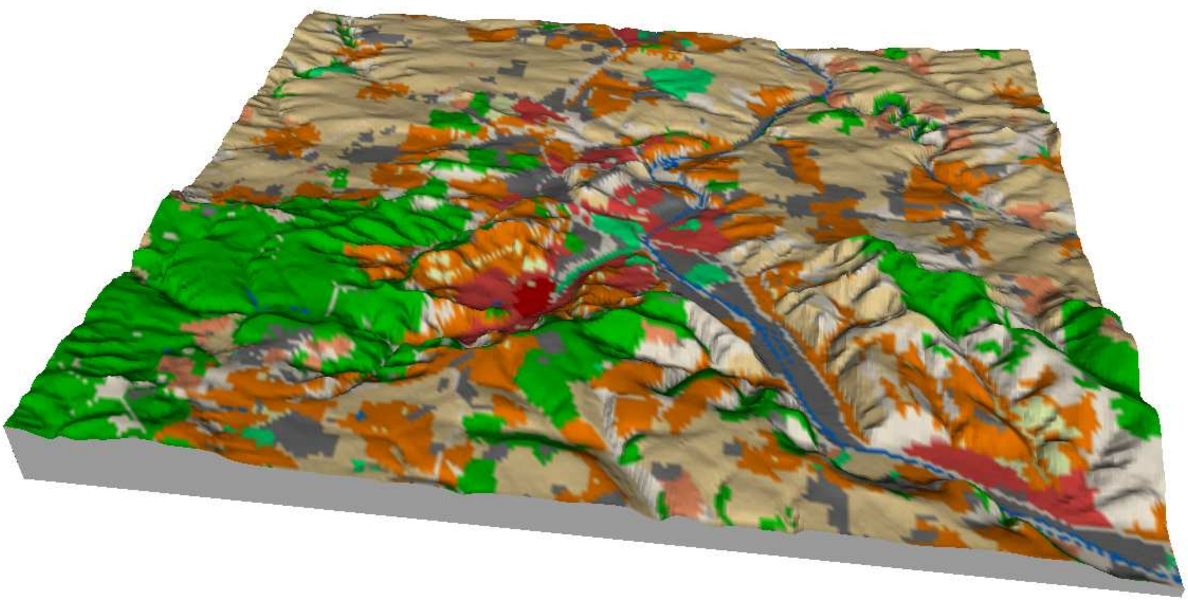


Figure 8.9: 3D-model of terrain overlaid with clutter data

Clutter data for network planning is most of the time stored in raster format. Till the year 2000 most of the clutter has been extracted from paper maps of various scale. The still most used paper maps are Russian topographic maps, which are available for approximately 80 - 90% of the world. The big disadvantage of the Russian maps is the date of creation, which is between 1980 and 1995 for European and areas of the former Soviet Union. For all other

countries the maps are even older. The use of paper maps from local sources like ordnance surveys is often restricted by military or only allowed after paying certain license fees. More recent clutter data can be generated out of satellite imagery. Clutter data with 25m resolution per pixel or less is often generated out of Spot or IRS 1C/D satellite imagery. Specially trained people according to visually dividable classification rules carry out the classification manually. The nowadays most used source is Landsat7 multi-spectral satellite imagery, which allows a semiautomatic classification. Typical resolutions for clutter data created out of Landsat7 multi-spectral satellite imagery are 25m, 50, or lower. Comparing to Spot or IRS 1C/D clutter data from Landsat7 is much cheaper because of 3 reasons:
the semiautomatic process for creation of the clutter data
the satellite scenes are bigger
there are less license fees to pay.

8.1.5. Demographic data

Statistical information about the population distribution or income situation inside a specific area is called demographic data. This statistical information can often be obtained from the statistical ministries. Most of the time they are in simple table format. For the use in GIS applications beside the statistical information the geographical geometries of the related areas are needed. Demographic data can be stored in vector and in raster format. In case of raster format, several layers have to be created, one for each type of statistical information, e.g. one layer for total population, one for households, one for income per family, etc.

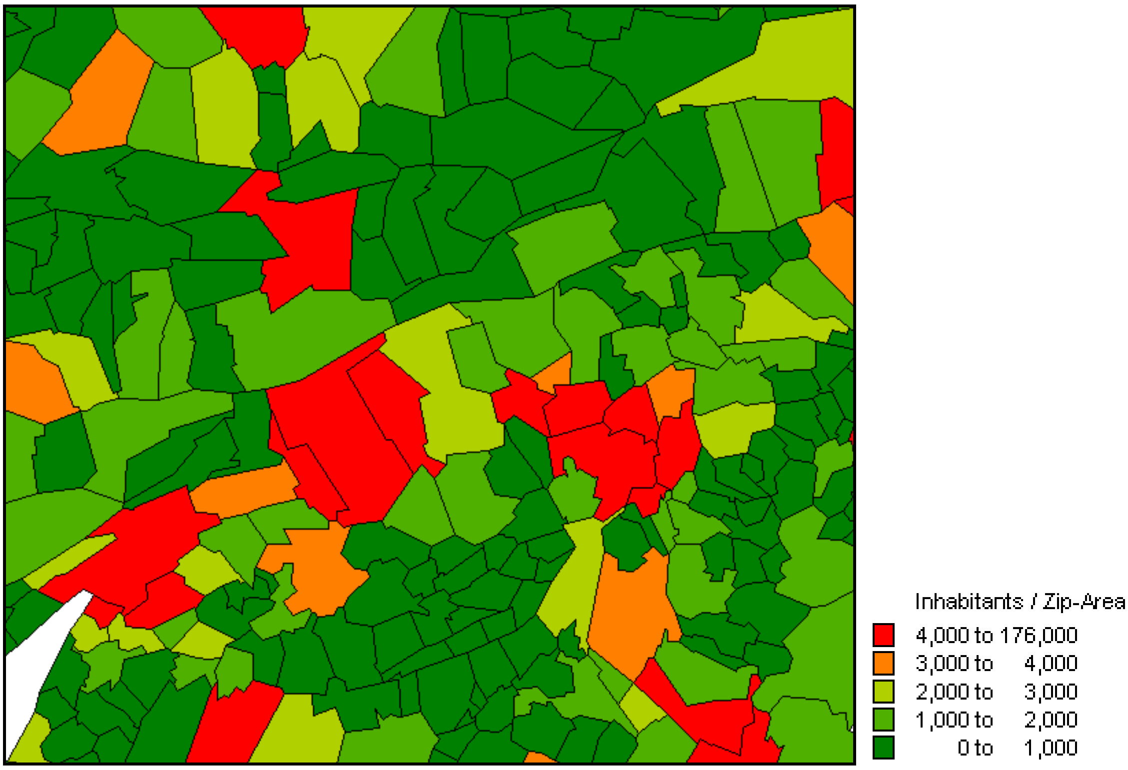


Figure 8.10: Total population based on zip-code vectors

There is demographic data available for each country of the world based on the information about the entire country, or about their main provinces. The degree of accuracy of demographic maps depends on the size of the geometrical areas, where statistical information is available. The smaller the areas, the more accurate the statistical information. For a lot of countries demographic data based on county-, zip code area, or electoral district is available.
If the geometrical areas are too large, the demographic information can be merged with existing clutter data in order to distribute the information only in those areas, which are indicated as populated by the clutter data. Some software packages allow to use additional weighting coefficients for a more realistic distribution of the statistical information.

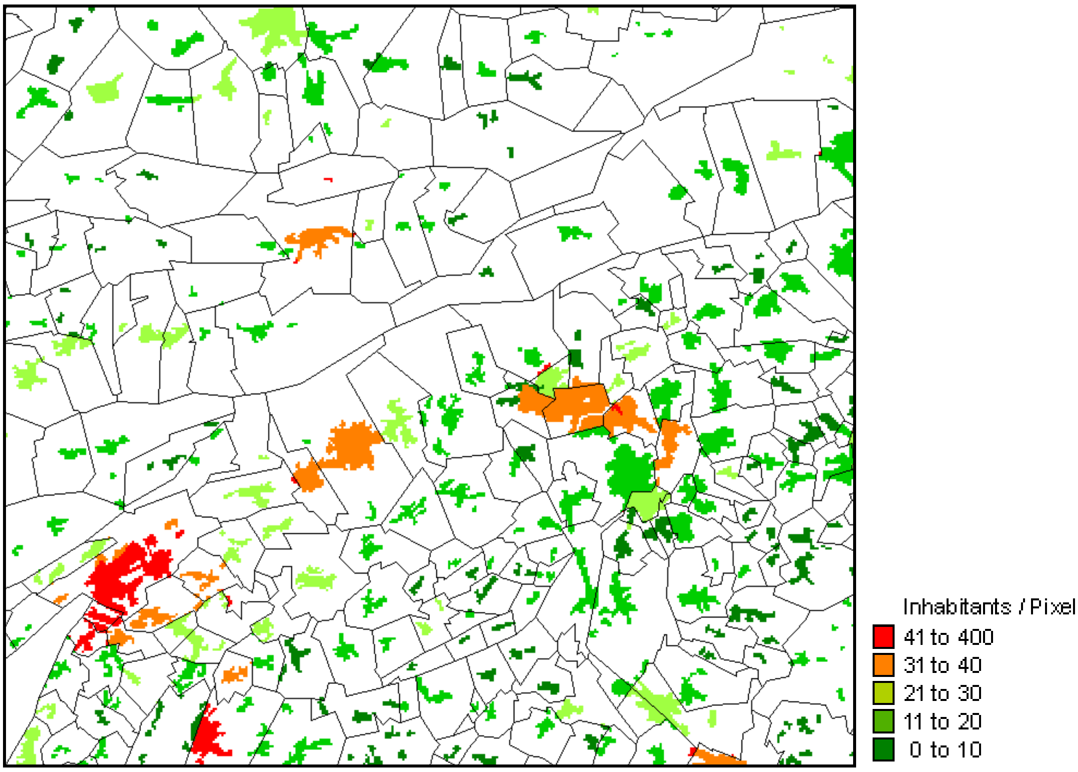


Figure 8.11: Total population based on zip-code vectors merged with populated areas from clutter layer.

8.1.6. Locations of populated places / buildings, Service areas, Clutter data

Locations of populated places / buildings

Fig 8.12 Digital maps with locations of populated places - Geo data

Modeling of user locations

Graph model with subscribers/users in the nodes of the graph

One node is one town, village, group of houses, building, etc.

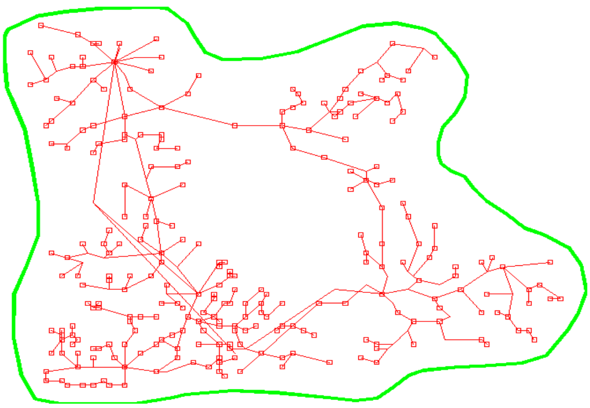


Fig 8.13 Map with nodes / sites, corresponding of the digital map from Fig 8.12

Typical model for subscribers/users in rural areas

Arcs of the graph represent geographical distances

Service areas

Group of subscribers/users, homogeneously distributed in
a geographical area (group of buildings, houses, etc.)

Typical model for subscribers/usres in metropolitan areas.

Service areas in the suburbs usually are quite big areas (e.g. complex of buildings/houses comprising several sqare km), in the center they are much smaller (e.g. one administrative building).

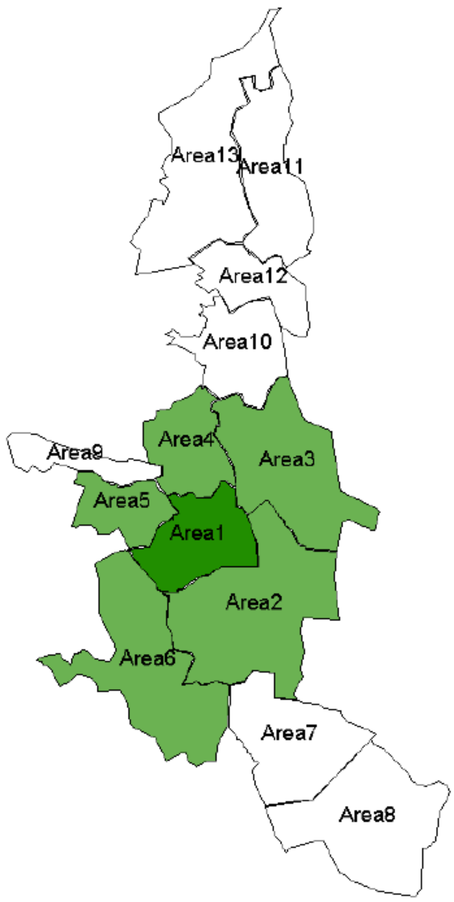


Fig 8.14 Example of service areas

- usually the city centre is surrounded by urban areas with high customer density, while the areas in the edge are suburban areas
- often the set of areas is similar to exchange areas

Customer densities are defined per square kilometre

Each area is described with a specified mix between different categories of customers

8.1.7. Digitizing of maps

If only paper maps are available for a particular network planning case they have to be converted in digital form usually as vector maps – this process is called digitizing of maps.

Technically digitizing could be performed with:

- Spesialised equipment (Digitizer), which reads typical points from a peper map as digital coordinates

- Through scanning of a paper map, wich then is exposed on a computer screen and then typical points from the scanned map are read as digital coordinates

In both cases importan part is the correct scaling and geo refrencing of the digital map.

8.2. Demand of services in relative penetration per customer category

8.2.1. Offered services

8.2.2. Customer categories

Customers with approximately similar habits of using the telecom network for one customer category.

Generally used categories are:

- Residential customers
- Business customers

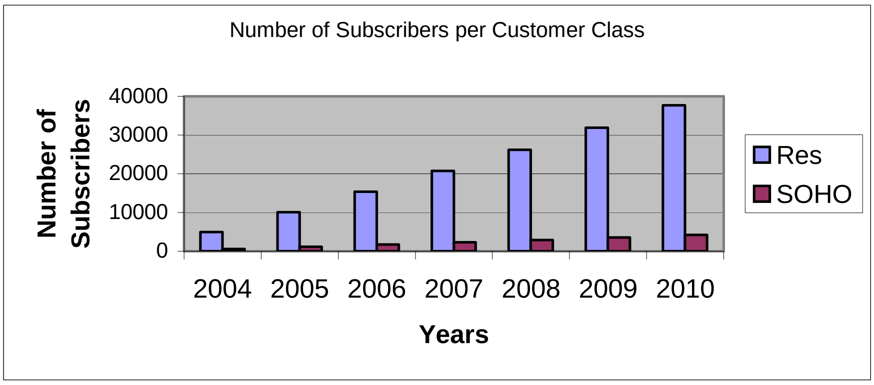


Fig 8.15 Example of customer categories

Business category is split usually into small business (SOHO), medium business (ME) and large business users (LE).

Onother possible definition of customer categories is through *Customer Classes* – groups of customer using the same services (one or more), e.g. Residential ADSL Basic, Residential ADSL Gold, Small Enterprises (SDSL), Medium Enterprises (SDSL), Residential VDSL

8.2.2. Demand per site and per area

8.2.4. Demand per time point

8.3. Demand of traffic, usually expressed as traffic matrices

8.3.1. Traffic per service per customer class

8.3.2. Traffic matrices per service

8.3.3. Traffic per time point

8.4. Information for the existing network and infrastructure

8.4.1. Exchanges, routers, concentrators, etc.

8.4.2. Transmission equipment, cables, etc.

8.4.3. Buildings, duct system, etc.

8.5. Telecommunication equipment characteristics and capabilities

8.5.1. Max capacities for utilization

8.5.2. Technical characteristics, e.g. cable attenuation/km

8.6. QOS requirements

8.6.1. For the system - e.g. congestion criteria

8.6.2. For the technology – e.g. permitted attenuation

8.7. Telecommunication equipment fixed and variable costs

8.7.1. Equipment structuring and modeling

8.7.2. Cost models - linear, step functions, etc.

8.8. Economical and Operational data

8.8.1. Purchasing, installation costs

8.8.2. Operational and maintenance expenses

Annex 1 – Network planning tools

Network planning tools are essential for network planners to be able to design multi-service networks that can meet today's growth in user applications and traffic. These networks also have to provide guaranteed service quality, availability, reliability, ensure minimal delay, and must be optimized according to various cost constraints.

Since the complexity is also growing in a very fast way, the planning tools must be powerful and flexible, to handle all the different network designing issues. The possibility of extension in a very easy way is also required, since the user's work must be only related to developing new algorithms and applications, instead of programming the integration of his methods into the main framework.

A portfolio selection of planning tools to support those planning activities is provided. The selection criteria are: capability to model modern technologies, commercial availability and being well proven in the field.

Used structure to describe the tools:

Tool xxx :

- Objective
- Domain of applicability: planning activity, network layer(s), technologies, etc.
- Capabilities: network type, size, routing type, etc.
- Required inputs
- Provided results
- Example cases

LIST OF NETWORK PLANNING TOOLS:

A1.1. Application of EXCEL

Microsoft (MS) Excel, as it is well known, is a powerful spreadsheet that is easy to use and allows you to store, manipulate, analyze, and visualize data.

It is a standard part of all versions of Microsoft Office, and is currently in its tenth version, known as Excel 2003.

At its most basic level, Excel simply provides a structured way to store data.
An Excel workbook is made up of worksheets, each of which contains an array of 256 columns and 65536 rows. That’s a total of over 16.7 million cells for data.
In a workbook there are maximum 255 worksheets.

Excel has efficient ways for managing the stored data.
Excel allows to sort data by as many columns as one may need, provides shortcuts to allow to move instantly to any cell, or to find any piece of data in any cell and methods of filtering stored data.

The real power of Excel is in analyzing rather than simply storing data.

As with any spreadsheet programme, Excel can handle mathematical calculations of any complexity.

It also has many Functions built in for specific tasks.
The most common of these, as SUM, MAX, MIN, AVERAGE can be calculated with a click of a button.

There are also over a hundred functions, grouped by category, invoked from dialog window.

Each function can be manually typed, or if preferred, Excel can guide the user through the process, prompting for the required information and giving extra help where needed (see figure A1.1).

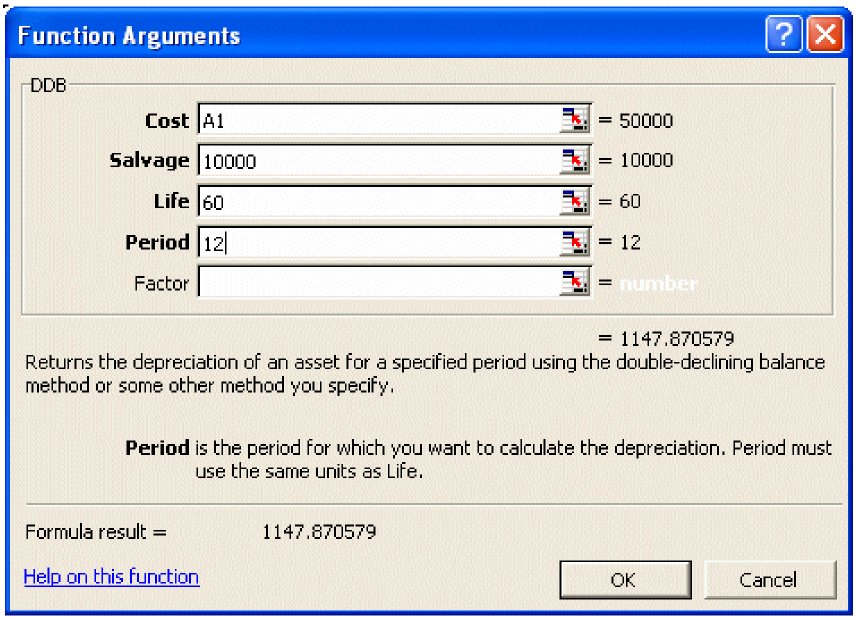


Figure A1.1 – Dialog window of Excel function calculating the depreciation of an asset

There are over 80 functions available within the Statistical category – mean, modal and median averages, standard deviations, ranking functions, etc.

In addition to analyzing data, Excel provides a number of very powerful tools for summarizing purposes.
Excel puts subtotal information below each category specified, and can further break down these categories, or add averages, maximums and so on as necessary.

Another major area in Excel application is the creation of charts.
Bar charts, pie charts, line charts, column charts, radar charts, surface charts, area charts, etc. (see figure A1.2).

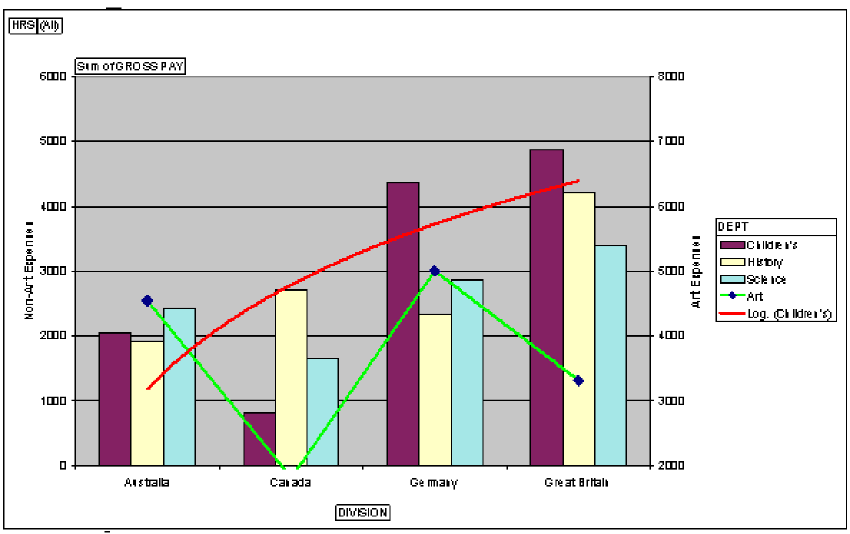


Figure A1.2 – Diagrams produced by the Excel specialized charting capabilities

Many of the charts can be presented in three dimensions, allowing for a variety of special effects.

The charts can be easily moved around the workbook or copied into Word documents or PowerPoint presentations.

As kind of Network Planning tool EXCEL could be used for:

- Entering and storing of network data, e.g. node coordinates, traffic volumes, equipment costs

- Application of simple network planning and forecasting methods, e.g. demand forecasting with trend methods, simplified methods for exchange locations optimization, etc.

- Presenting of tables and charts for quantities of customers, network elements, cost results, etc.

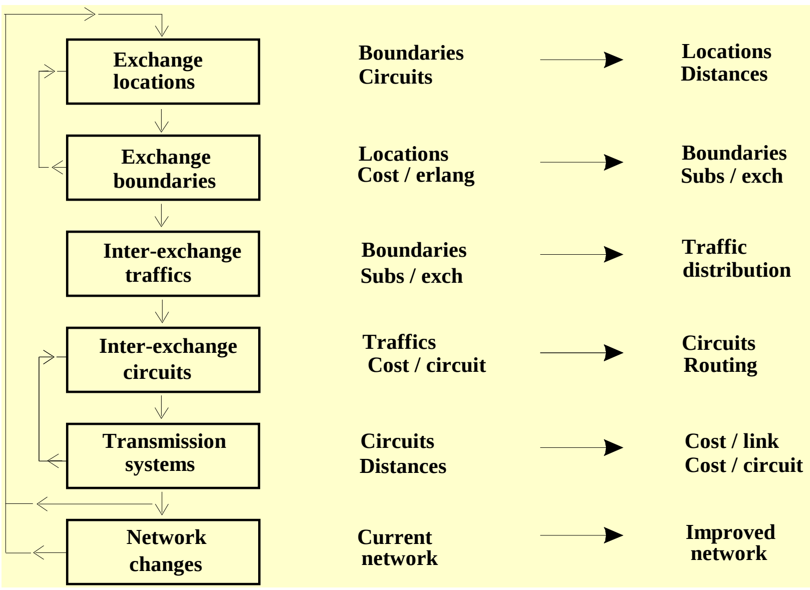
A1.2. PLANITU - ITU

Objective:

PLANITU is a tool for optimisation and dimensioning of circuit-switched telecom networks, based on an integrated interactive approach for finding minimum cost solutions for:

- location and boundaries of exchanges
- selection of switching and transmission equipment
- circuit quantities, traffic routing, switching hierarchy
- choice of transmission paths.

Fig A1.2.1. : PLANITU iterative optimization

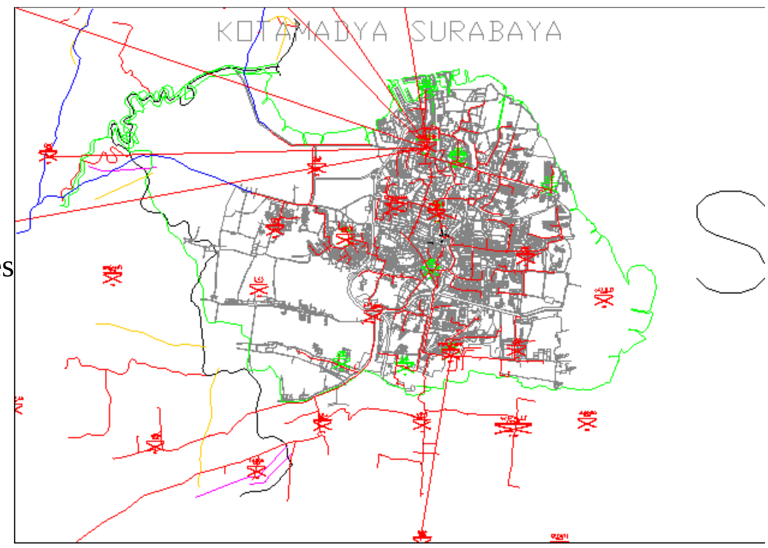


Coverage

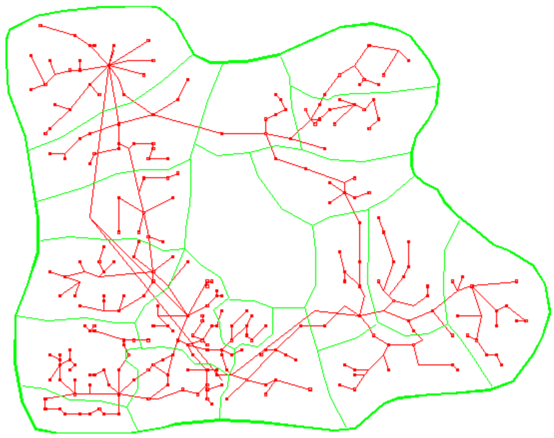
Local Networks

Exchange locations

- Exchange boundaries
- RSU locations & boundaries
- Inter-exchange network
- Exchange hierarchy
- Transmission systems



Rural Networks



- Exchange locations & boundaries
- Exchange hierarchy
- Inter-exchange network
- Transmission systems

National & International Networks

- Traffic routing
- Exchange hierarchy
- Inter-exchange network
- Transmission systems

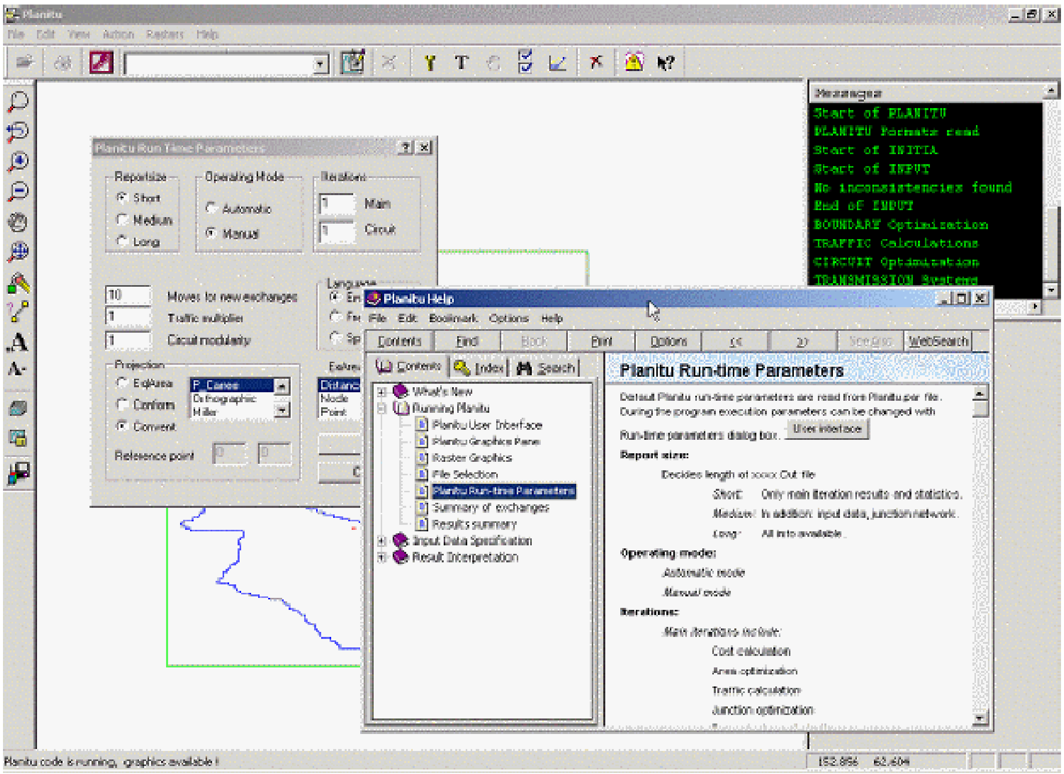
Access network optimization

- Dial-up Internet subscriber planning
- Broadband access planning
- Planning of cabinet areas

Backbone network optimization

- Dual homing (load sharing)
- Design of nonhierarchical circuit-switched networks
- Optimization of the fixed part of mobile (GSM) networks
- Optimization of Ring/ Mesh SDH/ SONET transport networks
- Design of ATM, IP MPLS, WDM networks using equivalent bandwidth paradigm

Fig A1.2.2. : Tool appearance and windows



Application :

- PSTN circuit-switched (TDM) networks
- Data (packet) networks – very limited
- Evolution to NGN – limited
- Training tool for network planning

A1.3. STEM

<u>Objective:</u>

STEM is a business decision making support tool that enables the analysis of business models and cost assignment for Telecommunication Networks and services over a period of time**.** Business planning is based on a service demand model that is categorised by market segment, service type and geo-type; That demand drives the resource dimensioning, replacements, costing and revenue generation as well as the calculation of all financial parameters and ratios.

<u>Platform:</u>

In order to run STEM, you must have a PC running Microsoft Windows 95, Windows 98, Windows 2000 or Windows NT, and at least 13Mb of free disk space. Platform is Object-oriented with an editing interface that associates data directly with icons and links between elements. Interfacing is provided to other MS Windows applications like Excel and Word.

(The Analysys STEM network investment modeling tool is a product of Analysys Consulting Ltd, Cambridge, UK see: www.analysys.com)

Issues addressed by the tool

- What are the main cost drivers of the business?
- Which technology offers the most cost-effective solutions?
- What are the average and long-run incremental costs of this network?
- What is the return on investment?
- What impact will changes in busy-hour traffic have on service profitability?
- How will economies of scale and volume influence financial results?
- How sensitive is the business to changes in demand and technology?
- What are the investment implications of varying speeds of network roll-out?

Applications concerned in business planning

- Network strategy planning
- Cost allocation
- Incremental service costing
- Market and competition analysis
- Systems design and sale Research and development
- Business case planning

- Network technology acquisition
- Tariff planning
- Technology and cost comparisons Service roll-out

Modeling Features

The following are the main features and characteristics for the telecom network solutions:

- Service Demand Projection per customer class
- All network layers and technologies considered
- Network modeling with several degrees of detail according to planning objectives
- Any network type and size
- Evaluation of network resources and associated investment (CAPEX)
- Evaluation of revenues for given tariffs and installation rate
- Modeling multiple resource lifetimes
- Modeling multiple time periods
- Modeling of demand elasticity to tariffs
- Interrelation between network growth and operational cost (OPEX)
- Cost assignment as a function of resource utilization rates
- Audit function to have explicit track of precedence, hierarchies, interrelations and causes for primitive or derived results
- Produces automatically the standard financial results like Cash Flow,
- Profit & Loss, Balance Sheet and up to 100 typical business related parameters
- Allows to add new results in tables or graphical formats as customer needs.

Fig A1.3.1 : Activity flow for the STEM techno-economical economical evaluations

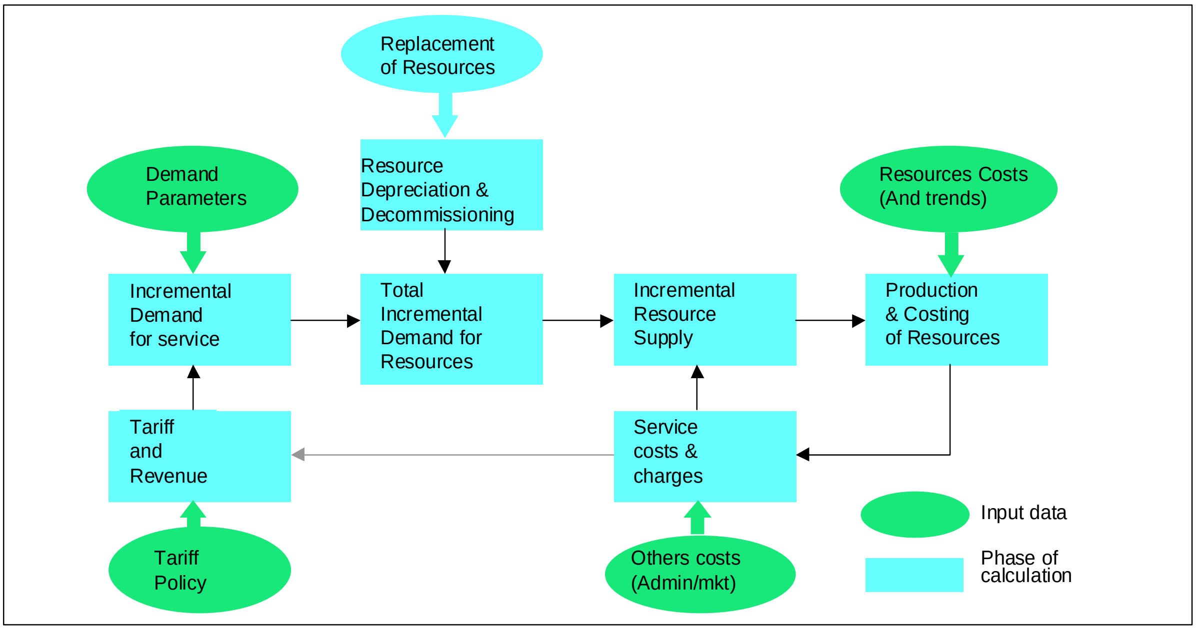
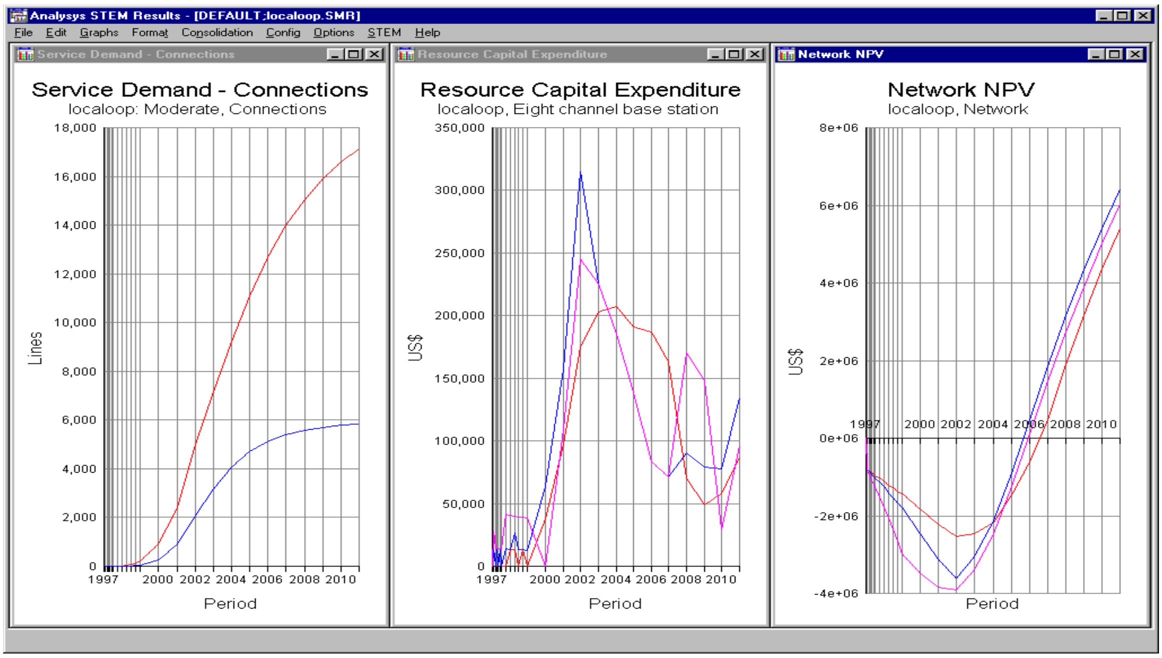


Fig A1.3.2 : Example of tool results

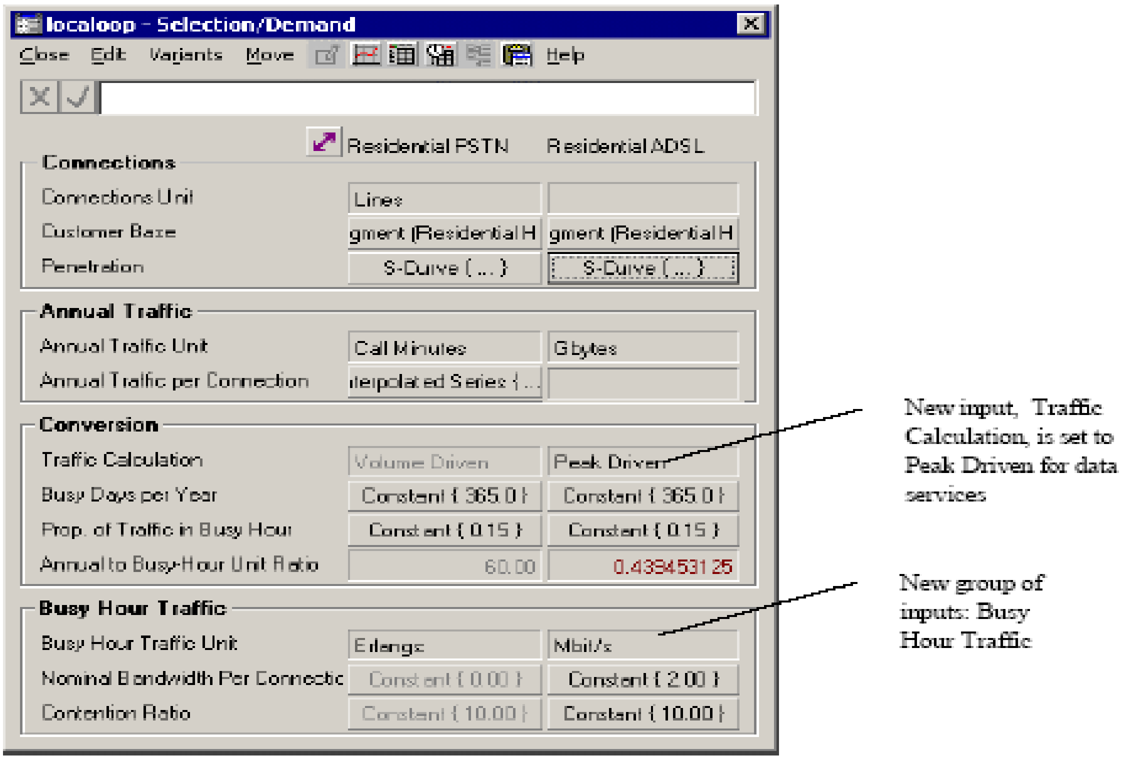


Capabilities of the New version 7.0

STEM version 7.0 was released in September 2004 at the STEM User Group Meeting. This milestone development embraces a new depth of analysis, including intrinsic support for data services, a range of new financial calculations, and the addition of Service results broken down by individual Resources. Clarity is the focus of this release, enhanced by new formatting options in both the Editor and Result programs. Main new capabilities are summarized:

- ***Demand parameters for data services***

STEM 7.0 makes it straightforward to model data services directly. The Service Demand dialog has been extended to allow more intuitive entry of demand parameters for data services. The new 'Peak Driven' calculation option works from new bandwidth and contention inputs and makes annual traffic volume a calculated quantity.



- Multiple contention ratios

In general, there will be a contention ratio at the first point of aggregation, on the immediate access pipe, where traffic may aggregate across, for example, other dwellers of a multi-tenant unit. However, deeper in the core network, there may be a further averaging effect due to multiple nodes coming together, resulting in a higher overall contention ratio. This can be readily modelled through the multiplier of an intermediate Transformation.

- ***New financial modelling options***

-Time-series unit costs and inline trend for Capital Cost

STEM models are typically forward-looking and made up of a combination of known quantities and estimates. So unit costs were originally defined as a spot value for a calibration period, linked to per-Resource and global trends, and multiple cost indices for capital costs. All trends and cost indices were normalised separately for each Resource according to its calibration period. This simple approach allowed for the rapid development of cost models, with efficient re-use of global cost trends. However, this approach did not accommodate other ways of working, such as linking to time-series costs calculated from other sources, or capturing known values and historical costs.

STEM 7.0 provides the flexibility users want. Unit costs are now time-series in their own right, allowing you to enter known or linked time series directly and leave cost trends unset. But you can still enter constant calibration values and use inline or global trends when this approach is easier or quicker.

A new Use Global Trends input also makes it possible to completely decouple cost assumptions for certain Resources, while retaining global trends as an efficient common hypothesis for the remainder.

-Modelling loans and bonds with individual debt facilities

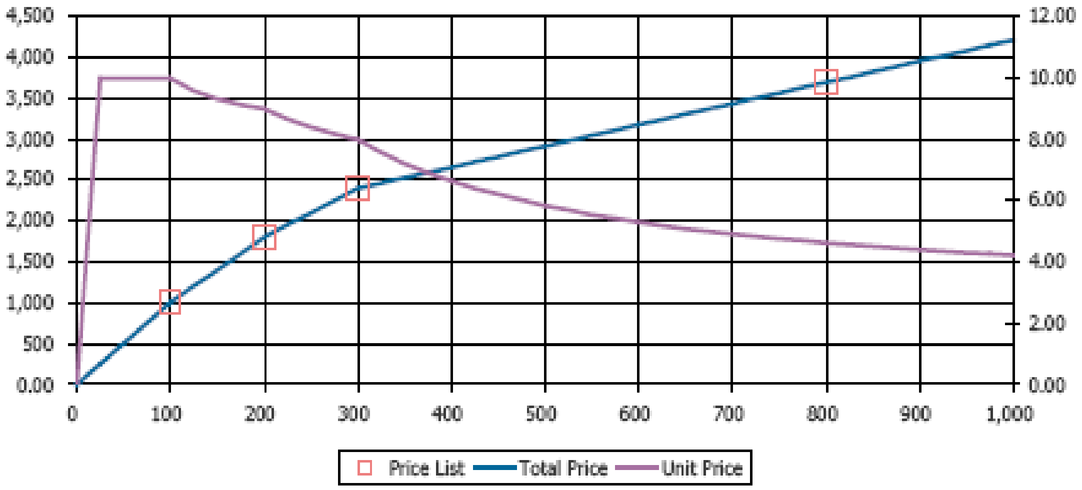
In recognition of the need to model mixes of loans variety, STEM 7.0 allows for the definition of individual debt facilities, with separate terms and schedules, to support the funding requirements for a network.

A typical debt facility has a fixed *term* (defined as a *start date* plus n years) within which funds may be borrowed, up to an optional *credit limit*. Separate *grace periods* are allowed for the principal repayment or amortisation (gp) and the interest payments (gi). New borrowing is only allowed up to gp where gp ε gi. After the principal grace period, amortisation may be paid in one or more equal annual instalments (*straight-line amortisation*), or there may be an *optional repayment profile*.
There is typically a *fixed interest rate* for the term, with payments calculated from the year-beginning balance. Small adjustments are made for the interim amortisation: a.(n – 1) / 2n, where a = annual amortisation, and n = number of payments each year:

-Price lists for Resource capital costs

The smooth logarithmic model for economies of scale from earlier versions of STEM has been replaced with a straightforward and intuitive price-list model which can capture specific supplier price points. (The logarithmic model was fine in theory but inflexible and almost impossible to match to real-life data.) STEM 7.0 has a new per-Resource Price List input which makes it possible to specify a series of cost/cumulative volume breakpoints.

The total cost for intermediate quantities is calculated by linear interpolation, that is, linear from zero to the first breakpoint, and also beyond last breakpoint at same gradient as the last segment:



Linear interpolation of total costs is equivalent to a reciprocal interpolation betwee unit cost breakpoints. Therefore costs defined as unit costs or discount factors are first scaled by breakpoint quantities before interpolating as total costs;

- ***Intelligent formatting options***
-Number format and orders of magnitude

Feedback from users showed that they would prefer to suppress excessive precision in the formatting of numbers, for the sake of clarity and consistency. In line with this, STEM 7.0 has a customisable number formatting system which allows the user to specify:
– an order of magnitude for a graph, such as millions or billions, which will be used automatically to qualify the y-axis scale
– the number of digits and decimals to be shown in a table
– whether values should appears as percentages.
These options can be applied to individual graphs and tables and are also stored with all pre-defined graphs in the Results configuration.
However, the selection of a number format, and especially the choice of orders of magnitude, depends critically on the actual numbers at hand. In other tools it may be necessary to manually format each graph or table to suit the specific data. In contrast, STEM 7.0 includes a system that will *automatically* select an appropriate order-of-magnitude label and the optimal number of decimals, depending on the actual values displayed. This system is controlled by a set of global parameters which you can control with a new Number Format dialog, which is accessed from the Options menu in the Results program.

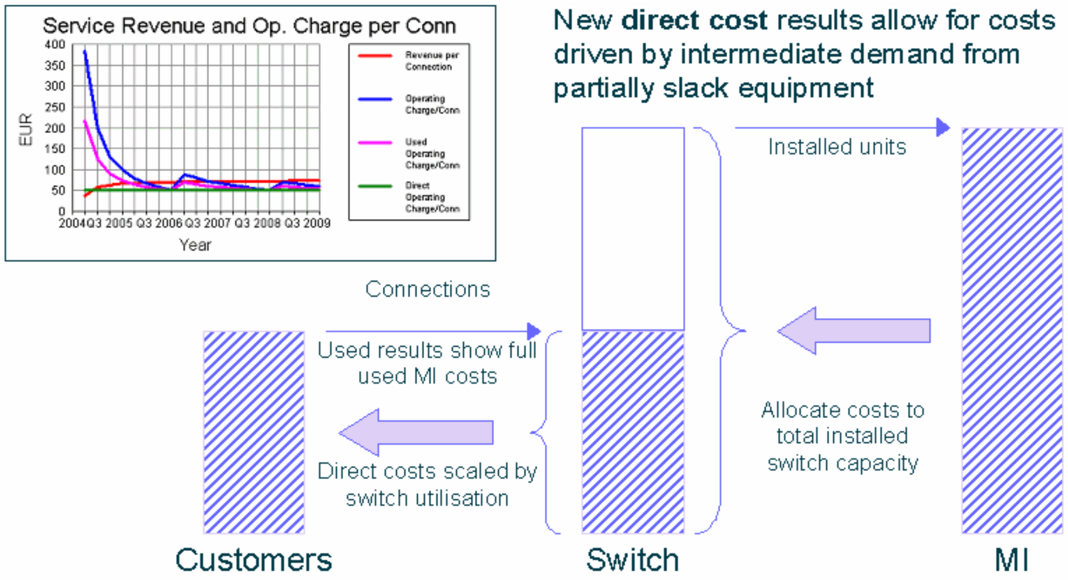
-Routine preview of inputs with Auto Graph
In the Editor, a chosen input can be graphed by clicking on the Graph button in the appropriate dialog. STEM 7.0 extends this feature with the addition of a window which will remain on screen and *automatically* display a graph of whatever input parameter is selected.
The Graph button on a data dialog showing parameters for an individual time series immediately graphs that time series.

-Visual grouping with colour blocks
Another improvement to the user interface in STEM 7.0 is the option to use blocks of colour to group together a set of model elements. This makes it easier to see at a glance which elements belong together, for example the Services grouped within a particular Collection. Colour blocks may be drawn around the members of Collections, Market Segments, Functions, Dimensions and Templates.

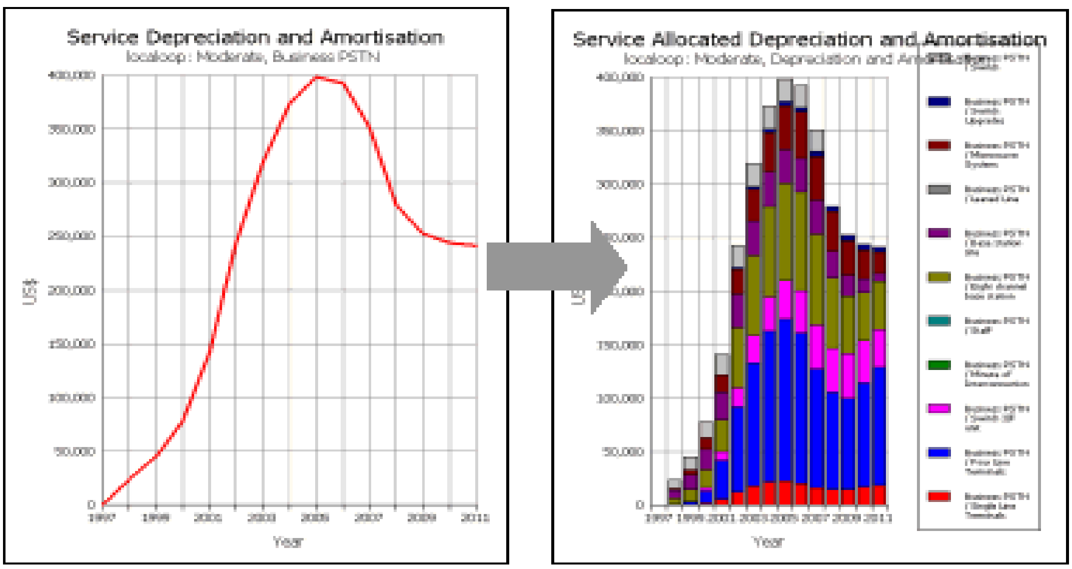
- Advanced service costing
A defining feature of STEM version 7.0 is the generation of allocated Service cost results, broken down by individual originating Resources, based on a scaleable implementation which is designed to avoid a combinatorial impact on performance.

STEM performs detailed cost-allocation through the calculation framework for handling incremental demand which is generated when a model is run. Appropriate shares of Resource costs are routed to the respective Services responsible for used and slack capacity. However, the 6.2 model engine only stored results for the total allocations, mainly because costs were aggregated by intermediate Transformations before being passed back to Services (though originally also to limit the size of results files on disk).

New direct cost results allow for costs driven by intermediate demand from partially slack equipment, and vary more closely in relation to the underlying service demand than used cost results. Direct costs represent the cost of a fully efficient network and are the keenest indicator for tactical pricing.



STEM 7.0 stores separate results for the costs of each separate Resource which are allocated to a given Service. No changes to the inputs are required; a STEM 6.2 model must simply be re-run with the new model engine. In the new Results program, we have added two new types of result, 'Service / Resource' and 'Transformation / Resource', for which all the usual cost results are available, as well as a Used Capacity result which can be used to understand respective Service shares of the installed capacity of a Resource.



A1.4. VPIsystems

Planning and Engineering Solutions from VPIsystems

VPIsystems, Inc. is a recognized expert in engineering decision support software used for modeling and optimizing communications network capacity and improving the efficiency of the network planning and engineering process.

VPIsystems provides network operators with solutions for improving the processes associated with network resource and capacity planning, deployment, and network optimization that result in major savings in CapEx and OpEx. VPI solves problems such as improving capacity utilization,optimizing new builds, streamlining network planning, optimizing tariffed network bids and central-office de-risking.

VPIsystems provides communications equipment vendors with solutions that automatically design and specify optimum equipment configuration in response to customer proposals and quotation requests. VPI software provides a competitive sales advantage, allowing you to preserve margins, eliminate design errors and be more customer responsive.

VPIsystems provides optical subsystem and communications equipment designers powerful simulation tools to optimize product designs. VPI software can enable you to rapidly compare multiple designs and predict performance without time consuming lab prototyping, leading to better and more cost effective designs.

VPIsystems has offices in Berlin, Melbourne, Minsk and U.S.A. Its Berlin office is located at: 6, Carnot Strasse, Berlin 10587, Germany. For more information about VPIsystems and its range of products contact: info@vpisystems.com

Overview of Integrated Network Planning using VPI products

The entire product range offered by VPIsystems is shown in Figure 1 below . The product range is offered as individual modules that are integrated on a platform called the

VPIlifecycleManager^{TM} . Each module addresses a unique planning function in the multi-technology, multilayer, telecommunications network hierarchy.

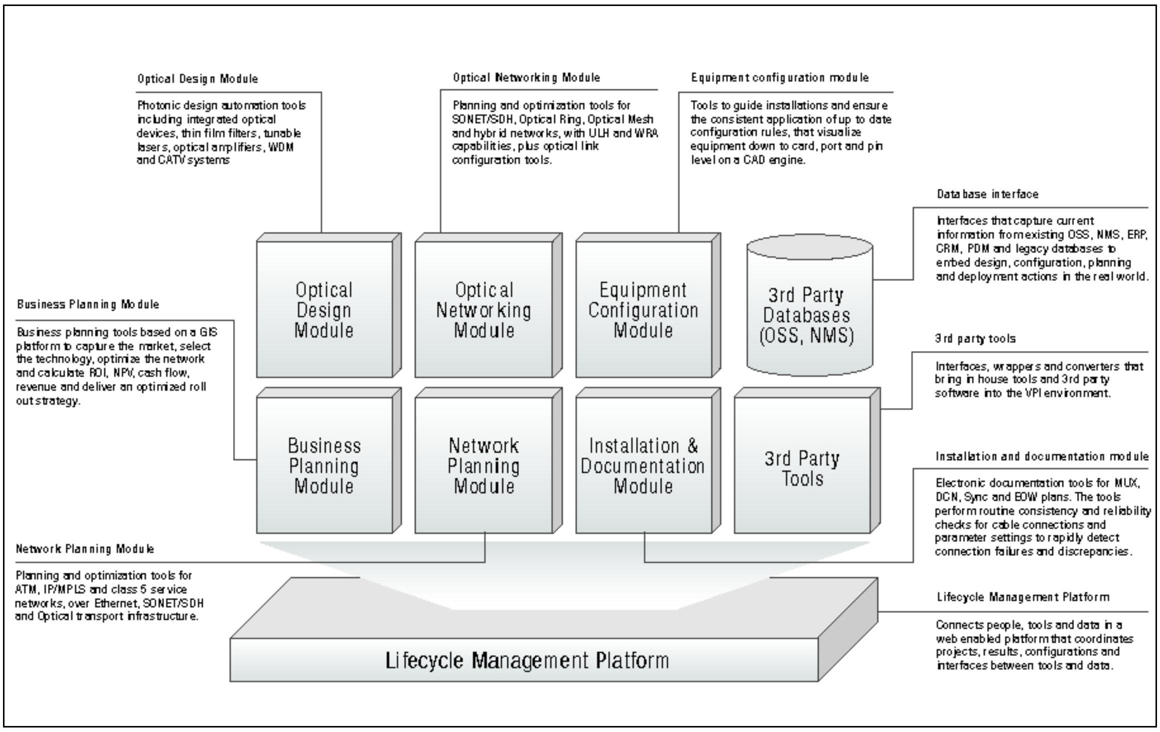


Figure 1 VPIlifecycleManager and supported modules

New Planning Environment

Several factors have combined to create a unique opportunity and need for integrated network planning today. Salient among these are:

1. market competition due to deregulation
2. the transition from voice to data-centric networks
3. the introduction of new technologies like IP/MPLS, ROADM, and MSPP.

Effective network planning and design is essential if the best use is to be made of new technologies while at the same time taking into account traffic distribution patterns, changing economic conditions, and new network concepts. The primary objective is to reduce investment and operational costs while improving service quality and flexibility.

Increased competition, the emergence of low cost service alternatives such as packet-voice, and the advent of high-volume/low-revenue services, such as Internet access, have significantly eroded the profit margins traditionally enjoyed by network and service providers. Consequently, a high degree of efficiency in all aspects of service and transport network operation—from service provisioning to infrastructure planning—is a must for network and service providers to stay competitive. It is becoming increasingly clear that an *integrated* network planning environment—one that provides a common platform to support all aspects of service and transport network planning—is the answer to the problem of improving the efficiency of the planning process. Providing access to a suite of expert design tools that optimize individual service and transport networks, while at the same time affording simplified access to network data via seamless integration with Network Management

Systems (NMSs), is the most effective way of enhancing a network provider's ability to compete.

Current Network Planning Process

Most network planning activity today is a widely varying mix of individual decisions based on guesswork or intuition, ad hoc back-of-the-envelope calculations, and occasional use of sophisticated stand-alone tools focusing on specific parts of the overall network planning problem. There is a clear lack of an integrated, systematic, quantitative approach that allows the planning process to be modeled in its entirety. Groups responsible for the design of specific service networks—such as circuit-switched voice, IP or ATM—design their networks as best as they can and rely on transport network planning groups to provide them with the bandwidth needed as cost-effectively and reliably as they can.

The transport network planning groups, in turn, attempt to optimize the transport network based on traffic forecasts received from the various service network planning groups. Typically, these groups make decisions on the network technologies and architectures to be deployed based on a combination of needs, such as getting the lowest cost per unit bandwidth, meeting the SLA requirements imposed by specific services, the type of restoration needed, the ease of operation, and so on.

This two-step process, involving individual service network planning and transport network planning, is further complicated by the lack of coordination among different organizations and areas of expertise, and by the existence of a plethora of NMSs each containing a subset of the network data. There are often multiple, inconsistent copies of a certain set of data and to achieve data consistency is in itself a problem of considerable magnitude for most network providers. As a consequence, the combined planning process often tends to be fragmented, inefficient, and inordinately long.

The Solution to Network Planning

By providing a complete suite of planning tools together with integrated NMS access and database support on a common platform, the VPIlifecycleManager™ radically transforms the network planning process, rendering it simple, transparent, fast, and cost-efficient. It does this by enabling an integrated network planning approach that eliminates guesswork, cross-organizational miscommunications, and manual processes that are costly, inefficient, and time consuming. The collaborative planning environment offered by VPIlifecycleManager™ supports teamwork across different organizations and functional areas, and promotes the seamless gathering of network data from different NMSs. This allows multi-organizational teams to effectively share their expertise and needs, and to collaboratively evaluate alternative service and transport network architectures to arrive at a solution that achieves the cost-performance compromise in a manner best suited to the overall company goals.

VPIlifecycleManager supports the following set of tools:

VPIserviceMaker™ATM

VPIserviceMaker™IP

VPIserviceMaker™Switch

VPIserviceMaker™SS7
VPIaccessmaker™
VPIserviceMaker™Distribution
VPItransportMaker™
VPItransportMaker™Sync
VPIlinkConfigurator™

These tools are brought together for collaborative employment by platform software known as VPIlifecycleManager™. Figure 2 below shows the interrelations between these tools.

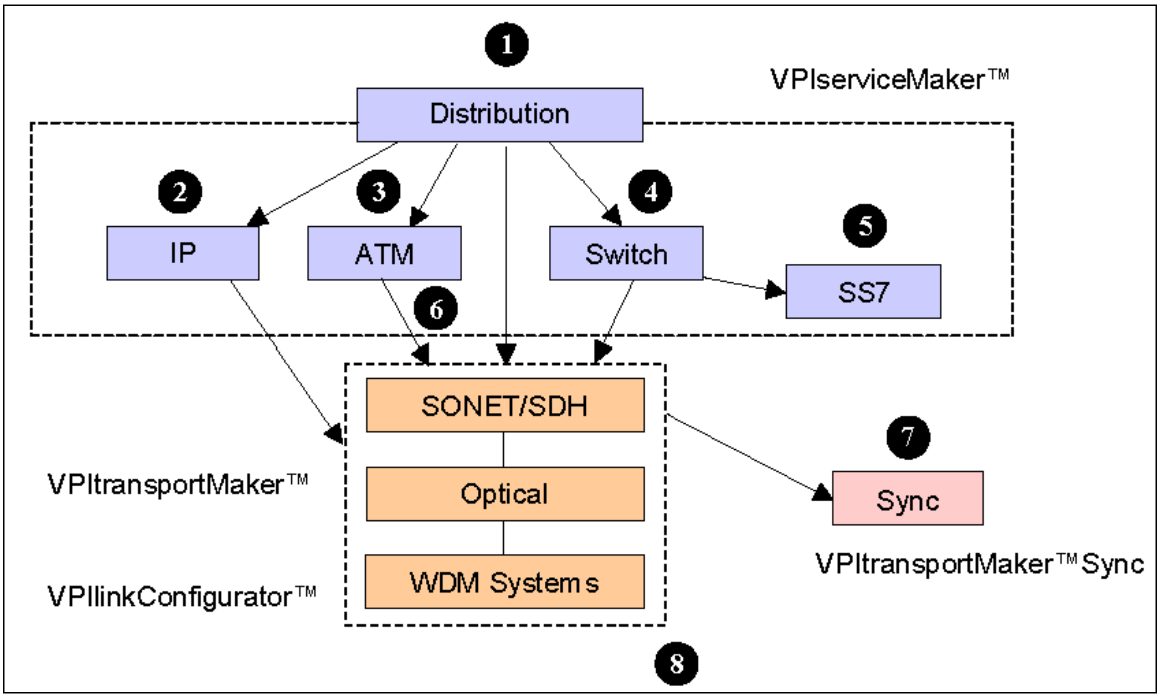


Figure 2 Interrelations between VPI Tools

VPIaccessMakerTM is a tool used for modeling business plans and feasibility studies for the deployment of access technologies. The tool captures subscriber information, models different service combinations and technologies and selects the best technology for the task, to calculate ROI, NPV, cash flow, revenue and an optimized roll out strategy. VPIaccessMaker uses a Geographical Information System (GIS) system, based on Map Objects ESRI® and MapX - MapInfo® to provide direct visualization of maps, network equipment and data**.**

VPIserviceMaker™Distribution is used to generate point-to-point traffic matrices based on various demographic and geographic assumptions. In addition, this tool can be used to estimate unknown traffic for the next planning period based on certain traffic growth assumptions. This tool offers an excellent means of generating an initial traffic matrix from uncertain data and offers various controls to perform what-if analyses.

VPIserviceMaker™IP is used for planning IP networks. It can perform IP network capacity design for various service classes supported on the Internet, such as best effort services (web browsing, HTTP, FTP, e-mail, etc.) and VoIP (Voice over IP). VPIserviceMaker™IP further supports OSPF (Open Shortest Path First) topology, effective bandwidth calculations for bursty traffic, network bottleneck identification, failure simulation, and modeling of link interface costs.

VPIserviceMaker™ATM is used for ATM network planning. The key functions provided include equivalent bandwidth calculation for bursty data, topology design based on traffic, link and equipment costs, Virtual Path (VP) classification based on traffic, VP dimensioning to determine the capacity to be assigned to a given VP, Virtual Path Connection routing and bundling, shared capacity restoration computation, network bottleneck identification and overload correction, equipment list and network cost generation, and call level simulation to verify that performance objectives are met.

VPIserviceMaker™Switch is a tool for planning and dimensioning circuit switched networks. It supports optimized trunk group dimensioning based on topology, traffic volume, and alternative routing strategies. It can also be used to determine a cost-optimized routing scheme based on a specified cost factor for each trunk group. The tool can also evaluate the traffic carried, and trunk group blocking, in existing networks.

VPIserviceMaker™SS7 is used to design common channel Signaling System No. 7 networks. It can optimize the signaling network topology, dimension signaling link sets, and route signaling traffic. VPIserviceMaker™SS7 can also analyze an existing SS7 network for routing and reliability problems, undertake failure analysis, and perform bottleneck analysis.

VPItransportMaker™ supports transport network design based on PDH, SONET/SONET, and optical networking technologies. It covers a wide range of network architectures, including ring, mesh, and ring–mesh hybrids. Using VPItransportMaker™, a planning engineer can optimize the network topology and determine the appropriate routing, protection, restoration, and equipment. VPItransportMaker™ allows you to define a variety of technology, architecture, and network constraints that must be explicitly honored during the design. The tool also supports an analysis module for checking design results and for performing what-if analyses. VPItransportMaker™ can be used for planning metro and long-haul networks.

VPItransportMaker™Sync is used for planning synchronization networks, including the optimization of clock distribution in DS1/E1 synchronous communication networks. The purpose of a synchronization network is to ensure that all DS1/E1 elements in a network have a timing source that is accurate to within acceptable tolerances. VPItransportMaker™Sync enables synchronization planning by generating a master clock distribution plan, creating alternative back-up timing supply routes, and providing an analysis and evaluation capability that checks for timing loops and for breaks in the timing supply paths under various failure scenarios.

VPIlinkConfigurator™ is used to design links in optical networks. It supports the synthesis of multiple design alternatives given a set of network planning requirements. VPIlinkConfigurator™ enables you to compare and rank link design alternatives. You can easily modify the synthesized link design, create new designs, and perform what-if analyses. You can also undertake sophisticated analyses of a link's optical performance and cost, taking into account the WDM system technology used, the fiber type, and the type of optical amplifiers.

Integrated Design Flows Supported in VPIlifecycleManager™

Depending on the network provider's environment and network planning needs, various design flows can be instigated using the VPIlifecycleManager™. The most common design scenario involves the following steps:

1. Generation of traffic matrices using VPIserviceMaker™Distribution. One or more traffic matrices may be generated for each service layer network to be designed. For example, you can generate a VoIP matrix for the Voice over IP application, an ATM CBR (Continuous Bit Rate) matrix for ATM network design, a point-to-point Erlang traffic load matrix for circuit-switched voice network design, and a point-to-point bandwidth matrix for designing a transport network at any desired layer (PDH, Ethernet, SONET/SONET, or Optical). Alternatively, you could begin your design process with VPIaccessMaker to model customers and service characteristics and derive the service demand for each access serving area. This can then drive VPIserviceMaker™Distribution to generate the traffic matrices for each service type.

2. The traffic matrix generated is used in conjunction with the appropriate VPIserviceMaker™ tool to produce an optimized service layer design, approximate equipment interface, and link/trunk costs. The link/trunk dimensioning provides a point-to-point bandwidth demand requirement that is then fed into VPItransportMaker™ to be incorporated into the design of the transport network.

3. Each point-to-point bandwidth demand matrix resulting from step 2, along with those generated in step 1, together with associated requirements for routing, protection, topology, restoration, available equipment types, and so on is fed to VPItransportMaker™. Here, every possible combination of transport network technology and architecture can be analyzed to determine the most cost-effective solution that meets the various SLA requirements.

While steps 1–3 above constitute the most straightforward workflow for undertaking network design, a number of iterative design loops may be executed to improve a specific design or to try out different combinations of service and transport network technologies and architectures. Thus, we may go back to step 2 after step 3 and revise the assumed link/trunk costs based on the total network cost determined during step 3. This leads to a revised set of service network designs, which in turn leads to a modified transport network design whose total network cost is now different. You can repeat this process by revising your service network designs using the newly derived average link/trunk costs. Perfect convergence, wherein the average service layer link/trunk cost in step 2 is in perfect agreement with the newly derived link/trunk cost after step 3, is rarely achieved. The iterative process is usually halted when the designer is satisfied that agreement within acceptable limits has been achieved.

The above process of collaboratively determining the needs of different service networks and the transport network needed to carry the services enforces a planning discipline that will lead to a vastly improved planning process. The network provider realizes immediate benefits in terms of fewer technical staff, more cost-effective designs, and shorter planning times.
Many other design refinements are possible even with the relatively simple three-step process described above. After step 3, you could go back to step 1, modify the assumptions behind traffic matrix generation, and then investigate the resulting impact on total network cost after step 3. Alternatively, you could revisit step 1 after step 2, change the traffic generation assumptions, and see how this affects service layer designs.

More sophisticated analyses could take into account the effect of new equipment that achieves layer integration. Thus, after step 3 you could examine equipment architectures that integrate service and transport layer functionality. This would allow you to derive, in addition to average service layer link/trunk costs, new service layer interface costs, and then to repeat steps 2 and 3. For example, an IP/WDM designer might first assume stand-alone IP router port costs at step 2 and, after doing a WDM mesh design at step 3, consider equipment that combines the functionality of an IP router, DWDM (Dense Wave Division Multiplexing), and OXCs (optical cross connects). The average router port costs derived from this new equipment type might be sufficiently different to warrant revisiting step 2. This may lead to a significantly improved IP layer design, a correspondingly improved WDM network design, and much lower overall network costs. It is evident, even in this simple illustration, that the collaborative planning methodology coupled with the use of powerful planning tools can lead to very significant cost savings.
Several other design flows are feasible, and would make sense in many practical situations. For example, you could first design a circuit-switched voice network using VPIserviceMaker™Switch and then design the associated signaling network using VPIserviceMaker™SS7. Another common scenario involves designing a PDH or SONET/SONET transport network and then undertaking synchronization planning using VPItransportMaker™Sync. Using the VPIlinkConfigurator™ tool, a network provider could then obtain a complete characterization of the network's embedded fiber database and use it, in conjunction with various vendor implementations of WDM systems, to determine the best optical network that may be supported by its installed fiber base.
As one example of such a planning process, consider an optical sub-network consisting of old fiber carrying only OC-48 signals, a second sub-network carrying a mix of OC-48 and OC-192 signals, and a third consisting of a transparent optical island comprising the latest wavelength banded Ultra-long Haul WDM systems with OADMS (Optical Add/Drop Multiplexers) that provide band add/drops and support multiple WDM system branches.

Demonstration of Integrated Network Planning

This section illustrates how you can conduct integrated network planning across multiple layers and technologies using VPIlifecyclemanager™. The example selected represents a typical network planning problem from a nationwide network provider's perspective, namely the USA backbone network shown in Figure 3 below . This is used as the underlying physical network where nodes represent traffic generation/switching points and links represent fibers connecting the nodes. To show how VPIlifecycleManager™ can model the multi-layer multi-technology complexity of today's telecommunication networks, we will design multiple service networks and one transport network. The service networks are an IP network, an ATM network, a switched voice (PSTN) network and an SS7 signaling network. All are supported over a common transport infrastructure, being a SONET ring network carried over a DWDM transport infrastructure.

Before starting any network design, you need to determine the traffic that the designed network will have to serve. Traffic information is the fundamental driving force behind any network design. Normally traffic, if not available, can be forecast from historical data, or estimated by market projection and subscriber population. Here we assume both cases; that is, some traffic is known, and some traffic is unknown and has to be estimated.

The unknown traffic is estimated using VPIserviceMaker™Distribution, which provides many models for estimating traffic. The data flows across a number of tools in this example, as illustrated in Figure 2 . The service layer networks (IP, ATM, Switch) are designed first, one by one. Then all the point-to-point bandwidth pipes required by service layer networks are mapped to SONET/SONET layers to design a common transport network. Finally SONET/SONET pipes are bundled into point-to-point DWDM transmission links.

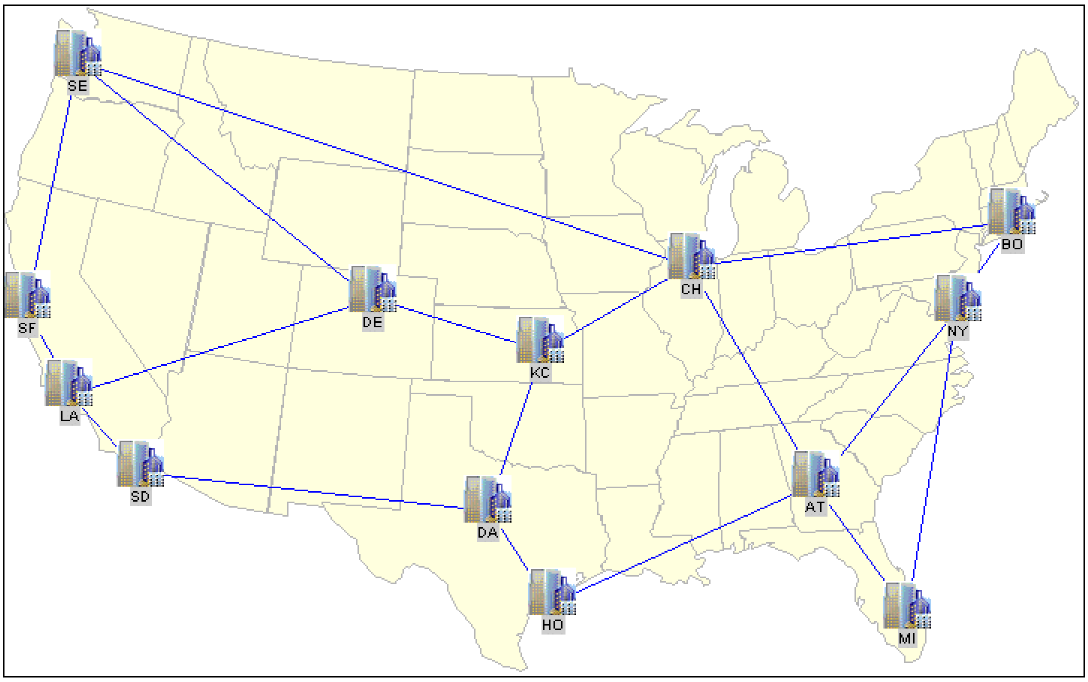


Figure 3 USA national backbone network

VPIserviceMaker™Distribution

In this section we show how to use VPIserviceMaker™Distribution to generate a matrix of point-to-point voice traffic (Erlangs) for the switched network design. We will assume that 10% of this voice traffic is VoIP traffic This will be the input data fed into the IP network design. In addition, we generate a traffic matrix of point-to-point constant bit rate services which will be fed into our ATM network design. Furthermore, we also want to create a traffic matrix of point-to-point circuits representing leased line services to feed into the transport network design.

We start by importing the network node data from the US national backbone network (see Figure 4). Each node represents a major city.

Note that all VPIlifecycleManager™ tools have the same underlying network model. Hence, network topology can be shared across different tools, either by explicitly using the import/export functionality in each tool, or by simply opening another tool's project file directly.

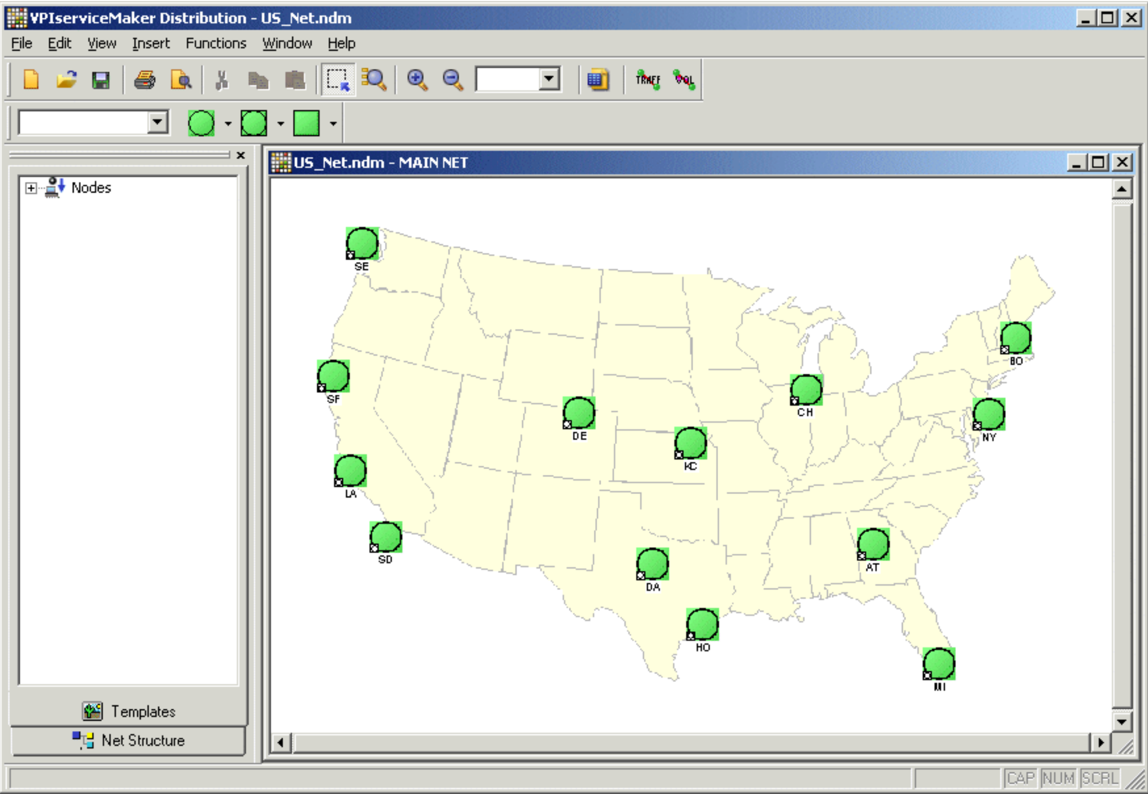
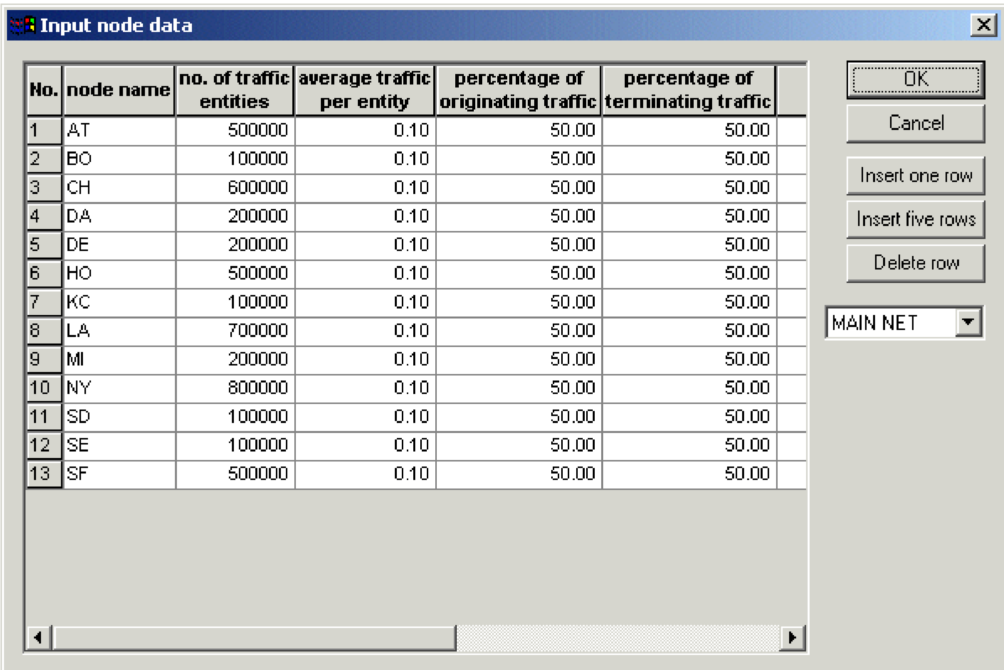


Figure 4 The set of nodes for traffic distribution

Next we specify the subscriber population of each city (in proportion to the city's population) and the average traffic per subscriber, as shown in Figure 5.



No.	node name	no. of traffic entities	average traffic per entity	percentage of originating traffic	percentage of terminating traffic
1	AT	500000	0.10	50.00	50.00
2	BO	100000	0.10	50.00	50.00
3	CH	600000	0.10	50.00	50.00
4	DA	200000	0.10	50.00	50.00
5	DE	200000	0.10	50.00	50.00
6	HO	500000	0.10	50.00	50.00
7	KC	100000	0.10	50.00	50.00
8	LA	700000	0.10	50.00	50.00
9	MI	200000	0.10	50.00	50.00
10	NY	800000	0.10	50.00	50.00
11	SD	100000	0.10	50.00	50.00
12	SE	100000	0.10	50.00	50.00
13	SF	500000	0.10	50.00	50.00

Figure 5 User population and profile

VPIserviceMaker™Distribution will then create a matrix of point-to-point Erlang loads, as shown in Figure 6. This voice matrix is then exported to a text file that can be used later in the switched voice network design.

We will come back to VPIserviceMaker™Distribution again when we need to create a traffic estimate for ATM and SONET network designs. IP design assumes 10% of the voice matrix as its VoIP traffic by specifying one tenth of subscriber population.

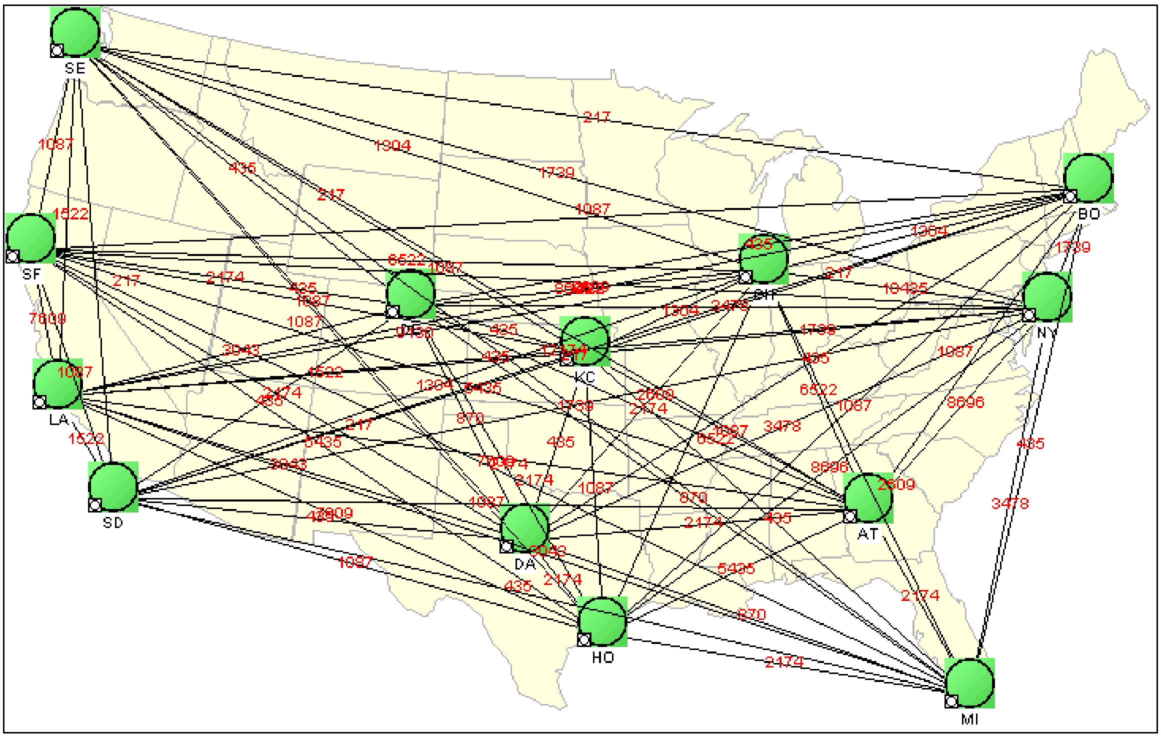


Figure 6 Pomit-Point Voice traffic

VPIserviceMaker™Switch

Now we design a switched voice network (PSTN) using the voice traffic generated by VPIserviceMaker™Distribution. Again we begin by importing network node and topology data into VPIserviceMaker™Switch. The result is shown in Figure 7 . We use the physical network topology as the initial topology. This can be changed after running the topology improvement function of VPIserviceMaker™Switch.

The next step is to import the voice matrix. To do this, we must first create an empty traffic matrix. We then open the matrix window and import the voice matrix data from VPIserviceMaker™Distribution. After running design optimization, we get the trunking design of the switched network shown in Figure 8, where the number by each link indicates the size of the link in DS0 units. A file of this data will be used later by VPItransportMaker™ as one of its input traffic matrices.

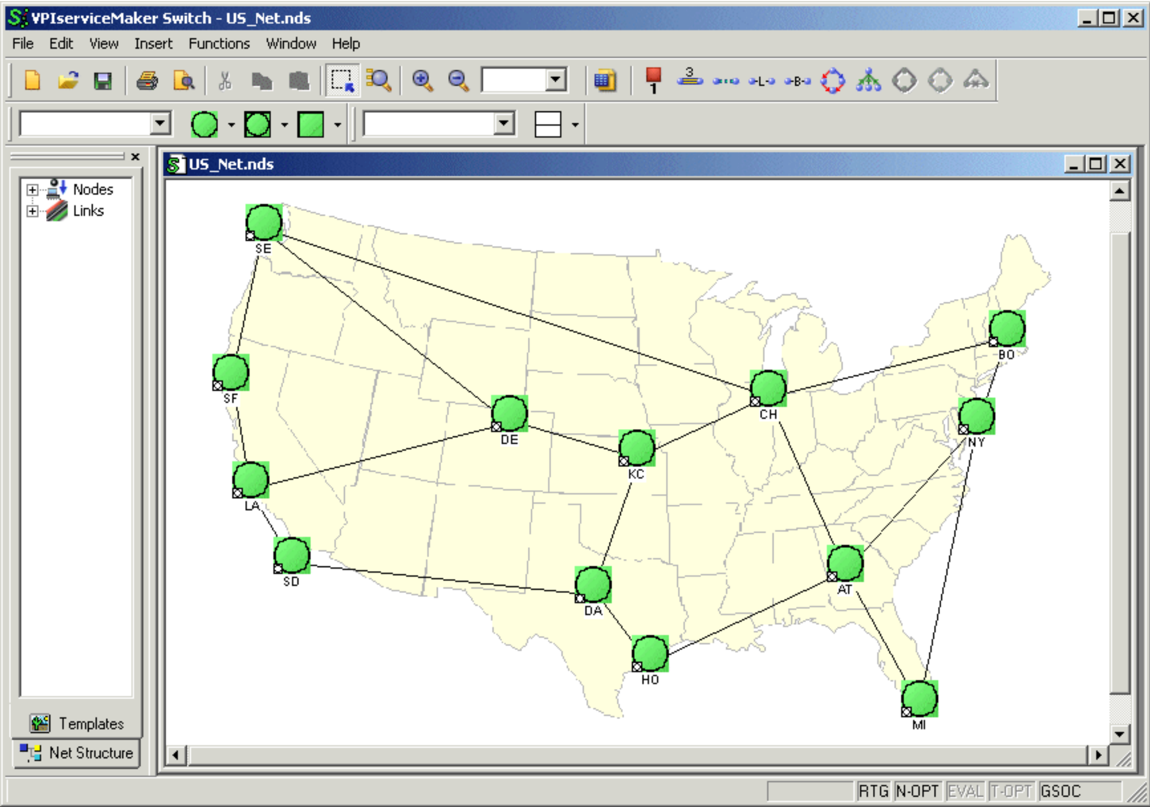


Figure 7 Switched voice network initial topology

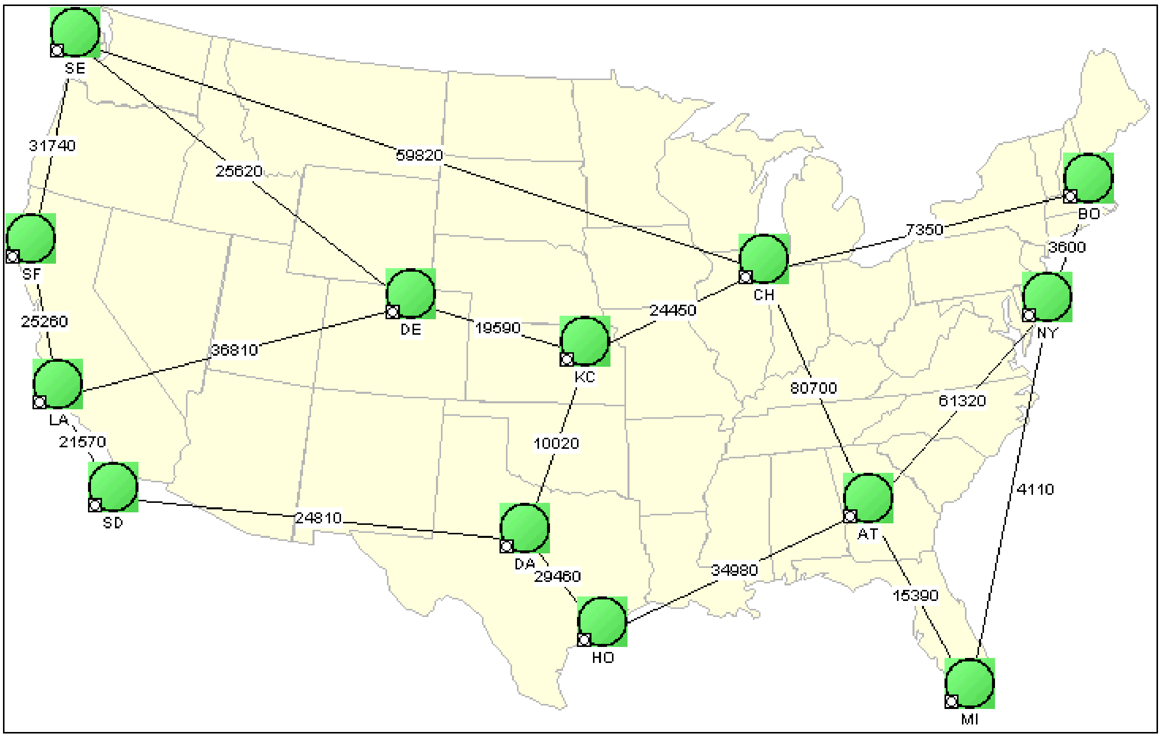


Figure 8 Trunk size of switched network

A SS7 signaling network can be designed in association with the switched voice network design. But since the bandwidth requirements produced by the SS7 signaling network are negligible for the SONET transport network design, the SS7 design is not included here.

VPIserviceMaker™IP

Next we design the IP network. Again we start by importing the basic network data into VPIserviceMaker™IP. But since the IP tool models traffic at the individual service level, we need to create user populations (each one represented on screen by a pair of computers) and servers (represented on screen by a single computer). These are new nodes added to the network. The original nodes are considered as core switching centers (and represented on screen by core routers). We also purposely add more connectivity. (Unused links—that is, links with no load—will be automatically deleted at the end of the design process.) Figure 9 shows the IP network setup.

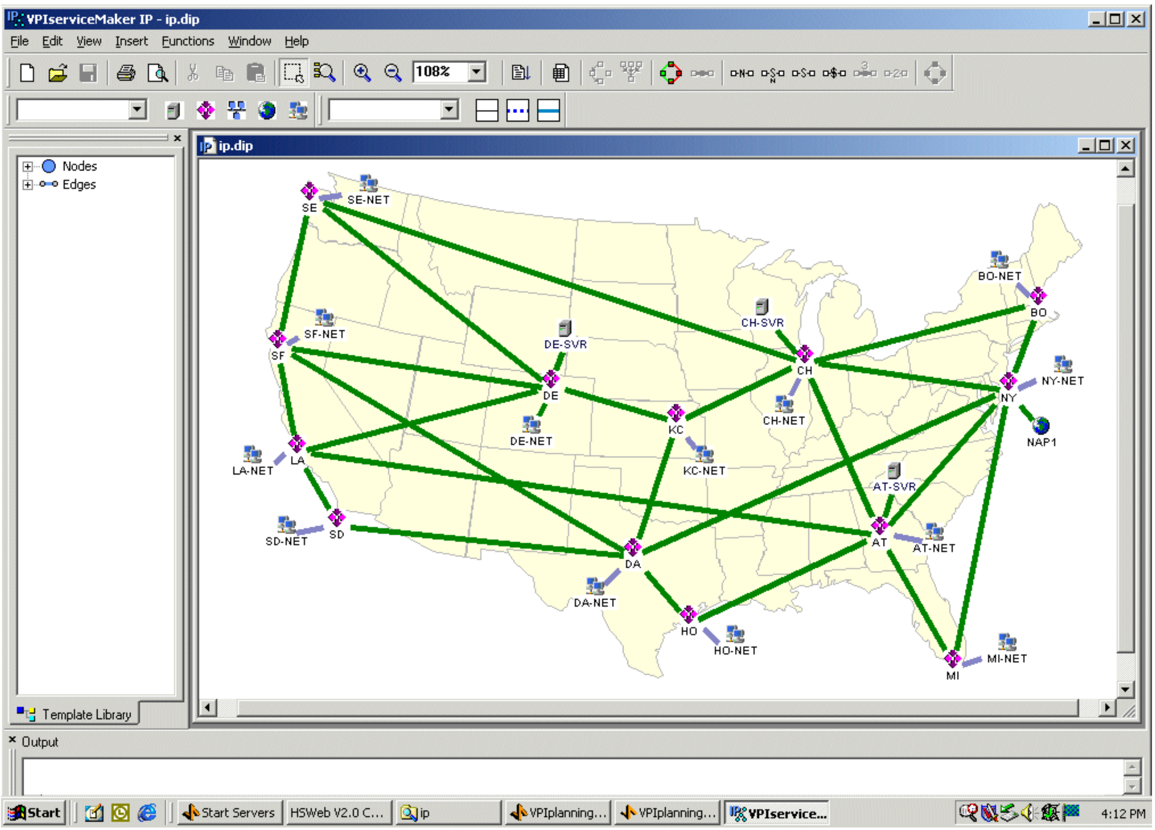


Figure 9 IP network topology

We now specify a traffic profile for each user population, each server, and each type of service. The only exception is VoIP traffic, whose traffic profile will be imported from VPIserviceMaker™Distribution.

The import procedure is similar to that of VPIserviceMaker™Switch; that is, we create an empty traffic matrix and use the import function. We then run analysis, routing, and effective bandwidth calculation. The resulting IP network dimensioning is shown in Figure 10.

Finally we export the IP network to VPItransportMaker™. A new VPItransportMaker™ project is created with IP network links being treated as a matrix of point-to-point bandwidth demands for the transport network design.

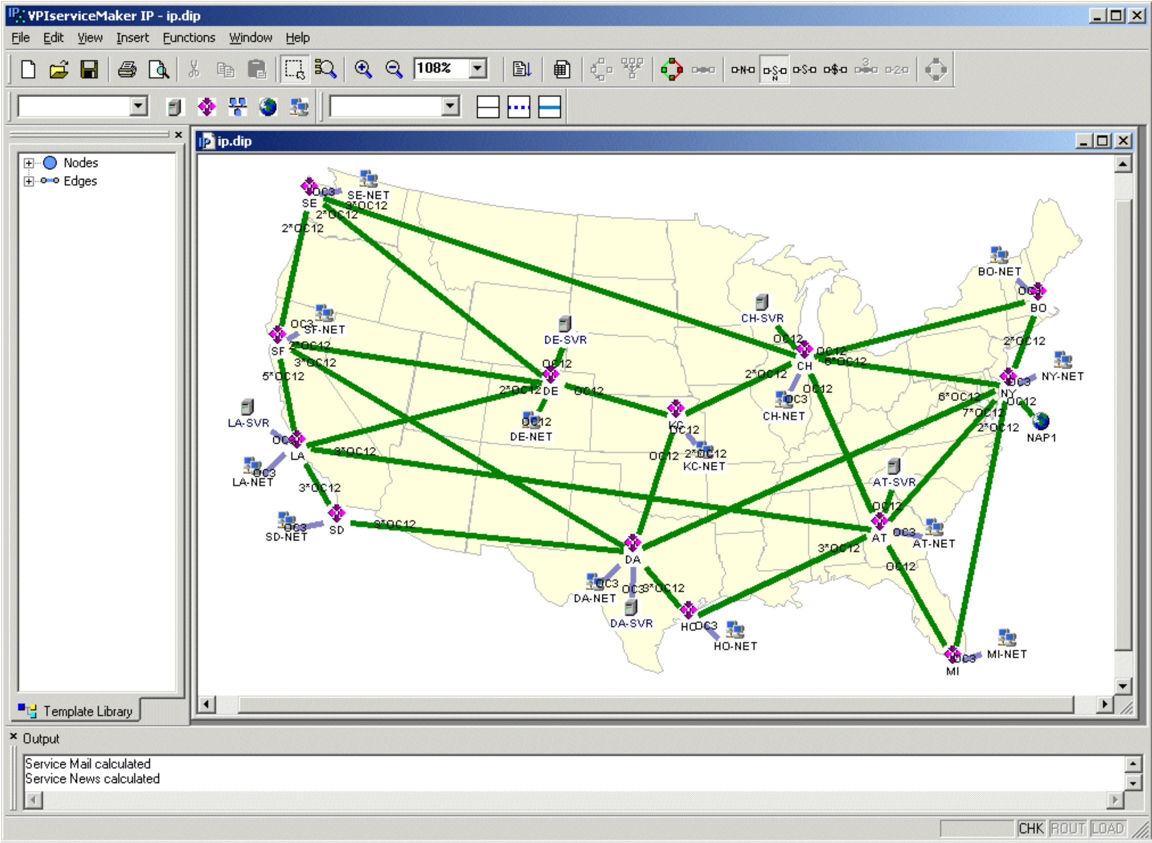


Figure 10 IP network dimensioning

VPIserviceMaker™ATM

Now we design the ATM network. We import the same network topology as before (see Figure 11). Our task is to model three known classes of services: Permanent Virtual Circuit (PVC) service, Metropolitan Area Network (MAN) data service, and Switched Voice service. The traffic matrix for each class is known. The fourth class of traffic is a constant bit rate service. Its traffic matrix is unknown, but it will be generated by VPIserviceMaker™Distribution.

Unlike voice traffic generation (where we need to specify user populations and average usages), for constant bit rate data traffic we only need to specify the total amount of terminating traffic at each node. We then choose, using VPIserviceMaker™Distribution, the single matrix method and the gravity model to produce a traffic distribution matrix. The traffic generated is then exported for use as the fourth traffic matrix in our ATM design.

After combining all traffic inputs, the aggregated traffic pattern for the ATM network design is as shown in Figure 12 .

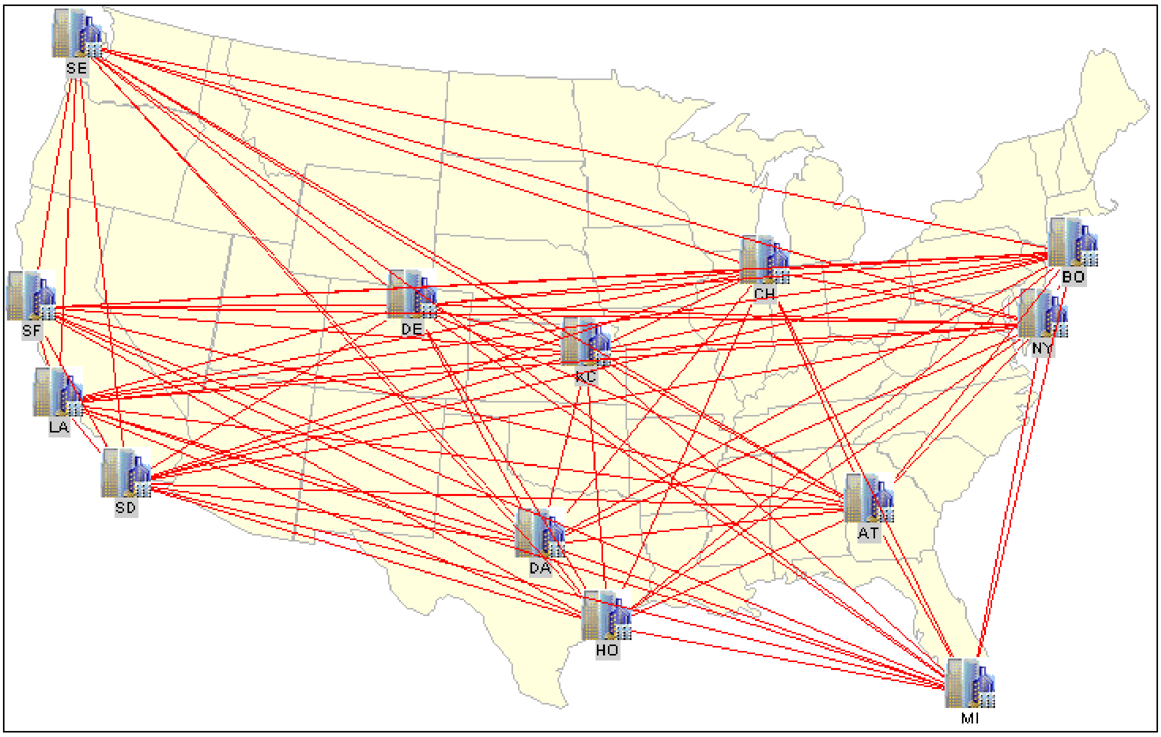


Figure 11 ATM traffic pattern

After a load optimized design, we arrive at a network with link capacities as shown in Figure 12.

Again we export the data to VPItransportMaker™ to create a VPItransportMaker™ project where the ATM network link sizes are grouped as one of the traffic matrices for transport network design.

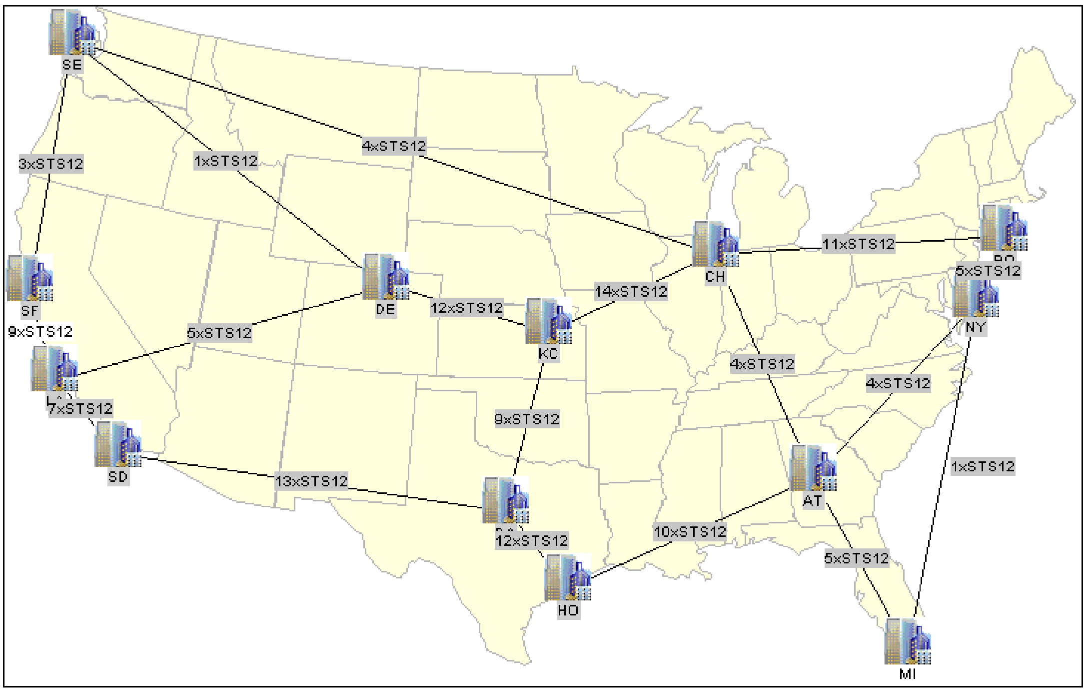


Figure 12 ATM network dimensioning

VPItransportMaker™

Now we are ready to design the transport network based on SONET over DWDM. We would like to provide protection at the SONET layer, and choose to design a SONET ring network.

We start with the VPItransportMaker™ project created by the VPIserviceMaker™ATM export. The fiber network topology is shown in Figure 13 . The ATM network bandwidth requirement is included as the first traffic matrix (with the name ATM_STM4).

The reason we do not start our transport design with the VPItransportMaker™ project created by IP export is that we added some new nodes—representing user groups and servers—to the IP network which we do not want to consider in our transport network design. But we can import the IP network links as traffic for VPItransportMaker™.

The nodes added during IP design are not recognized as VPItransportMaker™ network nodes and the traffic between them is automatically ignored. This is precisely what we want. Nonetheless, the IP network bandwidth requirement is represented as the second traffic matrix (called IP_STM4) imported into VPItransportMaker™ .

We also need to import the results of the switched voice network into VPItransportMaker™. To do so we import the VPIserviceMaker™ matrix. A new traffic matrix (called SWITCH) is now created with a DS0 bit rate.

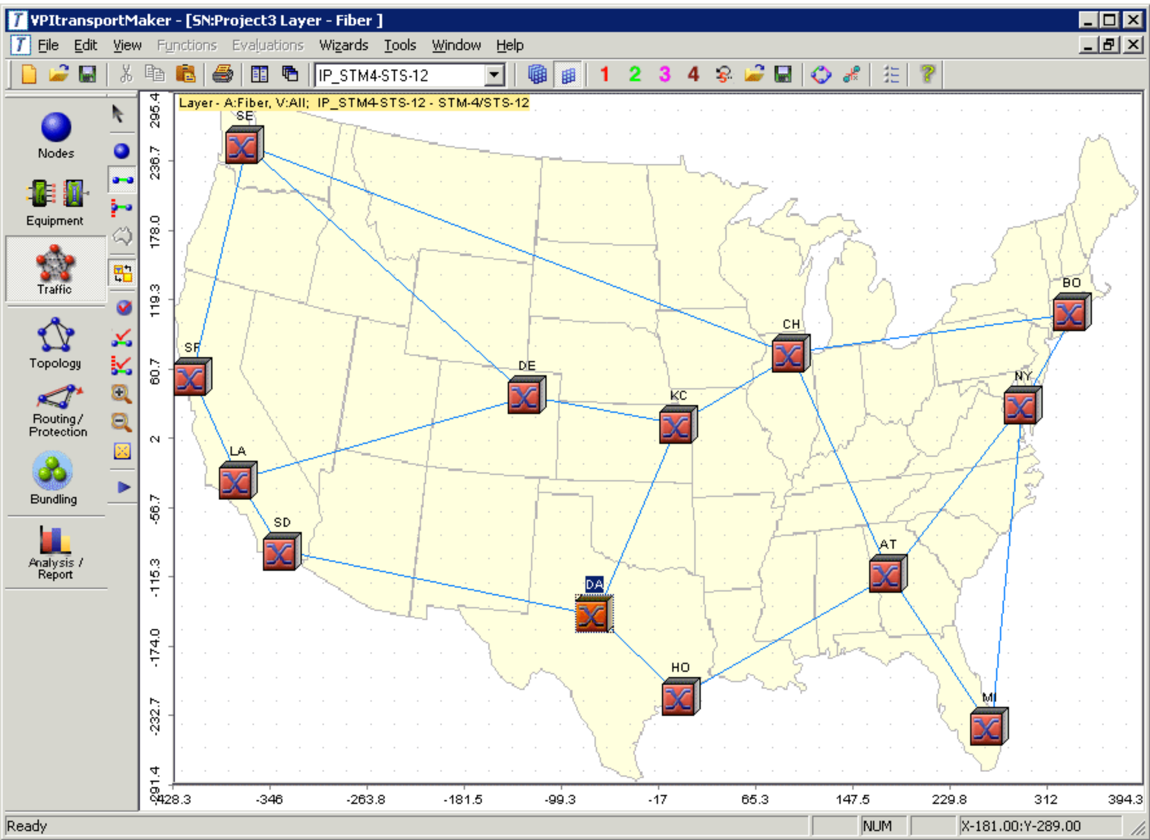


Figure 13 Physical network topology

We also need a fourth traffic matrix as an estimate of unknown leased line services. So we go back to VPIserviceMaker™Distribution and create a matrix of point-to-point OC-3 (STM-1) demands for the SONET network. For this purpose we only need to specify the total amount of terminating traffic at each node (in units of OC-3). A new traffic matrix named DISTRIBUTION with bit rate OC3 (STM1) is created.

We have now imported four traffic matrices: ATM, IP, SWITCH, and DISTRIBUTION. They are illustrated in Figures 14-17.

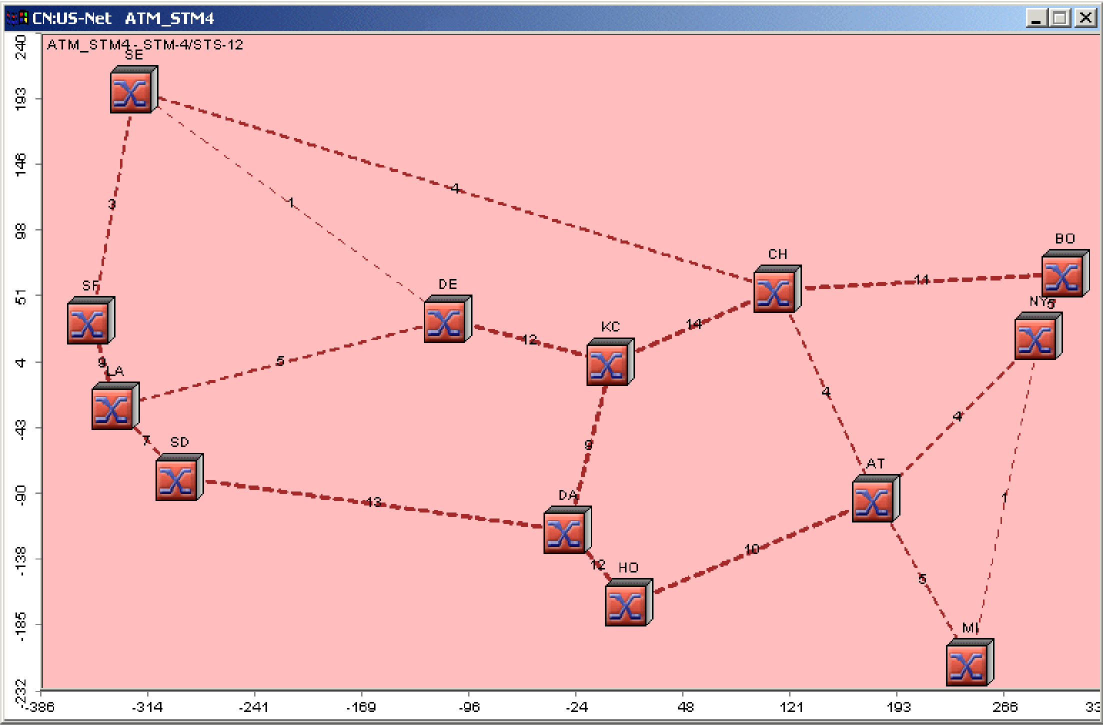


Figure 14 ATM bandwidth (STM4)

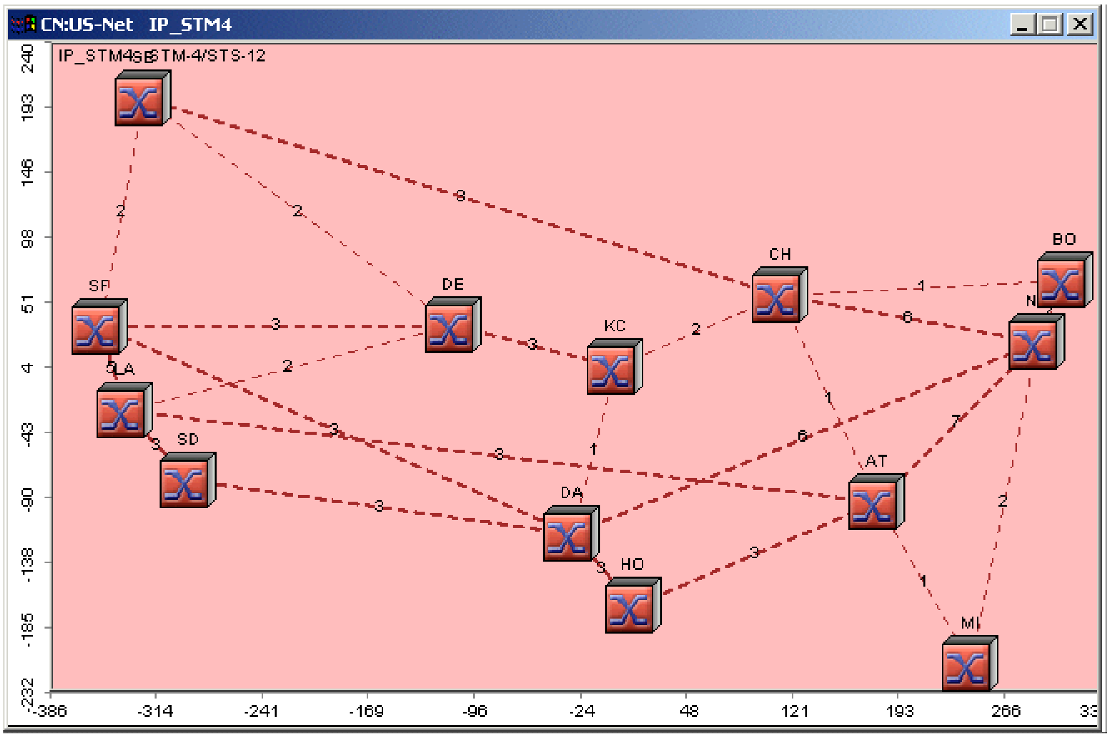


Figure 15 IP bandwidth (STM4)

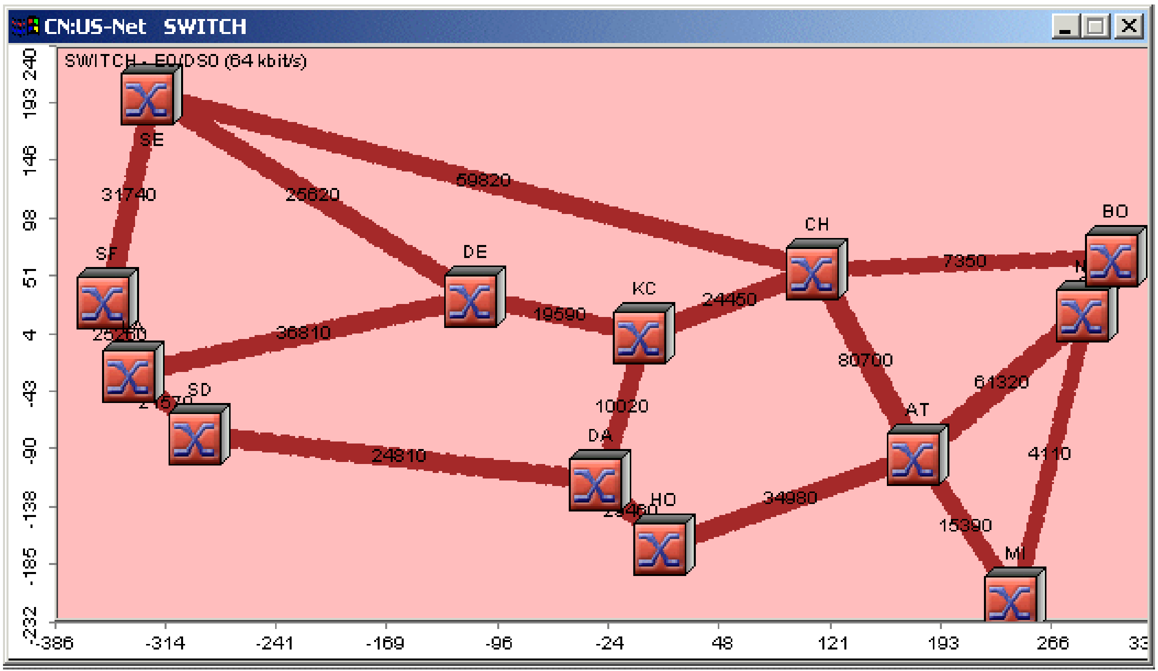


Figure 16 Switched voice bandwidth (DS0)

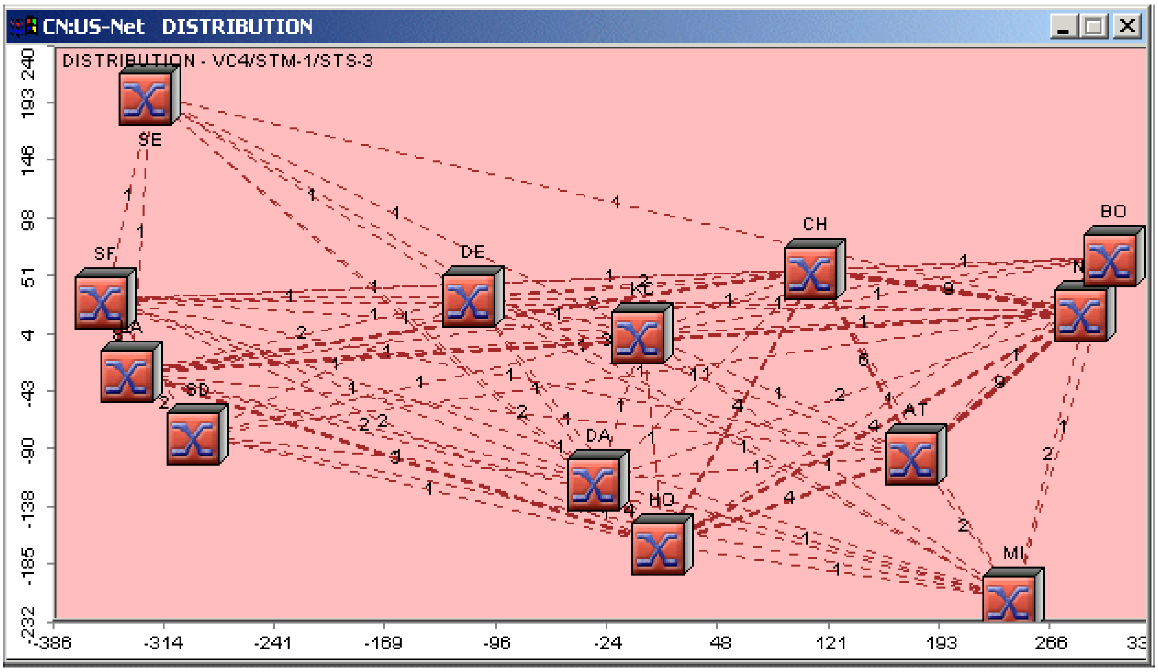


Figure 17 Distribution bandwidth (leased STM1 lines)

The SWITCH matrix from the switched voice network design is in units of DS0. DS0 cannot be handled by SONET add/drop multiplexers (ADMs) since the speed is too low. So we need to multiplex DS0s to higher-speed signals. We do this by first routing the traffic and then using the end-to-end bundling functionality in VPItransportMaker™ .

After bundling, the new SWITCH matrix is in STM-1 units (OC-3) and is renamed Switch_STM1 (as in Figure 18).

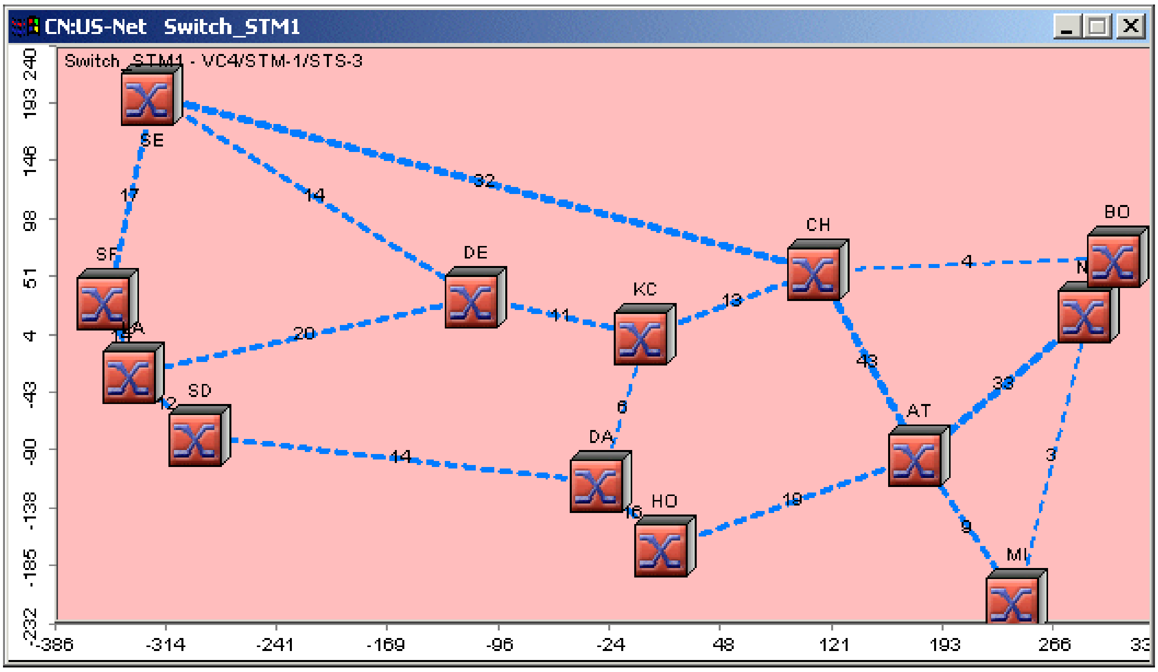


Figure 18 Switched voice bandwidth in STM1s

We are now ready to design the SONET and DWDM network. The basic steps are:

- Define a particular ring technology (such as a 4-fiber, STM-64, BLSR ring).
- Specify ring constraints (such a ADM add/drop capacity and granularity) and cost parameters.
- Specify general design parameters (such as enabling demand splitting, joint OMS optimization and cross connects for inter-ring traffic).
- Specify the DWDM system technology, which provides point-to-point wavelengths for the SONET ring network. You can specify such parameters as maximal number of wavelengths, optical amplifier spacing, regenerator spacing and cost.
- Run the ring designer to produce all the topological rings, modular rings, their interconnections, underlying DWDM systems, and traffic routing. (Here a modular ring refers to a physical SONET ring—as constituted by SONET ADMs—and a topological ring represents the topology of a modular ring. So multiple modular rings may traverse the same topological ring.)

Figure 19 shows the DWDM layer topology where each link is one or more DWDM systems. The number beside the link indicates the number of such systems. For this particular design, only one DWDM system is needed over each link. This is because each system provides 40 lambdas (OC-192) of capacity, which is more than sufficient for the size of our traffic.

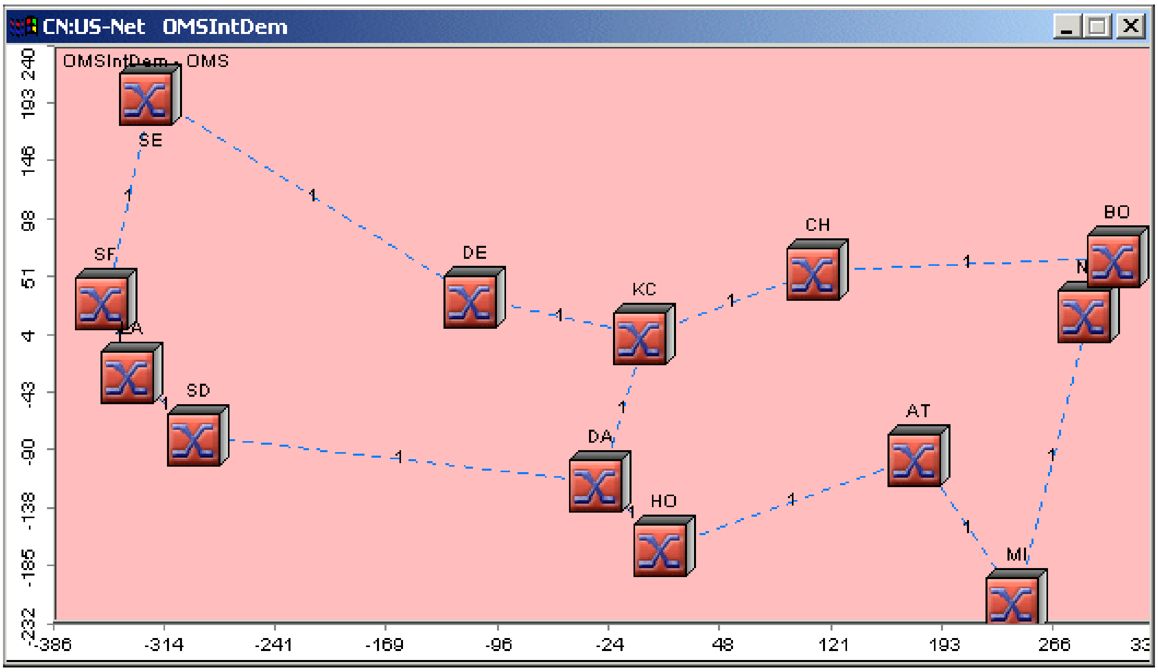


Figure 19 DWDM layer deployment

In the SONET layer, two topological rings and five modular rings are created. The two topological rings are routed exactly along the two loops of the DWDM topology shown in Figure 19, one on the left and one on the right. There are three modular rings over the right loop, and two modular rings over the left loop.

Summary of Integrated Planning Procedure

In this design exercise we have shown how the VPIlifecycleManager™ tools can be used to undertake integrated network planning across multiple layers. We have demonstrated a smooth end-to-end planning procedure, showing how the various tools can inter-work, and how VPIserviceMaker™Distribution can help estimate traffic where traffic data is not available.

The data flows in this exercise have been one-way: from traffic distribution to service layer design to transport layer design. It is possible to have a feedback process from the transport layer to service layers. For example, by looking at the spare capacity of the transport layer, you can estimate how to expand a service network. You could then adjust transport bandwidths allocated to the various service layer networks. You could also conduct what-if analyses of the potential impact of service layer changes on the transport layer.

Next Generation Products from VPIsystems

So far we have described the integrated planning solution supported by VPIsystems' products supported on the VPIlifecycleManager™ platform. In this section we present the next generation of VPIsystems products and solutions. The first of these is VPI's Network Lifecycle management solution which provides an integrated and end-to-end solution for a telecommunications operator's network planning and engineering process. The second is VPInetworkConfigurator™ a product aimed at automating the equipment vendor's pre-sales process. We provide a brief overview of these products and the motivation behind them, below.

VPIsystems Network Lifecycle Management Solution

Introduction

Revenue is lost when customer demands cannot be fulfilled by the available network infrastructure. Carriers usually overbuild to resolve this problem, which results in needless waste of capital resources, while not necessarily completely eliminating hot spots in the network. For example, switch trunk planners typically estimate growth forecasts with built-in spare. These estimates are then passed on to the transport planners who put various trunk estimates together to develop a transport plan that also includes some spare, resulting in spare-on-spare in the overall network. Yet operations still experience hot spots in the network with unexpected customer demand, resulting in lost revenue.

Unfortunately for most carriers, the processes required to identify idle capacity and bottlenecks, to analyze today's traffic for preparing forecasts, and to optimize and re-configure the embedded infrastructure for minimizing new investments, are fragmented, slow and inefficient, resulting in under-utilized infrastructure, and needless capital expense. Network Lifecycle Management (NLM) is an Engineering Support System (ESS) concept pioneered by VPIsystems in order to solve these problems and facilitate the automation of a Telecommunications Operator's Network Planning and Engineering process. NLM allows network operators to carry more traffic with less equipment and less people involved. By bringing all of the various planning and engineering process elements into one single generic process, NLM will ensure interaction between the functions with a single overall view of the process from end to end.

While telecommunications Engineering & Operations have traditionally been supported by a variety of software systems, the introduction of software systems to aid the integrated network Planning and Engineering processes is relatively new. Figure 20 helps understand how NLM relates to other well established Operations Support Systems (OSSs) on the telecommunications software landscape. Probably the best-known OSS systems that interface to NLM are the "Service Fulfillment", "Service Assurance", and "Activation" systems, which automate processes concerned with managing, monitoring, and utilizing the existing network resources. These systems mainly facilitate management of already-deployed network resources and usually act on logical and physical operational inventory databases. These types of OSS are designed to support many thousands of short transactions everyday and hence can be categorized as "Transaction Support Systems[1]".

In sharp contrast to the above, the network planning and engineering processes require a new type of software system, called Engineering Support Systems. Network Planning & Engineering provides the intelligence on how to build and extend service provider networks. It involves creation of new logical and physical resources to accommodate the forecasted traffic within the constraints imposed by the existing logical and physical network

[1] On the other hand, a different type of OSS, known as Business Support Systems (BSS), manages customer-facing processes such as "Service Order Management", "Customer Relationship Management", and "Billing"[1]. BSS systems act on operational product and service databases and facilitate administration, sales, marketing and billing of existing network resources.

infrastructure. The aim is to design, develop and deploy a CapEx-optimized network infrastructure that meets service requirements. For a given set of forecasted demands, the key network planning and engineering activities consist of checking available network capacity to see if it can accommodate the projected growth, generating network new-build plans where necessary, and producing detailed engineering designs for network upgrade.

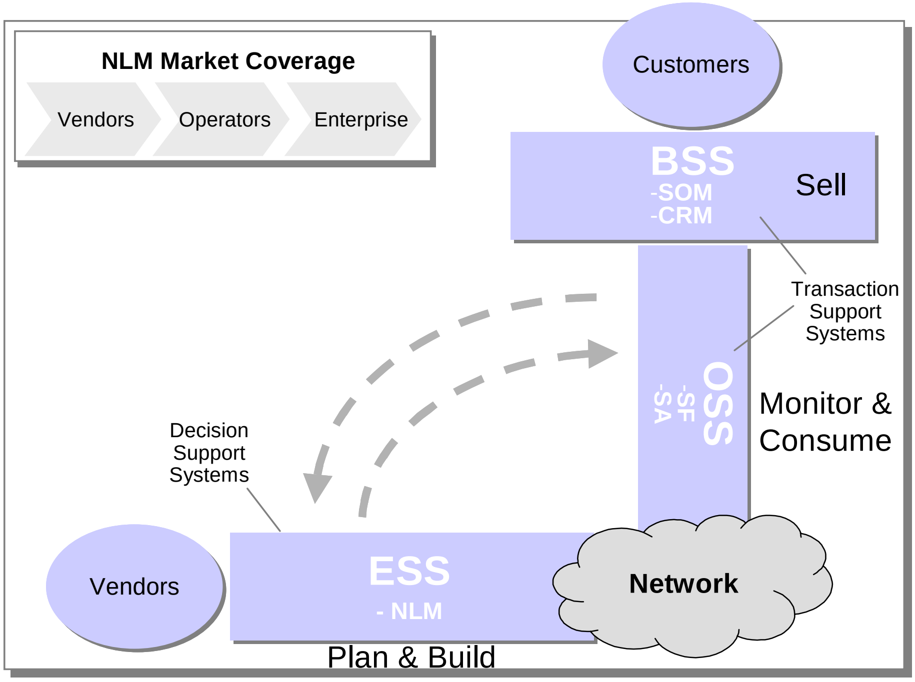


Figure 20: Telecommunications Software Landscape

In contrast to the OSS, Engineering Support Systems involve relatively few transactions, but each transaction may launch computation intensive algorithms operating on a large amount of data. Consequently, Engineering Support Systems have to be designed like "Decision Support Systems" so as to support few computation-intensive transactions with large volumes of data.

Key Requirements of NLM

A key requirement to NLM is to provide the necessary "Network Design" and "Configuration Modules" that can create feasible designs which ensure that when the equipment are deployed as per the design guidelines, the network will function as designed with near zero fall-outs. For this to happen, the designs have to be driven by the physical and logical constraints of the equipment. Capturing all details of not only the legacy equipment but also of latest technologies for producing optimum and feasible designs requires creation of a comprehensive equipment library.

Another key requirement is that NLM should be capable of automating detailed planning and engineering processes in carriers. VPI's NLM solution achieves this by providing the necessary "Workflow Automation Modules" that streamline the design, configuration, and deployment of network infrastructure. Driven by forecast network demand, the process of checking available capacity, generating network new-build and producing detailed engineering designs for network upgrades constitute key components of NLM.

Aside from the necessary design, configuration, and workflow automation modules, another key component of NLM is the underlying database, on which all modules operate. Network

planning & engineering business processes require detailed data on planning, availability, usage and state of various products, services, and resources in the network. This data is usually kept in various inventory systems. NLM should take the as-built network data from the operational inventory systems (logical and physical inventory) and combine them with detailed equipment data to build the Planning & Engineering Database (PED). The PED is the underlying database of NLM that keeps an off-line historical model of the operational databases, and hence needs to be periodically synchronized. As output, NLM issues and delivers "new build plans" and "Work Orders" for deployment of new-build network and re-optimization of the as-built network and initiates updates to the corresponding inventory systems about the changes made to the network.
In summary, NLM enables operators to deliver better services, more quickly and consistently, and make better use of already-deployed network resources. With large networks and many complex processes, the CapEx and OpEx impact on operators is potentially huge.

VPIsystems Pre-sales Process Automation Solution

A serious problem faced by equipment vendors has to do with the currently prevalent pre-sales proposal generation process. Sales opportunities are lost when product experts are overloaded and when the sales and support team lacks consistent, up to date product knowledge. This results in proposal responses that are non-competitive or sub optimal, lengthened sales cycles that jeopardize business opportunities, more costly solutions, and design errors creating additional post-sale expenses.

The VPI solution to this problem is VPInetworkConfigurator™ an expert software program that increases the productivity, responsiveness and competitiveness of the sales organization. It enables sales support and proposal personnel to rapidly provide responses to sales opportunities and proposal requests, which are optimized to lowest cost and are 100% accurate. Productivity improvements of 2X for sales support personnel are typical. Benchmarking against manual designs created by product experts typically shows 80% time savings and 20% lower cost of completed designs when compared to existing techniques while totally eliminating product configuration errors.

This solution is achieved by embedding VPI's world class planning and engineering expertise in an easy to use web enabled software that allows the vendor's global sales force access to the vendor's scarce product and design expertise. In addition to the core design engines developed by VPI, the software consists of a customizable product library module that can be populated by product experts, and a customizable design wizard that encapsulates design rules developed by vendor experts with a thorough knowledge of the product capabilities. Once the customer network data is captured by the sales person, the pre-built product library and design wizard take over and generate optimized designs that meet the customer needs. A key innovation of this software is the integration of the planning, link engineering and equipment configuration steps which enables the sales person to produce designs that are 100% compatible with the products chosen, and to generate orderable Bill Of materials (BOM). A schematic depiction of this process is shown in Figure 21 below.

Figure 21:: Integrated planning, link engineering and equipment configuration

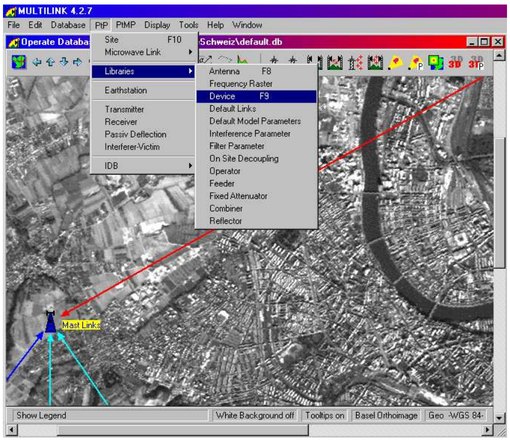
Value Proposition: Extensive benchmarking has shown that for complex network configurations, the overall design improvements result in network designs that are 25% - 30% less expensive than those generated by previous methods. This enables the sales force to be much more competitive, putting tremendous pressure on competitors without any lowering of product prices. New product training for sales staff has been minimized, and field sales personnel can immediately take advantage of newly introduced products and design rules to address existing customer opportunities, via software updates over the Intranet. Additionally, it has enabled the vendor to avoid expanding the sales support team to handle increased sales opportunities, thereby providing significant annual OpEx savings.

Conclusion: How to insure that the best solution is always proposed to every customer has been a classic problem of sales organizations. VPInetworkConfigurator is the first expert system that has solved this problem for vendors of network equipment. In the hands of the sales organization, it turns everyone in sales support into product experts with little or no training. It selects the proper network topology, equipment family and product configuration to meet unique customer requirements based on product design rules, prices and network constraints. It is 100% accurate down to the individual line card level. It can be programmed to learn new design techniques from ongoing competitive experiences in the field. It enables new product additions and design rules to be implemented instantaneously across the worldwide sales organization. It pays for itself both through OpEx savings and as quickly as with one win of a major competitive customer RFQ

A1.5. LStelcom

MULTIlink

Introduction



MULTIlink is a proven microwave link-planning tool from LS telcom AG, which provides the network planner with state-of-the-art and easy-to-use functions during the entire design process. MULTIlink is a complete solution for fast microwave link engineering and designing of PMP/WLL/LMDS networks. It can be used for planning and optimizing single links (e.g. path loss, coverage and availability calculations) as well as for doing network-wide analysis (e.g. interference calculation, channel assignment).

<u>Features and Highlights</u>

- Powerful Database containing Sites, Links, Receivers, Transmitters, Antennas, Devices, ITU/ETSI Frequency Plans.
- Advanced Map Handling / Network Viewing
- Interactive Link Engineering Desktop Environment
- Technologies: FDMA and TDMA
- Passive / Reflector Back-to-Back Link Profile
- Clearance of Fresnel Zone
- Reflection Points Determination
- Excellent Profile Handling
- Link Analysis
- Free Space Loss, Atmospheric Absorption, Clear Air fading, Obstruction Loss, Rain Attenuation Calculation according to ITU-R Recommendations
- Dispersive Fade Margin, Outage due to Dispersive Fade Margin
- Area-wide Field Strength Coverage Prediction
- Availability Calculations considering Rain and Multipath based on worst month and average annual Statistics
- Interference Analysis Calculation for both Long and Short Term
- Microwave Link Reports Creation

Special Modules

- Point-to-Multipoint Links / LMDS
- Satellite-Earth-Station Coordination
- Short-wave Point-to-Point

<u>Implemented ITU Recommendations and Regulations</u>

- ITU-R P.530-9
- ITU-R P.452-10
- ITU-R P.676 Atmospheric absorption
- ITU-R P.837 Attenuation due to rain
- ITU-R P.526 Diffraction mechanism (knife edge)

Satellite Earth-Station Berlin: (optionally)

- Ap S7 (Sat-ES)
- Ap 28 (Sat-ES)

Short Wave: (optionally)

- ITU Rec. P.533
- ITU Rec. P.372
- ITU Rec. BS.705

Frequency Range

The MULTIlink software package includes propagation models used in the typical frequency range from 700 MHz to 40 GHz. Optional modules covering 200 -700 MHz are also available. In addition, a shortwave module is provided to cover the frequency range from 150 kHz to 30 MHz.

Database

MULTIlink is able to store all used databases (e.g. terrain maps, technical data) either locally or on a network server. Based on Client/Server structure several users can be linked to a central database. Each user has a local working database for planning purposes. Easy copy and update processes are built in. Data integrity is established using record locking procedures.

Terrain Map Database

MULTIlink supports both raster and vector maps. Calculation results can be visualized as vectors (such as field strength or interference contours) or as raster data (for example area calculations). Raster or vector calculation results can be overlaid on background maps with an adjustable transparency factor.

Technical and Subscriber Data

All data is kept in the LS-MULTIBASE database or optionally in an Oracle database. Data can be entered either manually in spreadsheets, editors or using the standard ASCII interfaces. Customer tailored import solutions can be provided if request.

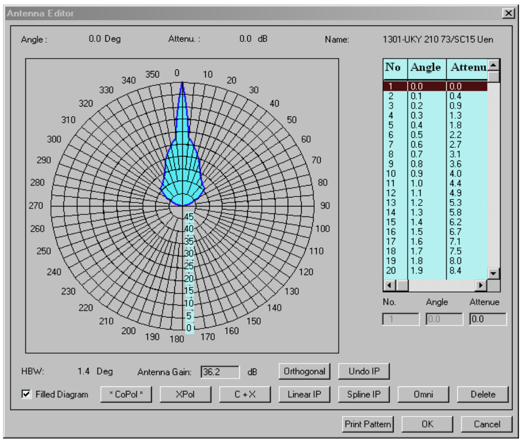
Antennas / Devices

The database comprises important technical information, like: antennas, transmitter, receiver, feeders, combiner or reflectors

Antenna pattern can be either imported or created manually by entering the angular discrimination values in a table. An antenna editor is provided for modifying the antenna pattern.

The horizontal and cross-polar radiation patterns of the antenna are essential parameters for interference analyses.

NSMA-Format is supported. Besides, many other kind of antenna formats are also supported because a generic ASCII interface is used. Customer specific input formats can also be implemented if request.

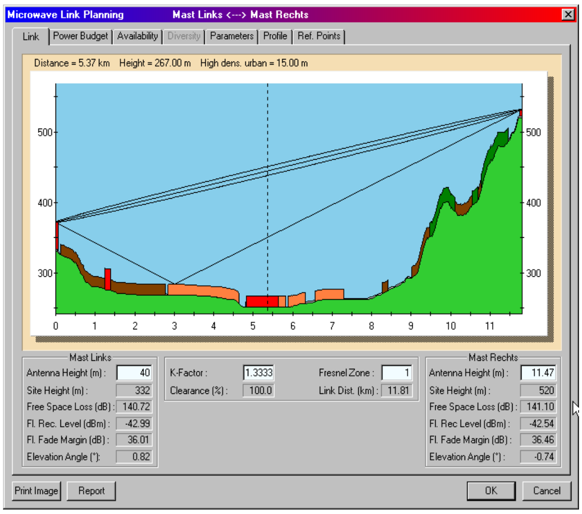


Frequency Raster
The definition of frequencies or channels is based on frequency plans described in ETSI Standards or ITU Recommendations.
"Manual frequency plans" are supported as well. This type of frequency raster allows the definition of arbitrary frequencies.

Planning

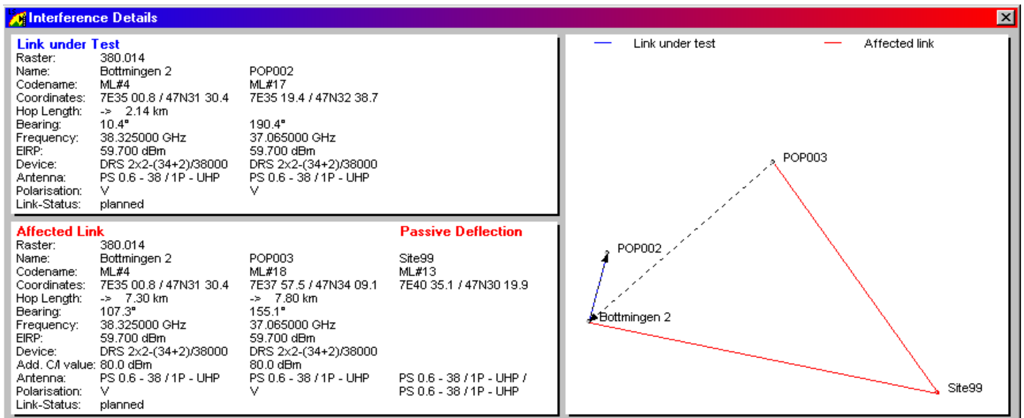
Microwave Link Planning

Using MULTIlink a network planner is able to design his microwave link directly in the interactive Link Planning Window. All necessary calculations, like Fresnel zone, path loss, power budget, link availability, diversity, reflection points, etc, could be done in this window.
The calculations incorporate the effects of atmospheric absorption at higher frequencies and the effects of different rain zones.
By a simple mouse click a microwave link report can be generated, containing all important data of the new designed microwave link.



Interference Analysis

MULTIlink allows detailed interference analysis of microwave networks. Short and long-term interference analysis is performed in accordance with the ITU-R 452 propagation model, using terrain and clutter data. The interference analysis can be performed to Point-to-Point links and also to the PMP scenario.



	Transmitter	Receiver	hop/km	bear.	ILL/dBm	ILS/dBm	DF/dB	AD/dB	PiRXL/dBm	PiRXS/dBm	C/IL/dB	C/IS/dB	TD/dB	Add. IF
1	POP003 2	*Bottmingen 2 1	6.1	216.9°	-32.1	-30.9	0.0	120.8	-152.9	-151.7	74.9	120.1	0.0	X
2	Bottmingen 2 1	*POP002 2	2.1	10.4°	-25.0	-24.6	0.0	47.0	-72.0	-71.6	-6.0	39.7	30.6	

MULTIlink generates a detailed interference report, which can be printed or saved.

Channel Assignment

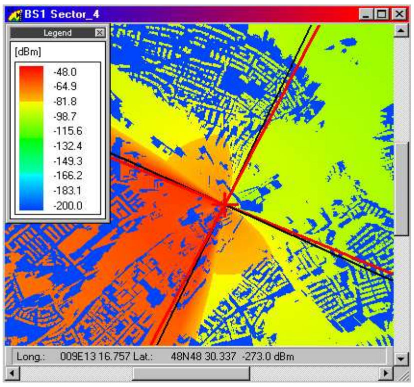
The channel assignment function is used to find usable frequencies for a selected link in a specific frequency raster. The Channel Assignment Algorithm performs an automatic interference analysis for the whole frequency band and creates a list of recommended channels (channels with minimum interference). For each channel, a "quality measure" is calculated.

Modules

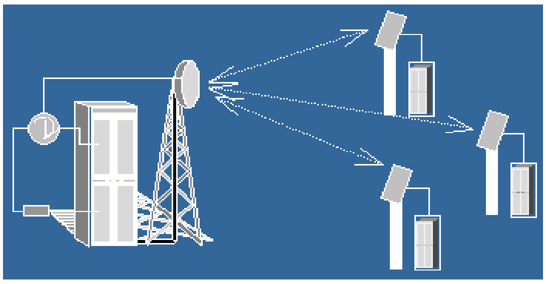
Basic Calculations

Line-of-Sight (LOS) Check
For each site or point on a map, a LOS Check can be executed.
The height of antenna above ground level is specified as parameters. Results are overlaid on a map.

Coverage Prediction
For coverage prediction several propagation modules are available. The propagation parameters used by the different modules (e.g. rain zone, k-factor, etc.) are configurable. Coverage prediction results are the basis of all further network investigations.

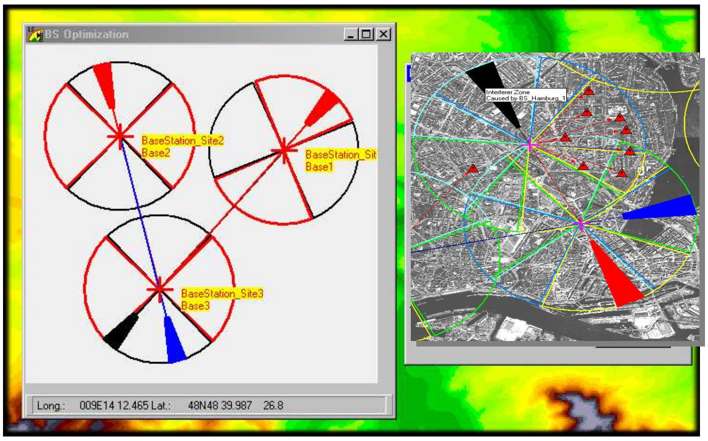


Point-to-Multipoint (PMP)



MULTIlink_PMP models a PMP / WLL network in a hierarchical structure using several network elements. The "Base Station" consists of several sectors. To each sector several subscribers (terminals) can be linked. Each sector covers a defined area (depending on the used antenna).

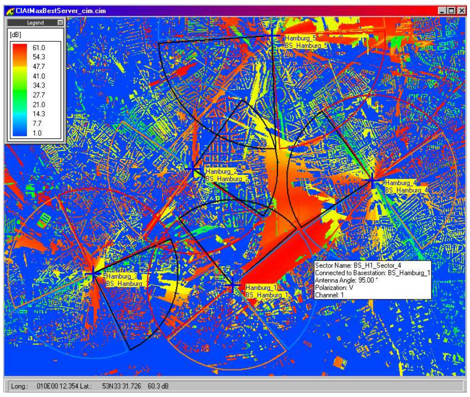
Fast Base Station / Sector Optimization



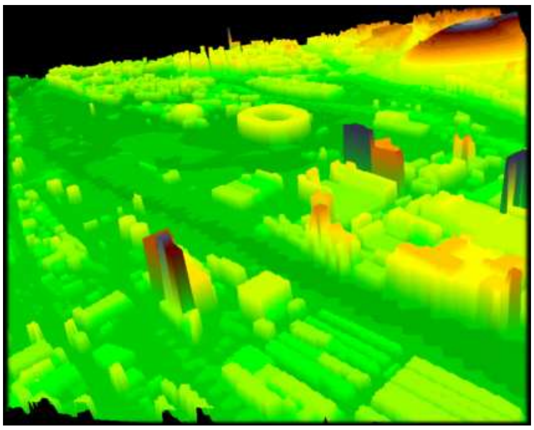
The PMP module in MULTIlink includes a fast sector optimization algorithm, which is based on free space propagation and geometrical assumptions. This function detects possible interferer zones in a fast manner and the user can eliminate the interferer zones by rotating base stations.

PMP Network Processor

The PMP network processor allows performing detailed network analysis to design and optimise PMP/WLL networks. Typical network analysis results are: Maximum Field Strength, Maximum Server, Best Server, C/I, etc.



3D View



The digital terrain model even overlaid with calculation results can be displayed three-dimensionally.

xG-Planner

Introduction

xG-Planner is a mobile network planning tool from LS telcom AG, which is applicable to 2G (GSM, TETRA), 2.5G (GPRS, EDGE), and 3G (UMTS). It is intended to cover the whole range of mobile network planning aspects including:
early project studies
license application or offer phases
first rollout
detailed network phase planning including site management
network operation
network optimization
It is a state of the art product with advantages relative to other existing tools on the market through its main functions to:
Provide fast and high quality coverage planning (several propagation and refraction algorithms, optional support for field strength calculations due to the Vienna agreement)
Hierarchical database (Network, Project, Project status and Cell level) to structure large projects
Storing of all results in a result database, filtering & context sensitive regaining of information
Spreadsheet visualization of database contents
Graphical and/or tabular management of all network elements
User role management to administrate user privileges
Configurable menu actions, access restrictions to certain user groups
produce optimum frequency plans
supply quality of service (QoS) predictions
xG-Planner provides the possibility to plan pure macro- and microcellular networks, as well as multilayer networks consisting of a combination of micro-, macrocells, extended cells or concentric cells.
Furthermore xG-Planner supports the planning of different mobile services like GSM900, GSM1800, GSM1900 (PCS), DECT, TETRA and UMTS. This is due to the fact, that network technologies as well as calculation algorithms can be allocated on a per cell basis. The tool is also open for keeping up with future system technologies.

Basic xG-Planner Module

<u>Graphical User Interface (GUI)</u>

The development of xG-Planner was focused on a modern, ergonomic, user-friendly software handling, which allows for convenient and comfortable user operation.
Some of xG-Planner GUI features are:
main windows with the complete tree of features (Menu bars, toolbar buttons)
context-sensitive menus & tool tips
overview cartographic window with fast navigation possibility
Simultaneous multiple map windows for different views
user configurable tool bar with icons providing fast access to functions which are often needed by the user; key shortcuts for fast access to the menu items; ergonomic arrangement of features similar to the general Windows standard.

Context sensitive mouse menus on objects displayed on the map window, direct editing of items in the plot or getting quick information on certain pixels; status line with actual information and cursor readouts.
definition of user individual layouts (table layouts)
Restoring of all user settings, reopening of last open windows
All cartographic windows use coupled cursor readout

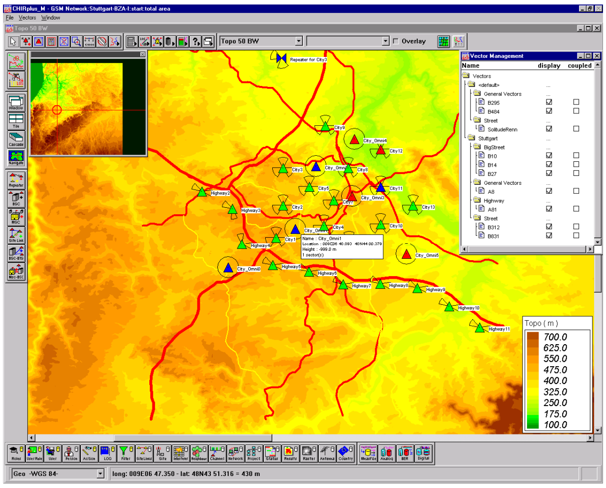


Fig. 1.6.1: Topographical map with sites and streets displayed. A small legend and overview window are also displayed

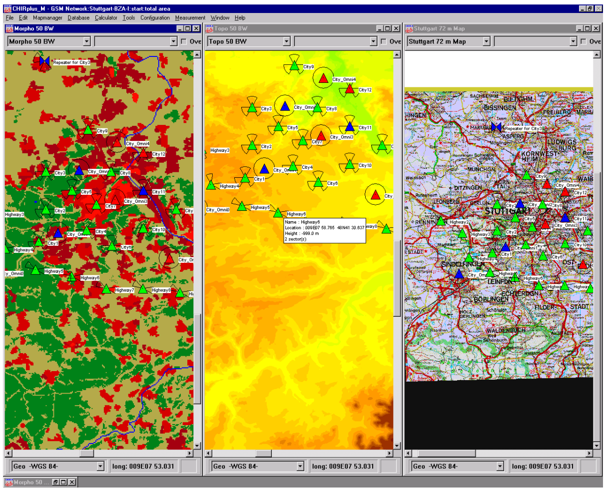


Fig. 1.6.2: Multiple cartographic views showing different types of information

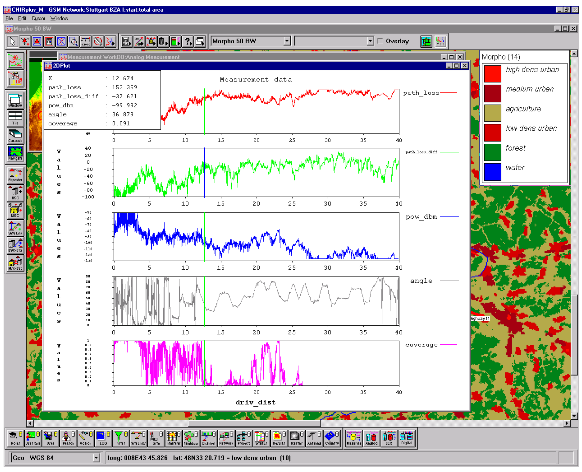


Fig. 1.6.3: Measurements in 2D plot representation

Database Model

A suitable radio network planning tool has to handle a huge amount of input and output data. Hence, the database structure is very important.
xG-Planner stores all the planning data in a fully relational database system.

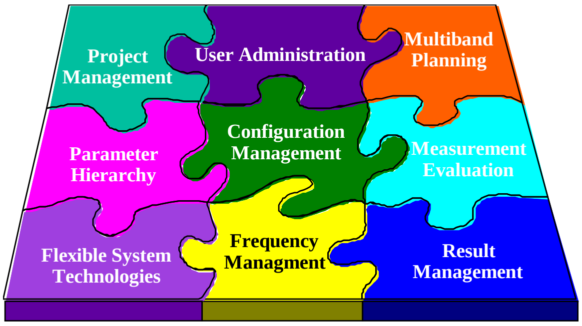


Fig. 1.6.4: Database Model

Going more into detail, this means that the powerful optimised relational database structure provides:
highest data integrity and consistency
hierarchical data organization
flexibility through:
user profile assignment
user role (user mode) assignment
customizable and transparent views on all data which is related directly to the planning
Further comforts are:
editing the database items using the following methods:
editing via forms directly from the displayed objects
editing via report windows (e.g. in tables) using powerful spreadsheet functions
automatic update of information in databases during interactive changes in plot and vice versa
log book functionality

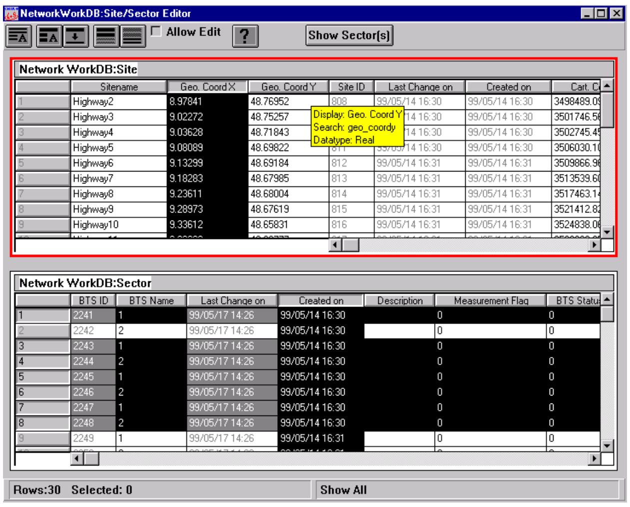


Fig. 1.6.5: Site/sector spreadsheet

Coverage Prediction Module

The computations within this module are based on the cell design and source databases (topography, morpho structure, traffic) and yield the field strength prediction and its derivations on a cell and network basis. Furthermore different cell shape calculations are performed.

In particular the following tasks can be performed:

site calculations like LOS calculation point to point and on an area

cell power calculation (downlink)

median power calculation for cells and repeaters (choice among several propagation models like free space propagation, flat earth model, LS model, enhanced Okumura Hata, Walfish Ikegami, etc)

signal delay difference and signal level difference (for repeaters)

coverage probability calculated from the power result

network-wide power calculations

cell shape calculations

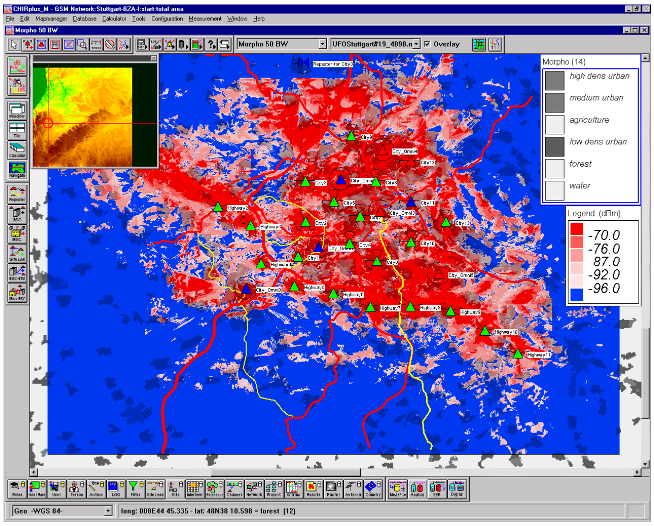


Fig. 1.6.6: Networkwide power overlaid on background morpho map

Microcell Module

xG-Planner provides the full amount of features necessary to plan microcellular networks. The ray tracing model searches for different propagation paths and sums up the contribution of different rays for each receiver pixel. Reflections on floors, walls, roofs as well as diffraction on horizontal / vertical edges are computed. The number of reflections and diffractions taken into account can be selected individually by the network planner beside a wide variety of options which are available within the 3D ray tracing model.

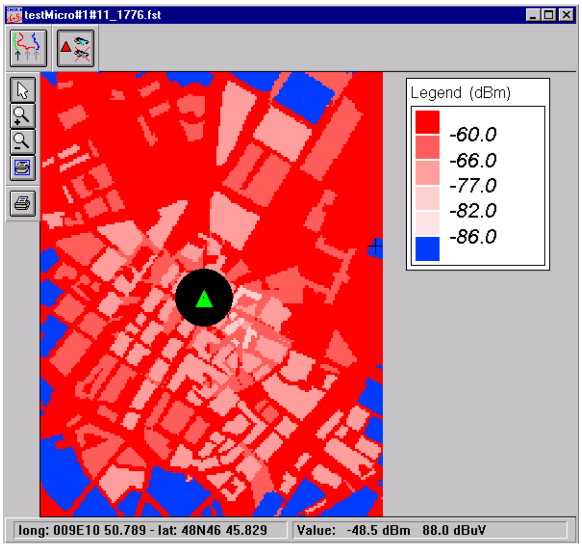


Fig. 1.6.7: Field Strength Prediction for Microcells

Ray Launching

In contrary to the ray tracing algorithm which searches for different propagation paths (ray classes) receiver-pixel-wise, the ray launching approach considers the rays sent by the transmitter with a fixed angle increment and follows them until a defined termination criteria is fulfilled (e.g. maximum number of reflections). Furthermore, during ray launching only reflected rays are considered, whose contribution to the field strength are summed up receiver-pixel-wise.

Field Strength Prediction with COST-231 Walfish Ikegami Model

Besides the above mentioned deterministic models a fast empirical model is provided: the COST231 Walfish Ikegami Model. Basically this model can be utilised in combination with the 3D Ray Tracing Mode for speeding up calculations.
This model can be calibrated by measurements.

Indoor Prediction

Indoor prediction can be applied in combination with the fully deterministic ray tracing model as well as with the COST 231 Walfish Ikegami model. It can be performed during standard prediction or separately during post processing
The prediction model can be calibrated by adding an offset to the predicted field strength, by modification of the diffraction model parameters and by setting the breakpoint.

Frequency Planning Module

The automatic frequency assignment is based on: the channel requirement for each BTS, the matrix of mutual interference probabilities for co-channel or adjacent channel, the total number of frequencies in the allocated bandwidth and the given constraints for frequency planning.
Types of calculations performed during frequency planning:
traffic calculation: calculation of required frequency channels out of the traffic density database, the assignment probability of the required number of traffic and signaling channels
setup of channel separation matrix as a preparatory step for the automatic frequency assignment
automatic frequency assignment: choice between Box algorithm (I and II) and Simulated Annealing as frequency allocation algorithms; assignment of actual channel numbers considering the structure of the available frequency band
optionally available: usage of frequency groups and frequency hopping algorithm

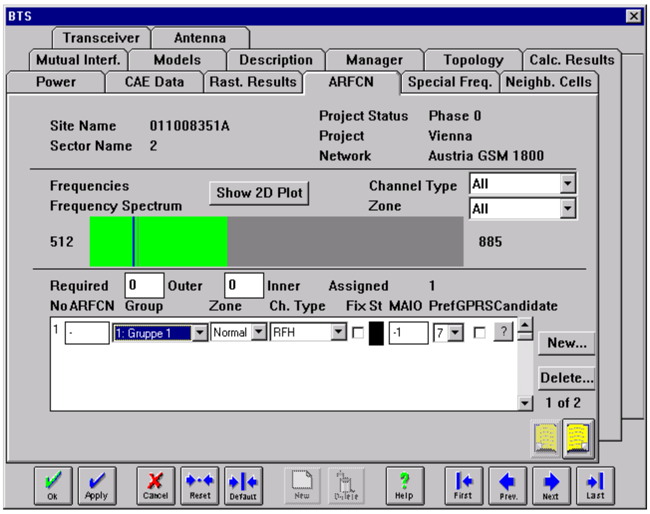


Fig. 1.6.8: Frequency Planning

Furthermore various additional frequency constraints can be considered for frequency planning:

comfortable individual cell definition of constraints for the automatic frequency assignment via graphical Interface: fixed frequencies; co-site separation, co-cell separation, free definable frequency bands; allowed, not allowed frequencies (e.g. at country borders, at borders of neighboring networks etc.)

The GUI offers different options for:

manual editing of the channel separation matrix

manual assignment of frequencies with the help of an interference ranking list (best possible choice of available channels)

fixing previously assigned frequencies against accidental tempering

statistical evaluation of frequency distribution and reuse

QoS Prediction Module

Aim is to provide a quality of service prediction of the network design based on interference coverage holes and BER according to the frequency plan. Its evaluation checks system performance and defines optimization possibilities.

The analysis includes the following types of calculations:

the traffic capacity analysis

powerful cell performance calculations:

final cumulative interference calculation based on the actual frequency assignment; output of results are C/I values in dB and probabilities %

quality of service prediction achieved by an outage calculation considering the combined effects of interference and coverage holes, optionally weighted by traffic density;

output of results as probabilities (BER and FER calculations in preparation)

network-wide performance calculations: final interference and outage calculations

averaging of interference and outage probability over serving cell area or over network

BSS Parameter Module

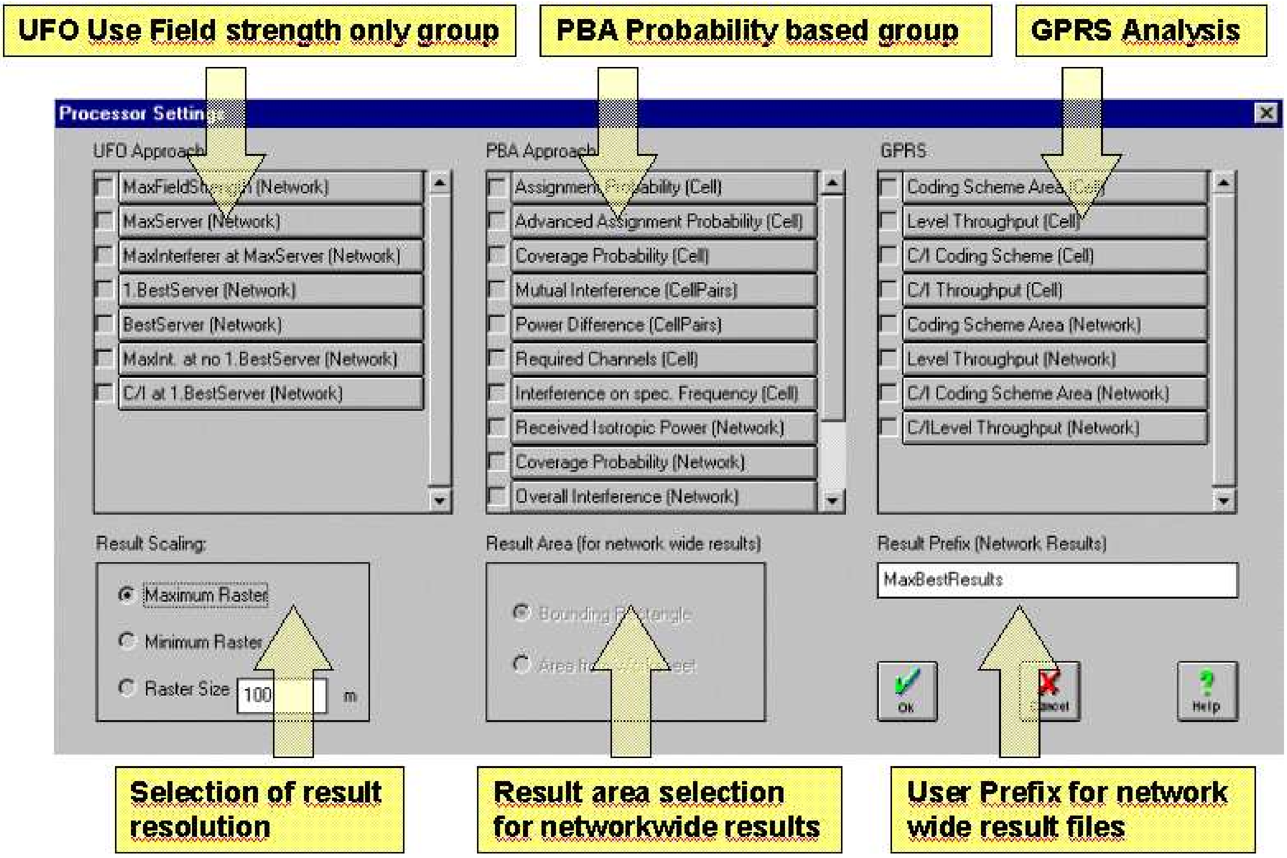
The module is responsible for creation of system dependent BSS parameters, which is the first step towards implementing the real network. The BSS parameter files are loaded in the OMC-R via a corresponding interface. This interface and the parameters that are passed to it are strongly dependent on the operator’s hardware.
Types of calculations in the BSS parameter generation module:
location areas (LAC) allocation and Cl allocation
calculation of neighborhood relationships/neighbor cell lists
geometric
best server based
interference based
link planning parameters (traffic, number of channels, link distance,...)

Measurement Evaluation Module

Major purpose of the measurement evaluation is the visualization of the real network behavior and the comparison (calibration) with network planning requirements / prediction. The visualization of measurements is done by mapping them together with cartographic background information and statistical analysis.
Analogue and digital measurements can be imported into the measurement database and evaluated.
The following tasks to be performed at different stages of radio network:
propagation model calibration: adaptation of parameters used in the field strength prediction model to the real conditions in the planning environment; comparison of measured and predicted field strength under variation of the parameter(s) of the OH model to be calibrated
site verification: verification of possible transceiver sites regarding the fulfilment of propagation requirements
installation error detection: detailed analysis for problem detection after installation of the network (e.g. missing HO-relationships, ping-pong-HO etc.)
acceptance test: analysis of the huge amount of test drives in the service area of the network

GPRS Module

xG-Planner optionally also supports 2.5G functionality like GPRS. For simplicity it is included in the tool’s central network processor as a third function collection:



The GPRS part of the processor thus collects the GPRS based. Currently, the following algorithms are already included:
Calculation of GPRS coding scheme areas CS1..CS4 (best case, based on field strength level)
Throughput of data in kbps/s per cell
Coding scheme areas network wide
Throughput network wide
Real CS and throughput calculations based on interference situation

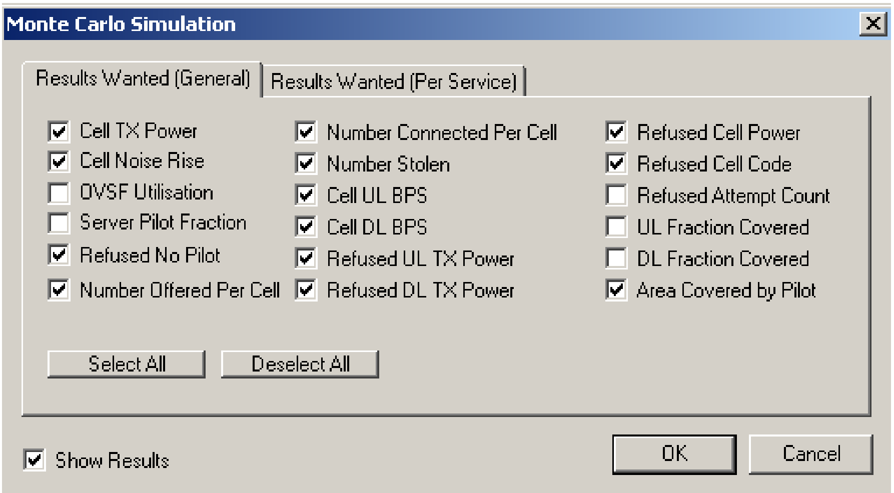
UMTS Module

xG-Planner addresses the UMTS planning part with different modules, which are intended to serve the planner for his different needs during the project phases. These represent different levels of detail:
A propagation based planning module for initial bid-planning estimations
A Monte Carlo based planning module for regular network roll-out
Optionally, there is also a third module available, intended for academic hotspot evaluation purposes:
A UMTS Real Time simulator for chip-level analysis of deterministic single UMTS users.

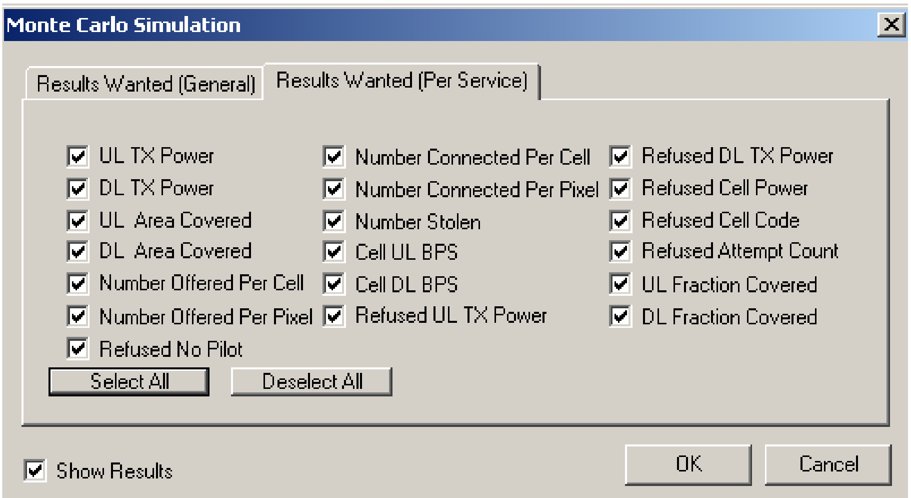
Monte-Carlo Simulation

In the following we focus on Monte Carlo (MC) simulation and its corresponding approach to plan UMTS networks as Monte Carlo simulation is the standard method for UMTS network planning. For UMTS, downlink and uplink must be analyzed, but as the mobiles are (by their

very definition) not static in position, it requires a simulation (instead of a calculation as was in GSM).
The following screenshots give an overview of the result types that are calculated in the framework of xG-Planner' Monte Carlo Simulation. The first figure shows the available cell related results the second figure reflects the "per service" results (that is, one plot for each defined service per MC simulation) that are calculated for each service.



Cell related (general) results of the Monte Carlo Simulation



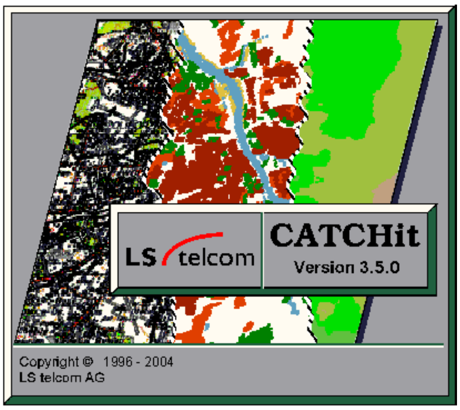
Service related results of the Monte Carlo Simulation

Scrambling Code Planning

xG-Planner's Scrambling Code Planning Engine is responsible for the allocation of cell-specific downlink scrambling codes within a UMTS (3GPP WCDMA variety) compliant terrestrial network. The Scrambling Code Planning Engine is capable of handling an arbitrary number of ranges of allowed codes. These codes are assigned in a manner such that there is minimal interference between cells with the same scrambling code.

CATCHit - Terrain Database Management Tool

Network planning, especially performed with RNP tools, requires the collection and management of numerous data. RNP planning tools generally don't offer more than the standard terrain database functionality like:
Open data layers
Create simple polygons
Change color, size and, line type of vector layers
Overlay vector and raster maps
These basic functionalities are not sufficient to fulfill the requirements for efficient management of terrain databases for RNP purposes.
CATCHit, the digital terrain database management tool of LS telcom, is the perfect assistant for all tasks coming up around digital terrain databases. Generally the functions of CATCHit can be divided into 3 main categories.
Generation of digital terrain data information
Conversion of existing digital terrain data information
Maintenance of existing digital terrain data information



Digital Terrain Data Generation

CATCHit is offering the following functionalities for the creation of new terrain information.

<u>Geo-referencing of scanned paper maps</u>

Paper maps often show a coordinate system grid for measuring distances and positions. After scanning these paper maps, this information is only visible for the user but not accessible for the GIS application. In order to combine the scanned map with the correct coordinate system usable in GIS applications, the map has to be geo-referenced. At places where the real world coordinates are known, reference points have to be placed. These reference points combine the visual scanned map with real world coordinates. Eight to twelve reference points have to be placed all over the map.

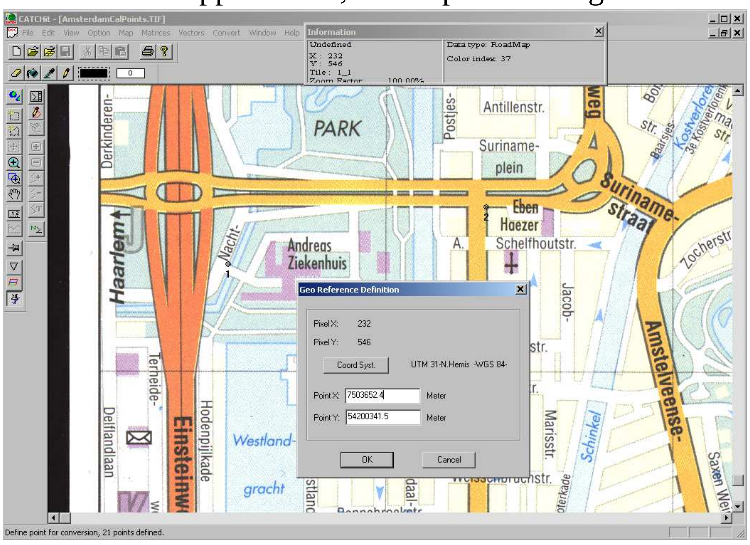


Figure 1.6.9: Placing a reference point and specifying coordinate system and coordinates

CATCHit allows using different coordinate systems for each reference point. This is very useful for the geo-referencing of city maps, which do not have a regular coordinate system grid included. The reference points can be taken from GPS receivers, where the coordinates are given in Longitude – Latitude (WGS84). Additional points can be written out of 1:20,000 or 1:50,000 scale paper maps, which usually use a metric coordinate system like UTM and a local Datum. CATCHit will automatically transform all the reference points into the coordinate system that will be used as coordinate system for the scanned map.

Vector tools

Vectors plus attributes are an important way to store geographic information. Most of the time the vector information is taken out of scanned paper maps. The extraction process is called digitization.
CATCHit serves the following digitization tools for vector creation and handling:
Creation of points, lines, poly-lines and closed polygons, with or without attributes
Move point or line
Add new points / remove point
Continue the digitization at the end of an existing poly-line
Break a poly-line or polygon into two parts
Combine two poly-lines to one seamless poly-line
Open / Closed poly-/ polygon conversion
Change of attribute
Change of line color, width and style
Import of and export to standard vector file formats

Automatic vector to raster conversion

Terrain Data information can be stored in vector or in raster (grid) format. Most RNP applications are grid based tools, because of the faster access to the geographic information at a certain point. Therefore it is often important to convert vector information into raster data. CATCHit serves an automatic process for the vector to raster conversion.

Interpolation of DTM's using a ray tracing algorithm

A Digital Terrain Model (DTM) in raster format stores the height above sea level as information. It is the most important terrain data layer for RNP analysis. Still 90% of the DTM's are created out of paper maps, using digitized contour lines and elevation points as source. These contour lines and elevation points are stored in vector format. The height between the contours has to be filled using interpolation methods. CATCHit is using a ray-tracing algorithm for the interpolation of DTM's. Its special source data access ensures the creation of a seamless DTM without needing much RAM, even if the target area covers several map sheets.

Demographic Data Processor

Demographic data, like total population, population divided by male/female, or number of income is very useful in RNP's daily work. Such kind of data is typically available on the market in vector format. The demographic information is always related to some areas like zip- code or district area. These areas cover not only built up areas but also contain forest, open land or water. If the demographic information were equally distributed over the entire zip code or district area, the digital model would simulate that people are living in the forest, lake or on agricultural land. This simulation doesn't represent the real situation.

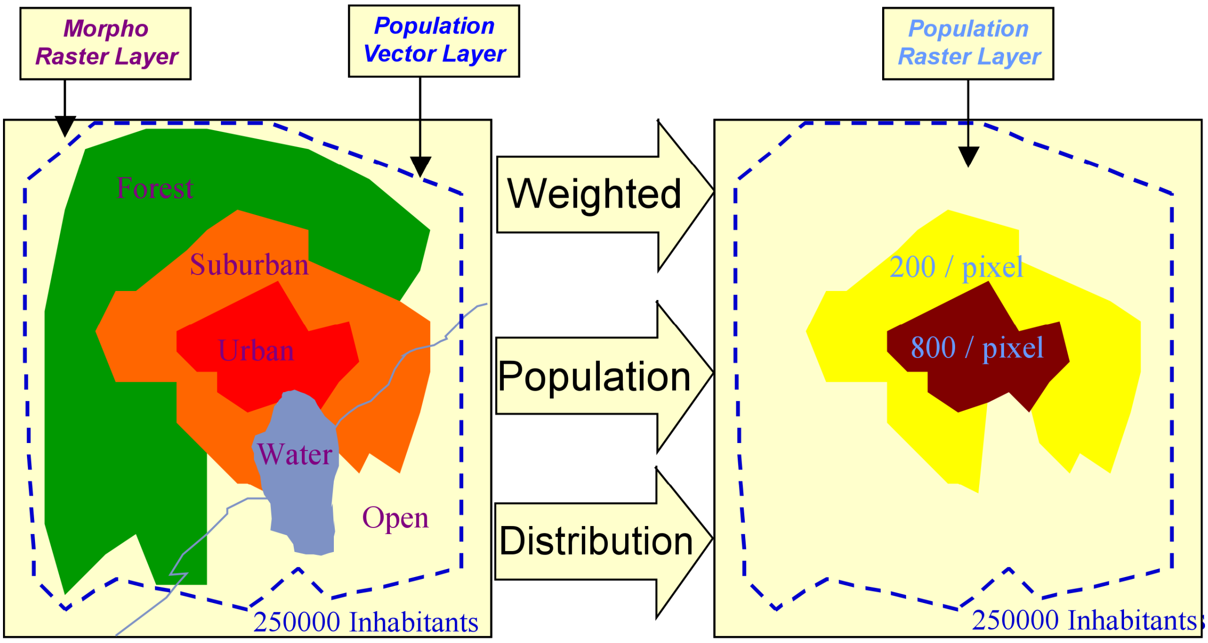


Figure 1.6.10: Weighted distribution of demographic information in populated clutter areas

CATCHit offers a special processor for the distribution of the demographic information that comes closer to the reality. The processor uses a clutter map for the detection the populated areas. The demographic information will be distributed only in these areas. Additional weighting coefficients for each clutter class allow the creation of different scenarios, like daytime and nighttime.

Terrain Data Conversion

The "standard file format" did not exist, there are several important file formats on the market. Therefore it is important to be able to read this "standard" file formats and convert them into the file format, which can be used by your RNP applications.

<u>Import / Export</u>

CATCHit supports several "standard" file formats for vector and for raster data.
Some supported vector formats are:

- LS telcom ASCII
- LS telcom Binary
- MapInfo TAB
- MapInfo MIF
- Planet

Some supported raster formats are:

- ESRI ASCII Grid

- ESRI ASCII XYZ
- ESRI BIL
- LS telcom Binary Grid
- Planet
- TIF plus TFW or TAB file for coordinate system information

Coordinate System Transformation

Besides the file format conversion, terrain data often has to be transformed to a specific coordinate system. Most countries have their own coordinate system, which is limited by the area of this specific country, International operating data suppliers usually use global coordinate systems for the terrain data like UTM- or geographical projection based on the WGS84 Datum (Mathematical model of the earth).

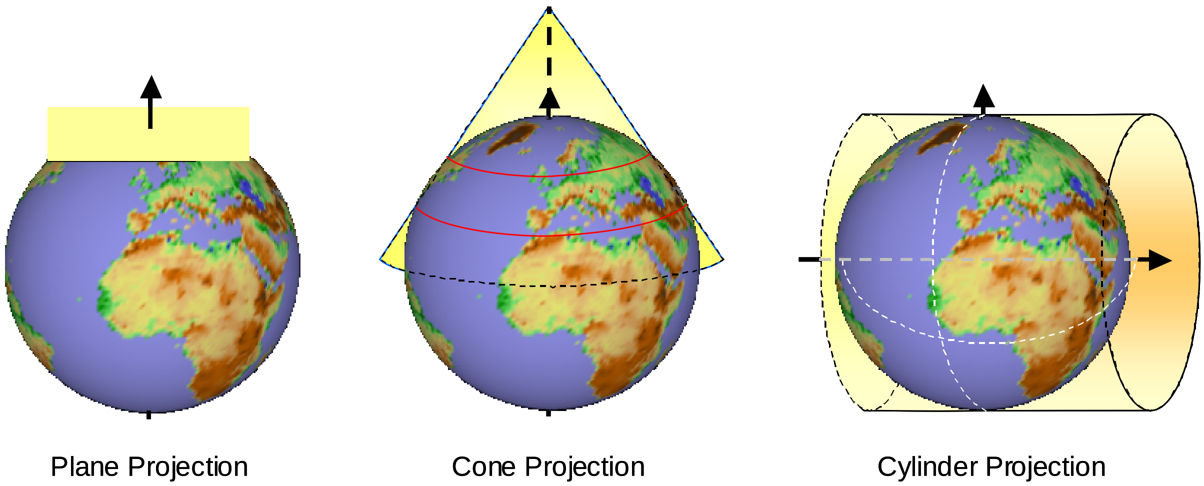


Figure 1.6.11: The main projection categories

A coordinate system transformation is needed in order to store all terrain data layer in one and the same coordinate system. The recent version of CATCHit supports over 600 different local and global coordinate systems and mare than 300 different Datums.

Terrain Puzzler

The file format conversion and coordinate system transformation of huge terrain databases is very time consuming, if one process is done after the other. Therefore CATCHit offers the powerful module "TerrainPuzzler", which is able to perform both processes in one step. Four items are characterizing the main tasks of the TerrainPuzzler

1. File format conversion
2. Coordinate system transformation
3. Merging of different terrain data files and source
4. Change of resolution

These four tasks can be carried out in one step. Sequential read and write allows to handle files that are even bigger than 1 GB. Recently 3 interpolation methods are supported which are used to determine the new value for each pixel of the resulting map layer. The supported interpolation methods are:

- Next neighbour
- Bi-linear

- Cubic convolution

Change Value

Each RNP tool and every data supplier has its own clutter data classification. The numbers of classes available, the categorization of the classes, and the corresponding class numbers, which are used to store the clutter information, are user specific. Therefore new clutter layers always need an adoption of the clutter. This reclassification can be carried out with CATCHit with the "Change value" tool.

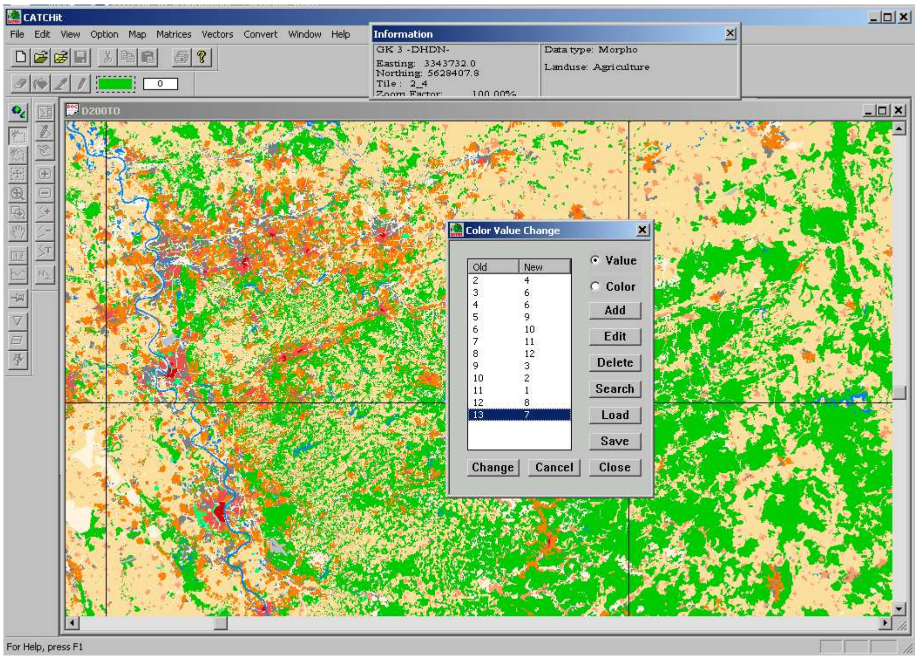


Figure 1.6.12: Change Value – Reclassification of clutter data according to RNP tool specification

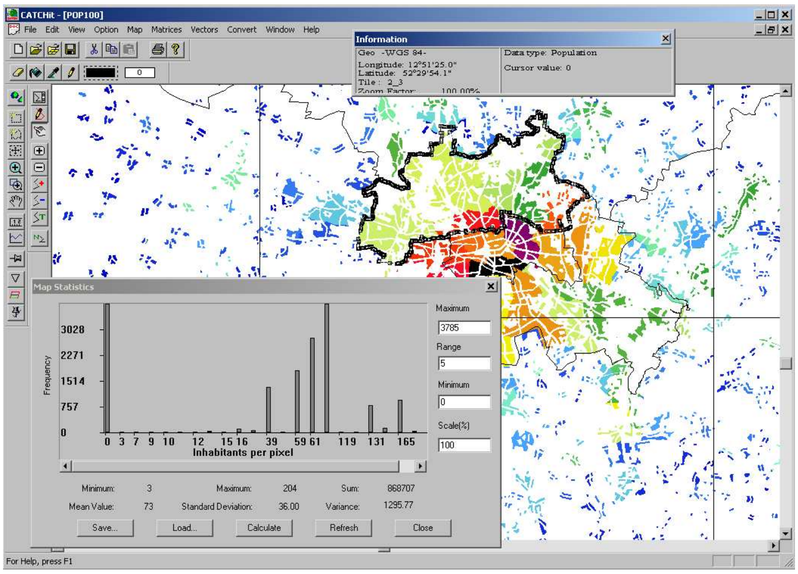
This tool allows searching for every appearing value within a selected area. The found values are listed in a table. Each value can now be changed to another one. This way a correspondence list can be created and stored for later use. The correspondence list can be created in another tool like Excel as well and loaded from a simple text file. Pressing the calculate button will start the change of the values for all pixel within the selected area according to the correspondence list.

Terrain Data Analysis and Maintenance

Every terrain database needs to be maintained. Population is growing. Industrial areas and cities are changing their faces continuously. Since the accuracy of analyses and simulations depends very hard on the topicality of the applied source, it is of utmost importance keeping the sources up-to-date. On the other hand some errors might be detected in the recent terrain data layer, which need to be corrected. Therefore CATCHit has implemented tools for terrain data analysis and maintenance.

Data analysis

For the analysis of a terrain data layer the “Map Statistics” function of CATCHit can be used. It calculates for a selected area the following parameters:
Minimum value, Maximum value, Sum, Mean value, Standard deviation, Variance
The selected area to be analyzed can be limited by a polygonal selection; a 2D-plot shows the value distribution in a graphical way and can be stored in a text file for further analysis in other tools like Excel, etc.



Updates of terrain data layer always need a quality check. Therefore the new version of the layer has to be compared with the old one. CATCHit offers the geo-correct copy and paste tool with mathematical overlay function. The sum or the differences of both data layer can be calculated and colored displayed. This allows a graphical detection of the changes and developments of the new data layer in a graphical manner

Figure 1.6.13: Map Statistics for polygonal selection area in population layer

Data Maintenance

Errors in the terrain database are most of the time difficult to detect but could have great impact on the RNP results. Therefore a tool is needed that allows checking the data of a certain suspected area pixel by pixel. CATCHit offers a “Window as Table” tool. The pixel values are written in a table view of a 10 x 10 pixel big area. The coordinates area displayed besides the table elements and can be changed to any coordinate system that is valid for this area.

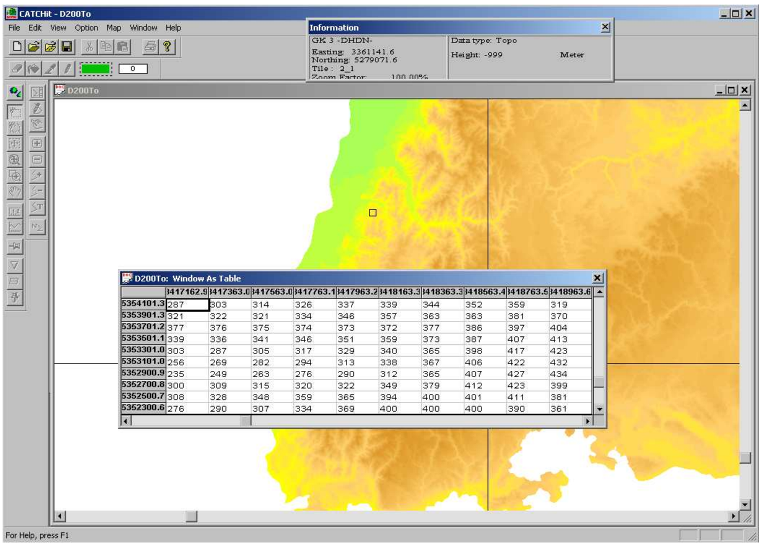


Figure 1.6.14: “Window as Table” view of the terrain data with coupled selection area

The table area is directly coupled with the map layer. The values can be changed within the table. Changes will automatically be updated within the map window.

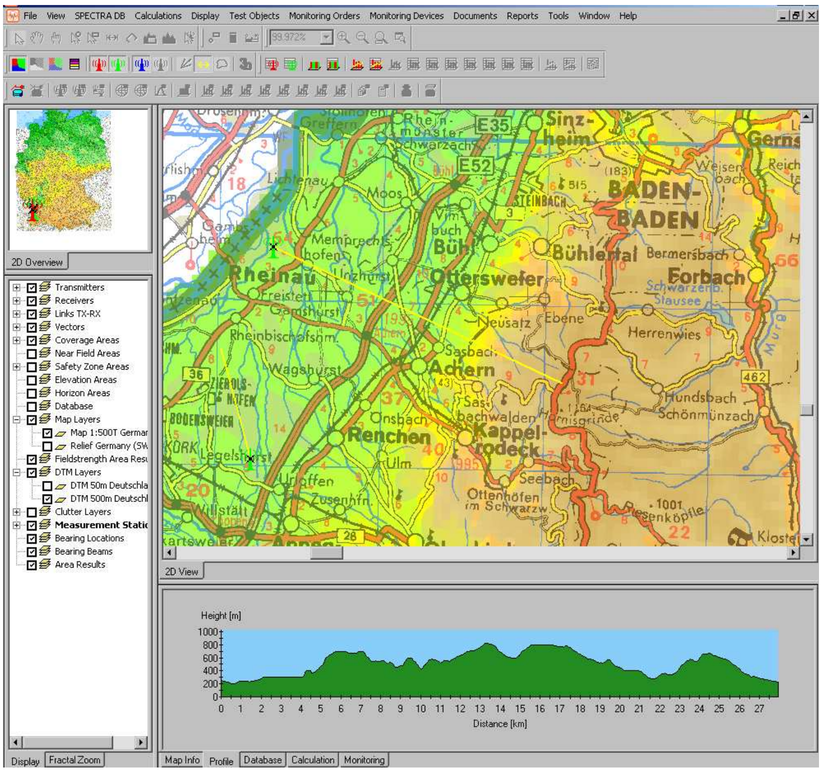
SPECTRAemc

SPECTRAemc is a comprehensive and easy to use visualization and calculation tool providing additional interface to different contemporary database systems. It enables the user to perform EMC calculations and general network planning tasks in conjunction with a powerful wave propagation calculation library for intra and inter radio service applications.

Features and Highlights

SPECTRAemc includes the following main functions:

- Selection of licensed transmitters/receivers from a central database
- Visualization of the selected transmitters/receivers on a map
- Access to the properties of the selected transmitters/receivers
- Various calculations based on the on board wave propagation library
- WAVE PROPAGATION LIBRARY: including specially tuned wave propagation models for the complete radio frequency range from VLF to EHF (3 kHz - 300 GHz)



- Field strength calculation at a single point or in an area
- Calculation of coverage areas, contours, safety zone and near field
- Interference analysis (interference, desensitization, frequency pre-selection and area based analysis)
- Inter-modulation analysis
- Reports on calculation results and selections of technical data based on powerful Crystal Reports templates
- 3D view of DTM maps including transparent overlay with other types of map layers

Implemented ITU-Recommendations

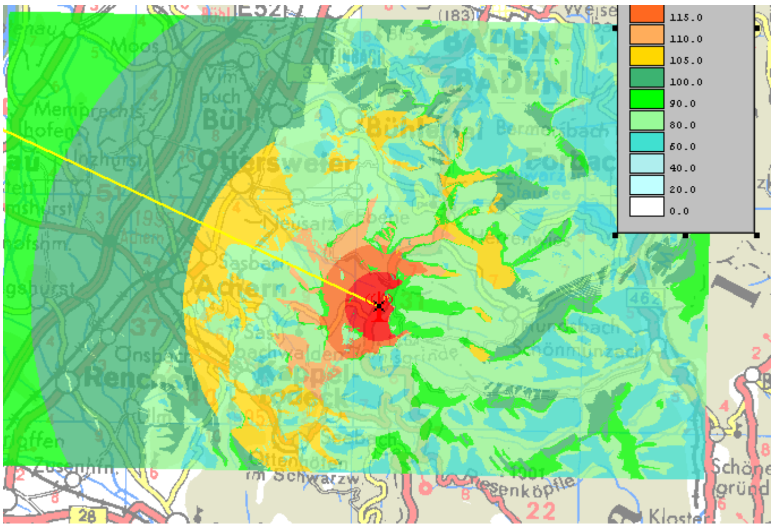
ITU-R SM.1370 SMS
ITU-R P.1546 Terrestrial services
ITU-R P.530 Planning of microwave links
ITU-R P.533 HF propagation
ITU-R P.452 Microwave interference
ITU-R P.676 Atmospheric absorption
ITU-R P.837 Attenuation due to rain
ITU-R P.526 Diffraction mechanism (knife edge)

Terrain Map Database

SPECTRAemc supports both raster and vector maps. Calculation results can be visualized as vectors (such as field strength or interference contours) or as raster data (for example area calculations). Raster or vector calculation results can be overlaid on background maps with an adjustable transparency factor. Several third party map formats are supported.

Coverage Prediction

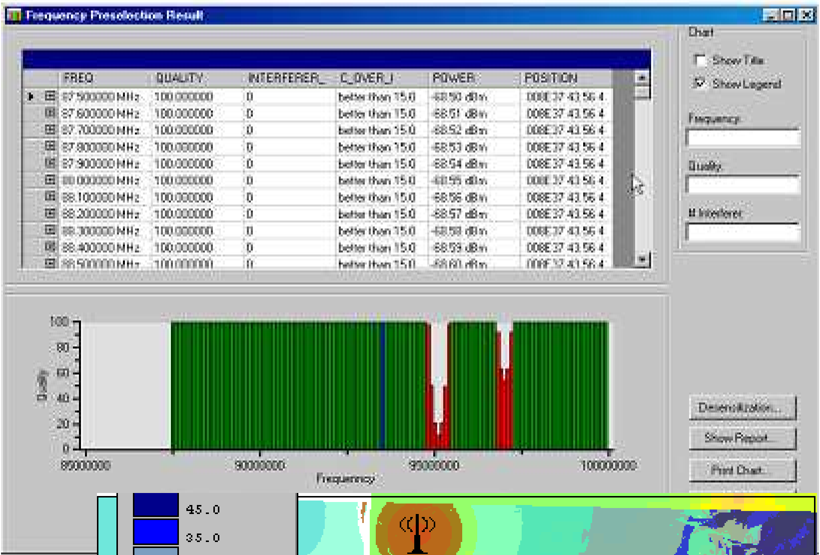
For coverage prediction a variety of propagation modules for the frequency range VLF to EHF are available. The propagation parameters used by the different modules (e.g. rain zone, k- factor, etc.) are user configurable. This includes standard ITU recommendations as well as modules used in GSM, DCS and UMTS services (e.g. Okumura Hata)



Interference analysis

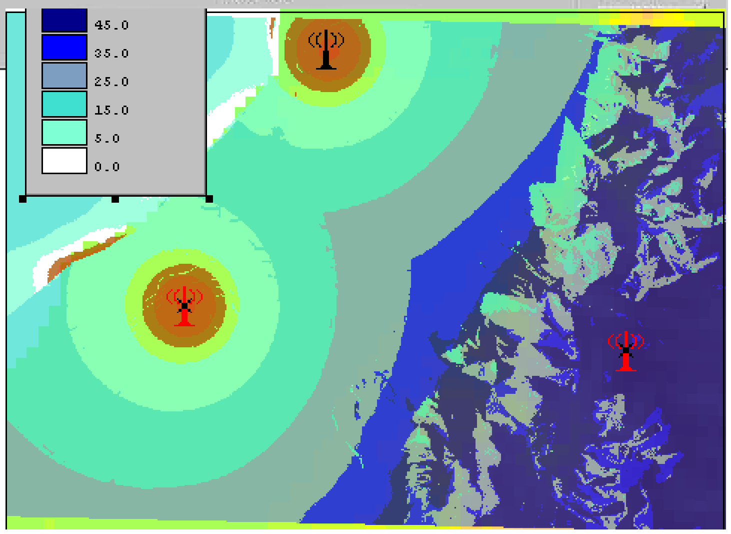
Based on ITU-R SM.1370 interference analysis and frequency assignment within existing networks is done in threesteps.

- Receiver desensitization analysis
- Transmitter noise analysis
- Frequency interference (co-channel, interstitial and adjacent channel or distant channel) analyses



An extensive report on the results is issued for these cases.

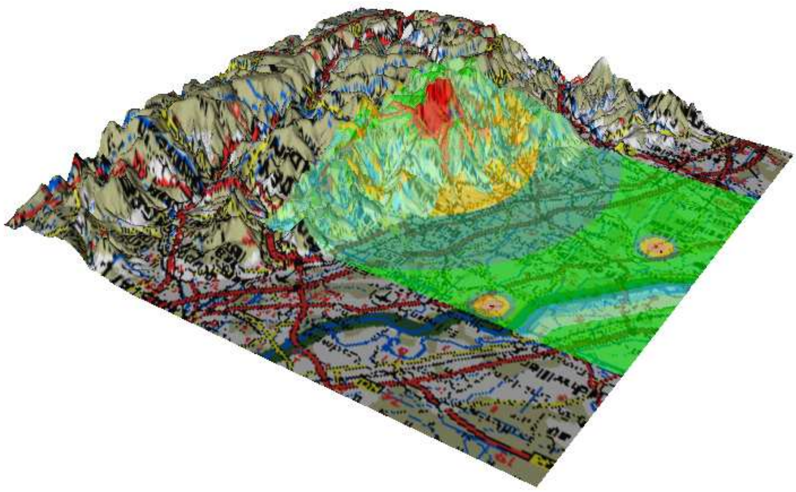
In addition to these results, area based interference evaluation can be calculated, using a typical receiver with user configurable parameters. It enables the user to perform field strength based analysis as:



- C/I evaluation
- Maximum server analysis
- Composite coverage analysis

3D-View

SPECTRAemc offers for a visual evaluation the possibility to display area results on top of terrain data as a 3D-view. Transmitter, receivers and links are displayed also. Using this feature the user can immediately detect areas of interest for a further detailed analysis.



Annex 2 – Case Studies

A selection of most frequent case studies (ie: Network extension, transmission, signalling, migration to NGN, mobile, etc.) is provided in order to illustrate the application process.

List of case studies:

A2.1. Forecasting of services

On the national transit level of a network the volume of services used by the network customers, which transit over the national network, is presented with the national traffic matrix.

For the consolidation of the semi-meshed national transit (LD) circuit switched network, shown in Case Study A2.2, such traffic matrix is constructed and forecasted, using as tool EXCEL.

To construct the traffic matrix data from different sources are used:

- Subscriber traffic per category of populated place, per customer class and per network level
- Measurements of the traffic load on the interexchange trunks and of the traffic interest between different network areas
- Evaluation of the monthly traffic variations within one year

Initial data are the national traffic matrix of the incumbent network operator, extended with the traffic from/to the mobile operators.

Traffic data are formed as 34 x 39 EXCEL table with total traffic of 9120.59 Erlang (see extract in Table A2.1.1).

	TRD_B													
TRD_A	**Sliven**	**Smol**	**Sofia**	**SPRINT**	**St. Zag**	**STTS**	**Targ**	**Varna**	**VAS**	**V. Tar**	**Vidin**	**Vraca**	**Yambol**	**Grand Total**
Blagoevg	**0,46**	**0,49**	**1,99**	**0,63**	**1,09**	**45,73**	**0,07**	**2,55**	**1,60**	**1,50**	**0,44**	**0,48**	**0,35**	**200.83**
Burgas	**11,43**	**0,71**	**0,98**		**5,84**	**73,04**	**0,29**	**19,94**	**4,40**	**2,04**	**0,12**	**0,30**	**10,06**	**391.78**
Dobrich	**0,24**	**0,14**	**1,11**	**0,17**	**0,45**	**23,85**	**0,19**	**30,57**	**2,09**	**0,85**	**0,07**	**0,76**	**0,26**	**149.99**
Dupnica	**0,02**	**0,08**	**0,32**	**0,35**	**0,03**	**13,51**	**0,04**	**0,11**	**0,79**	**0,01**	**0,67**	**0,10**	**0,05**	**63.51**
Gabrovo	**0,44**	**0,13**	**0,41**		**2,99**	**23,67**	**0,35**	**3,40**	**2,24**	**11,63**	**1,37**	**1,11**	**0,15**	**133.88**
GLOBUL	**2,47**	**1,84**	**3,95**		**5,50**	**32,34**	**1,00**	**7,70**		**2,74**	**1,87**	**1,88**	**2,43**	**133.44**
Haskovo	**0,96**	**2,52**	**1,39**	**0,18**	**7,38**	**24,88**	**0,02**	**2,76**	**2,60**	**1,63**	**0,49**	**0,59**	**0,90**	**180.84**
International	**10,98**	**2,88**	**8,20**		**16,48**	**109,58**	**3,77**	**25,82**		**8,98**	**7,62**	**7,54**	**6,53**	**675.16**
Lovech	**0,07**	**0,09**	**2,03**	**0,86**	**1,46**	**30,76**	**0,20**	**1,76**	**2,41**	**5,63**	**0,04**	**1,70**	**0,15**	**137.28**
MOBICOM	**1,99**	**1,91**	**2,27**		**5,25**	**17,68**	**0,75**	**4,69**	**0,01**	**1,94**	**0,65**	**1,32**	**1,90**	**90.45**
MOBILTEL	**6,98**	**6,69**	**12,51**		**12,30**	**165,30**	**4,25**	**28,27**	**0,07**	**14,71**	**5,91**	**10,02**	**5,14**	**602.32**
Montana		**0,12**	**1,24**	**0,05**	**0,52**	**33,61**	**0,06**	**1,99**	**1,56**	**1,01**	**3,46**	**9,80**	**0,54**	**113.47**
Pazardjik	**0,89**	**1,75**	**3,39**	**0,24**	**2,26**	**32,70**	**0,10**	**1,69**	**3,20**	**0,40**	**0,39**	**0,18**	**0,06**	**188.49**
Pernik	0,16	0,14	3,28	0,10	0,58	40,67	0,28	1,49	1,09	0,74	0,35	0,46	0,10	**110.99**
Pleven	0,33	0,07	1,75	0,55	1,38	45,97	0,70	4,87	3,82	14,20	1,90	6,26	0,14	**220.72**
Sliven		0,29	0,32	0,82	9,91	16,10	0,43	3,29	2,14	2,99	0,33	0,29	7,68	**134.14**
Smolyan	0,13		0,17		1,02	12,21	0,30	1,55	0,75	0,24	0,25	0,34	0,10	**69.11**
Sofia	0,99	0,29		0,27	0,78	117,95	0,01	2,20	2,73	1,53	0,11	2,33	0,15	**247.64**
Stara Zagora	11,52	0,71	0,51			39,87	0,24	4,50	2,54	3,25	0,12	0,60	6,77	**243.42**
STTS	19,18	15,53	121,92	5,66	26,34		10,84	68,38	24,19	35,65	18,06	37,65	10,83	**2423.18**
Targovishte	0,39		0,26		0,42	9,01		8,09	1,15	3,20	0,05	0,08	0,56	**81.40**
Vraca	0,63	0,22	3,97	0,58	1,19	44,00	0,11	3,28	3,53	2,74	5,59		0,03	**178.19**
Yambol	3,35	0,06			2,29	12,12		0,74		0,65	0,06			**59.15**
Grand Total	**86,52**	**55,56**	**183,85**	**11,81**	**155,11**	**1349,29**	**41,74**	**296,09**	**85,22**	**150,23**	**55,47**	**94,51**	**64,47**	**9120.59**

Table A2.1.1 Extract from the measured national traffic

Corresponding matrix of traffic interest between network areas with 0 to 1 coefficients is calculated.

The data are rearranged as 27 x 27 EXCEL table to reflect the national network structure.

Also, in this table the total traffic per direction is calculated (see extract in Table A2.1.2).

TRD_A	T_SfA	T_SfB	Blag	Burgas	Dobrich	Haskovo	Kardjali	Pazar	Shumen	Yambol	GSM_SA	GSM_SB	Internat.	Total_Nat	GSM	Grand Total
T_SfA	0.00	0.23	0.07	0.06	0.01	0.02	0.01	0.04	0.01	0.01	0.50	0.50	0.11	0.47	0.42	1124.52
T_SfB	0.23	0.00	0.07	0.06	0.01	0.02	0.01	0.04	0.01	0.01	0.50	0.50	0.11	0.47	0.42	1124.52
Blagoevg	0.35	0.35	0.00	0.02	0.02	0.02	0.00	0.02	0.01	0.00	0.50	0.50	0.11	0.44	0.45	266.48
Burgas	0.22	0.22	0.01	0.00	0.02	0.02	0.00	0.02	0.03	0.06	0.00	0.00	0.05	0.54	0.41	308.04
Smolyan	0.18	0.18	0.03	0.02	0.00	0.02	0.02	0.04	0.01	0.00	0.00	0.50	0.04	0.57	0.39	59.56
St.Zagora	0.17	0.17	0.02	0.06	0.01	0.10	0.03	0.01	0.01	0.05	0.00	0.00	0.05	0.55	0.41	271.61
Varna	0.18	0.18	0.01	0.07	0.13	0.01	0.01	0.01	0.09	0.01	0.00	0.00	0.06	0.55	0.39	425.24
V.Tarnovo	0.20	0.20	0.01	0.03	0.01	0.02	0.00	0.01	0.04	0.01	0.00	0.00	0.06	0.53	0.41	366.18
Vraca	0.33	0.33	0.02	0.02	0.01	0.01	0.00	0.02	0.01	0.00	0.50	0.50	0.06	0.53	0.41	298.57
Yambol	0.20	0.20	0.00	0.17	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.65	0.33	46.68
GSM_SA	0.34	0.34	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.70	0.00	244.47
GSM_SB	0.26	0.26	0.07	0.00	0.00	0.04	0.02	0.04	0.00	0.00	0.00	0.00	0.25	0.75	0.00	302.51
GSM_VT	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	1.00	0.00	49.21
GSM_PD	0.00	0.00	0.00	0.00	0.00	0.16	0.07	0.16	0.00	0.00	0.00	0.00	0.00	1.00	0.00	58.04
GSM_VN	0.00	0.00	0.00	0.14	0.06	0.00	0.00	0.00	0.06	0.04	0.00	0.00	0.00	1.00	0.00	110.56
GSM_SZ	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	1.00	0.00	61.34
International	0.15	0.15	0.05	0.04	0.02	0.02	0.02	0.03	0.02	0.02	0.50	0.50	0.00	0.57	0.43	675.67
Grand Total	766.58	766.58	161.21	181.96	90.45	106.40	52.03	114.61	85.01	64.47	814.98	1024.89	671.23			7828.07

Table A2.1.2 Extract from the traffic interest matrix

The total traffic in this EXCEL table is 7 828.07 Erlang, as far as all internal for the 27 areas traffic is excluded .

Forecasted traffic matrix is based on the measured and rearranged traffic matrix, multiplied with a coefficient K,

K= K1x K2 x K3 x K4 = 1,34

Where,

K1 compensates the traffic measuring method precision : **K1 = 1,05**

K2 is yearly traffic variations (e.g. January compared to July) : **K2 = 1,10**

K3 reflects the subscriber forecast : **K3 = 1,05**

K4 is forecast for the transit traffic growth, based on improved economic situation and lowered tariffs : **K4 = 1,10**

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File Edit View Insert Format Tools Data Window Help

C9 = =1.34*MAT!C9

	M	N	O	P	Q	R	S	T
1	9.35	13.52	10.60	25.44	47.29	48.30	61.83	7.36
2	9.35	13.52	10.60	25.44	47.29	48.30	61.83	7.36
3	0.95	0.65	0.86	1.93	4.84	4.53	4.08	0.52
4	6.01	15.31	0.95	9.53	26.71	5.44	1.92	13.48
5	3.16	0.32	0.19	0.78	40.96	2.32	1.41	0.35
6	0.26	1.29	3.38	11.88	3.70	3.03	1.68	1.20
7	0.18	0.44	2.47	2.33	0.61	1.21	0.53	0.99
8	0.40	1.19	2.35	3.92	2.27	1.43	1.51	0.08
9	0.27	0.22	0.19	1.01	2.00	1.61	1.45	0.14
10	1.71	0.54	0.22	5.30	8.89	39.71	16.24	0.38
11	4.62	3.39	18.73	25.84	18.46	14.49	8.65	5.32
12	7.83	3.96	0.69	4.32	33.84	32.15	2.89	1.64
13	0.00	0.90	0.14	2.12	24.49	9.13	1.54	0.80
14	1.50	0.00	0.39	14.97	4.41	5.35	1.20	10.29
15	0.43	0.17	0.00	1.52	2.08	0.98	0.91	0.14
16	1.06	17.97	1.31	0.00	6.76	11.13	1.94	9.53

Table A2.1.3 EXCEL view of forecasted traffic matrix calculation

The total forecasted traffic is 10 489.6 Erlang (see extract in Table A2.1.4).

Forecasted traffic matrix

TRD	T_SfA	T_SfB	Blagoev	Burgas	Dobrich	Haskovo	Kardj	Pazard	Pernik	Pleven	Plovdiv	Ruse	Shumen	Sliven	Smolyan
T_SfA	0,00	160,72	51,05	40,11	10,26	16,28	4,95	25,43	25,25	44,62	71,67	34,92	9,35	13,52	10,60
T_SfB	160,72	0,00	51,05	40,11	10,26	16,28	4,95	25,43	25,25	44,62	71,67	34,92	9,35	13,52	10,60
Blagoevg	54,43	54,43	0,00	2,39	2,68	2,39	0,22	2,64	5,45	3,95	8,10	0,86	0,95	0,65	0,86
Burgas	49,60	49,60	1,85	0,00	3,66	4,80	0,72	5,10	0,24	2,90	15,77	8,52	6,01	15,31	0,95
Dobrich	16,72	16,72	0,56	2,26	0,00	0,47	0,11	0,37	0,14	1,88	1,54	8,63	3,16	0,32	0,19
Haskovo	17,60	17,60	1,74	3,26	3,39	0,00	13,29	2,83	0,56	1,42	21,69	1,97	0,26	1,29	3,38
Kardjali	6,99	6,99	0,44	1,13	0,30	9,22	0,00	0,94	0,02	0,85	9,77	1,23	0,18	0,44	2,47
Pazardjik	24,18	24,18	3,12	1,61	0,21	0,44	0,78	0,00	0,02	1,42	43,53	3,74	0,40	1,19	2,35
Pernik	29,45	29,45	8,70	0,75	0,04	0,33	0,00	0,51	0,00	1,33	2,09	1,27	0,27	0,22	0,19
Pleven	53,94	53,94	2,39	2,79	1,03	0,69	0,96	1,29	0,71	0,00	12,04	9,04	1,71	0,54	0,22
Plovdiv	83,61	83,61	7,88	16,07	2,65	22,55	11,08	35,89	1,44	9,25	0,00	10,07	4,62	3,39	18,73
Ruse	42,01	42,01	1,31	4,52	7,58	3,41	0,63	0,88	0,21	10,90	9,27	0,00	7,83	3,96	0,69
Shumen	12,38	12,38	0,99	3,33	2,66	0,37	0,22	0,55	0,69	1,46	4,24	9,95	0,00	0,90	0,14
Sliven	11,00	11,00	1,20	11,33	0,53	1,03	0,16	0,88	0,14	1,32	4,76	1,01	1,50	0,00	0,39
Smolyan	8,30	8,30	1,33	0,77	0,05	0,71	1,11	1,70	0,02	0,73	15,55	0,58	0,43	0,17	0,00
St. Zagora	33,99	33,99	3,38	11,21	1,10	19,97	5,93	2,47	0,56	3,20	29,60	3,43	1,06	17,97	1,31
Varna	56,49	56,49	2,98	22,95	40,89	3,15	1,99	2,25	1,32	10,32	14,97	24,78	27,89	4,73	2,09
V. Tarnovo	51,32	51,32	3,29	7,35	3,24	4,83	0,10	2,07	0,93	30,50	14,16	29,97	10,33	2,42	0,71
Vraca	70,65	70,65	3,23	4,67	1,82	1,17	0,39	3,20	1,32	17,43	6,44	6,36	2,77	0,87	0,64
Yambol	8,12	8,12	0,04	6,97	0,06	0,94	0,07	0,55	0,03	1,20	2,69	0,89	0,13	4,48	0,09
GSM_SA	78,40	78,40	22,59	0,00	0,00	0,00	0,00	0,00	7,73	20,38	0,00	0,00	0,00	0,00	0,00
GSM_SB	78,40	78,40	22,59	0,00	0,00	12,62	5,39	12,74	7,73	20,38	40,03	0,00	0,00	0,00	6,99
GSM_VT	0,00	0,00	0,00	0,00	9,41	0,00	0,00	0,00	0,00	0,00	0,00	23,90	8,44	0,00	0,00
GSM_PD	0,00	0,00	0,00	0,00	0,00	12,62	5,39	12,74	0,00	0,00	40,03	0,00	0,00	0,00	6,99
GSM_VN	0,00	0,00	0,00	21,06	9,41	0,00	0,00	0,00	0,00	0,00	0,00	23,90	8,44	7,66	0,00
GSM_SZ	0,00	0,00	0,00	21,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	7,66	0,00
International	78,91	78,91	24,29	18,12	9,96	8,32	11,26	13,11	5,63	16,00	55,41	34,92	8,84	14,71	3,86
Grand Total	1027,2	1027,2	216,0	243,8	121,2	142,6	69,7	153,6	85,4	246,1	495,0	274,9	113,9	115,9	74,4

Table A2.1.4 Extract from the forecasted traffic matrix

All dimensioning results shown in Case study A2.2. are based on the forecasted traffic matrix, calculated as shown above with the standard features of the EXCEL.

A2.2. Consolidation of national transit network

Consolidation of a semi-meshed national transit (LD) circuit switched network consists of applying of hierarchical routing with dual homing for the transiting of the traffic.

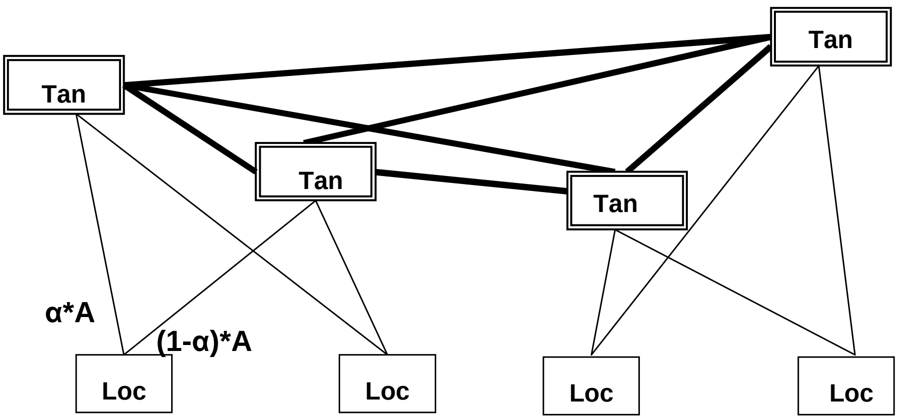
<u>Dual homing (load sharing) :</u>

In the hierarchical routing one option is to overflow/transit traffic through two different tandems (Tan), i.e. to implement dual homing for the source of the traffic (Loc).

General rule is to divide traffic in equal portions, i.e. 50% to 50%.

More universal approach will be to use coefficient **α, 0< α <1.**

Fig A2.2.1. : Dual homing (load sharing)



<u>Dimensioning of the LD network :</u>

Dimensioning of the national LD network consists of routing of the traffic over the hierarchy and dimensioning of each trunk for the required QoS.

A planning tool will be needed for a real practical case, because of the large number of cases and the complicated routing.
PLANITU is appropriate tool for such task.

Main input data are source-destination traffic matrix of the LD network.

Results:

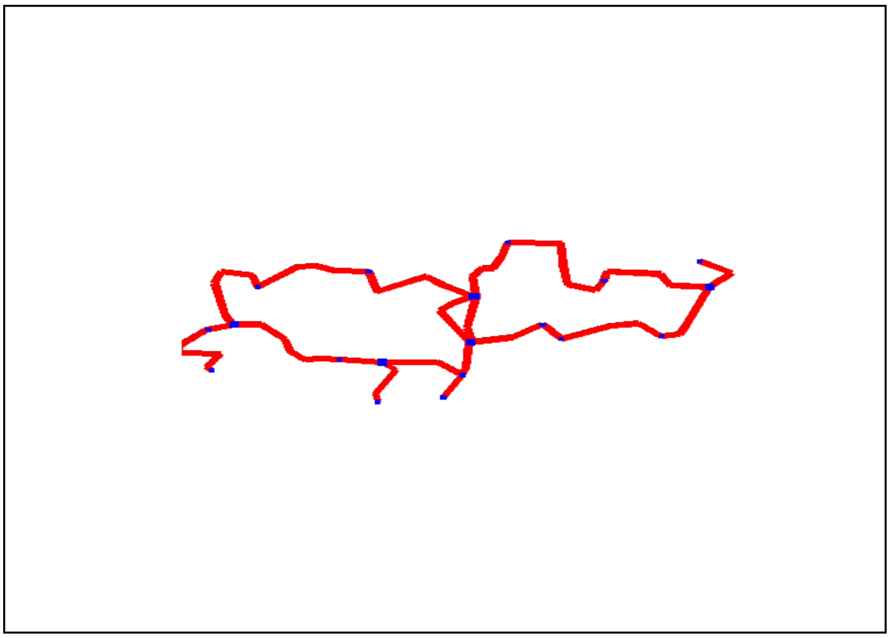
Fig A2.2.2. : Example of routing of traffic and dimensioning of dual homing

```
        Exchange    1      Blagoev

        J  Name        A      M    V/M     Circs  Avl    Cong     Total    Routing

        1  Blagoev    0.00   0.00  1.00       0     0    0.000    0.000     D
        2  Pernik     5.45   5.45  1.00       0     0    1.000    0.004     T 26 27
        3  Vratza     4.08   4.08  1.00       0     0    1.000    0.009     T 26 27
        4  Pleven     3.95   3.95  1.00       0     0    1.000    0.004     T 26 27
        5  Pazarjik   2.64   2.64  1.00       0     0    1.000    0.007     T 26 27
        6  Smoljan    0.86   0.86  1.00       0     0    1.000    0.008     T 26 27
        7  Haskovo    2.39   2.39  1.00       0     0    1.000    0.012     T 26 27
        8  Kurdjali   0.22   0.22  1.00       0     0    1.000    0.007     T 26 27
        9  Ruse       0.86   0.86  1.00       0     0    1.000    0.004     T 26 27
       10  Dobrich    2.68   2.68  1.00       0     0    1.000    0.005     T 26 27
       11  Shumen     0.95   0.95  1.00       0     0    1.000    0.012     T 26 27
       12  Sliven     0.65   0.65  1.00       0     0    1.000    0.005     T 26 27
       13  Jambol     0.52   0.52  1.00       0     0    1.000    0.005     T 26 27
       14  Burgas     2.39   2.39  1.00       0     0    1.000    0.013     T 26 27
       15  GSM_SA    80.83  80.83  1.00       0     0    1.000    0.006     T 26 27
       16  GSM_SB    80.82  80.82  1.00       0     0    1.000    0.014     T 26 27
       17  GSM_VT     0.00   0.00  1.00       0     0    1.000    0.004     T 26 27
       18  GSM_PD     0.00   0.00  1.00       0     0    1.000    0.008     T 26 27
       19  GSM_VN     0.00   0.00  1.00       0     0    1.000    0.009     T 26 27
       20  GSM_SZ     0.00   0.00  1.00       0     0    1.000    0.003     T 26 27
       21  Intern    39.54  39.54  1.00       0     0    1.000    0.003     T 26 27
       22  Tr_C_VT    4.53   4.53  1.00       0     0    1.000    0.004     T 26 27
       23  Tr_C_PD    8.10   8.10  1.00       0     0    1.000    0.007     T 26 27
       24  Tr_C_VN    4.84   4.84  1.00       0     0    1.000    0.005     T 26 27
       25  Tr_C_SZ    1.93   1.93  1.00       0     0    1.000    0.002     T 26 27
       26  TrC_SfA   54.43 178.55  1.00     210     0    0.002    0.002     D
       27  TrC_SfB   54.43 178.55  1.00     210     0    0.002    0.002     D

        Total:                            420     0
```

Fig A2.2.3. : Dimensioning of the LD network

	SF-A	SF-B	BL	PK	VR	PL	VT	RS	VN	DB	SH	BS	YA	SL	SZ	HS	KD	PD	PZ	SM	Σ
SF-A		870	150	60	150	150	150		180						120			150			1980
SF-B	870		150	60	150	150	150		210						120	90	60	210	120	60	2400
BL	210	210																			420
PK	90	90																			180
VR	240	240																			480
PL	240	240																			480
VT	150	150						180	240	60	60				60			60			960
RS							240		240												480
VN	180	180					150	180		120	90	150	60	90	240			60			1500
DB							90		150												240
SH							90		120												210
BS									240						240						480
YA									60						60						120
SL									90						120						210
SZ	120	120					60		210			150	60	90				90			900
HS		120																150			270
KD		90																90			180
PD	150	360					60		90						90	90	60		120	60	1080
PZ		120																150			270
SM		60																60			120
Σ	2250	2850	300	120	300	300	990	360	1830	180	150	300	120	180	1050	180	120	1020	240	120	12960
DIE	420	420					60		60						60			90			1110

Fig A2.2.4. : Transmission layer of the LD network



The consolidation of the national LD network results in:

- transition from semi-meshed towards dual-homing network structure
- more robust and reliable traffic handling and routing
- simplifying the network management
- readiness for smooth transition towards Class 4 NGN solutions, deploying MGW in the location of the existing upper level transit exchanges.

A2.3. Business planning

Application of STEM

A2.3.1. Problem of network evolution and study case scope

- One of the most common planning issues today in mobile networks is the design of network migration from the 2G technology and capabilities towards the 3G technology and associated services. In particular, decisions have to be taken on the target network and technology to evolve, the adequate timing for the migration, the policy to introduce new services and the estimate of the expected investments and profitability.
- The main objective of this case study for a reference medium developed country was to characterize the involved parameters in the evaluation for an scenario that has already a GSM solution with an intermediate level of penetration in the population, the impacts of the migration and the assesment on an evolution either towards and intermediate solution like the EDGE or towards a full 3G UMTS.
- In order to assess convenient migration alternatives, estimate needed investments for infrastructure modernization, project revenues, project NPV and business feasibility; a techno-economic modeling was performed and later implemented with the STEM tool as described in following sections.

A2.3.2. Modeling scenarios for business analysis

This evaluation contemplates the overall market size of the country with the corresponding weighted average values for each business parameter. In order to have enough observation period for the migration from 2G to 3G, business evaluation is performed in a 10 years time frame from Y1 up to Y10. Consolidated reference inputs from the network correspond to the year Y0 and evaluation starts in an initial population around 3 Million inhabitants and growing at a cumulative rate of the order of 2, 5% per year. Current mobile services penetration is low as compared to similar countries in development and a large space exist for new customers grow that will more than double in the 10 years period.

From the processing of the geographical information in the country, 3 type of geo-scenarios are defined on the base of population, area, population density, subscribers penetration, number of current radio cells and traffic per subscriber: Urban Type comprising the nucleus or major cities with high/moderate values of previous variables, Suburban type including cities or areas with medium/low values and finally Rural type with very low values of those parameters. This characterization will imply a differentiation in the modelling of the mobile infrastructure, number of sites and related costs.

According to the case study objectives, two migration scenarios are evaluated in order to know the impact of investments and revenues in the evolution:

- Case A as a conservative plan evolving to EDGE within the 900 MHz and 1800 MHz frequencies and the services and Quality that may be carried according to the possible Peak Rates and Sustained Bit Rates in this technology. This will save investments in the infrastructure mainly in low density regions but still will be able to serve many of the new data services with low and medium speed.
Additional services to be handled in EDGE as compared to GSM/GPRS include data up to 144 Kbps peak rate, audio streaming, video download, video messaging, news, location based services, etc.

- Case B as a more ambitious plan to exploit all potential in new multimedia services with higher capacity in voice traffic and higher Peak Rates, Sustained Bit Rates and Quality in data but implying higher investments in infrastructure and new frequency assignment in the 2GHz band. This option will generate additional revenues mainly from the high data rate services and real time multimedia services that require high Grade of Service
Additional services to be handled in UMTS as compared to GSM/EDGE include data up to 384 Kbps or 2 Mbps peak rate, video calling, video mailbox, intranet/extranet, enhanced quality news, enhanced location services, videoconferencing, enhanced video streaming, mobile TV, etc.

From the point of view of traffic flows consideration and taking into account the confluence of a multimedia environment, the following modelling was developed:

- Packet mode flows are characterized both by the Peak rates and Sustained Bit Rates (SBR) that are used to define which services may be handled. Sustained Bit Rate is defined as the bit rate of a service that may be carried in a sustained manner by the network resources with the fulfilment of the Grade of Service conditions required by that service in terms of packet delay, jitter and loss probability. Period for measurement of SBR is typically 5 minutes. SBR is also used as the link between the information flow for dimensioning purposes and the information volumes that generate service revenues. It has to be noted that SBR for each service is lower than the peak rate with a proportion that is a function of the service or service class characterization.

Dimensioning of the upper layer network resources follows the standard circuit mode or packet mode criteria as a function of the origin/destination traffic flows and is equivalent for all scenarios under analysis.

When analyzing migration scenarios to different radio type solutions, access dimensioning requires special care to ensure validity of the comparisons and the following criteria have to be taken into account for the number of base station sites in all technologies: GSM/GPRS, GSM/EDGE, UMTS and CDMA:

- a) Coverage dominated by Frequency of the radio system used, that decreases the radius with a quadratic relation to the frequency.

- b) Coverage dominated by Bandwidth of data services to be provided that are very sensitive to the signal to noise ratio and specially for the upper radio signal. This condition being more restrictive that the previous one and also with a quadratic behaviour is common to all technologies under consideration.

- c) Coverage dominated by Topography as a function of the terrain conditions of each area to be covered and very dependent of each particular region. This coverage is to be considered jointly to the previous ones and may be modelled with some extrapolation on the basis of the existing network.

- d) Coverage dominated by Voice Traffic capacity measured by the capacity in erlangs of each cell for a given grade of service. This criterion is a function of the service mix in the area and number of subscribers.

- e) Coverage dominated by Data Traffic capacity measured by the capacity in Sustained Bit Rate of a given service type or service class that ensures the agreed Grade of Service. This criterion is the most restrictive one in the IMT-2000 systems as both capacity in Mbps and signal to noise ratio by the distance to the source are applicable. Special care has to be taken to ensure the service level agreement (SLA) in all the cell area and not only in the close vicinity to the BS. This criteria has a quadratic behaviour and is frequently the most critical to fulfil in a mature network, being dominant when traffic of high speed real time services have to be provided in all CDMA based technologies.

The overall BS dimensioning is a combination of the previous 5 factors according to each geo-scenario type and has the following combined effects:

In a high density area of urban type the design at the start year is already dominated by the capacity in erlangs of the GSM solution with an initial cell radius in the order of magnitude of 1 to 4 km and no increase of BS is needed for the radio frequency. An initial saving is obtained due to the higher erlang capacity per site in 3G that nevertheless has the counterpart of an increase that is required by the high speed data services. The final effect is a slight increase of sites.

In a medium density area of suburban type**,** existing design at start has cell radius between 4 and 10 km and the same combined effects appear, although the capacity saving is lower and the criteria e) for the SBR may imply a significant increase in sites.

In a low density area of rural type**,** existing cell radius larger than 10 km and up to 20 km is common and all the radio coverage criteria are dominant as compared with the erlang capacity one. In theses type of areas, an important increase of sites and investment in infrastructure is needed both for the higher frequencies and the higher service bandwidth/speed rates.

A2.3.3. Business evaluation with STEM tool

The business evaluation of a number of migration scenarios like the ones described above, require powerful tools to be able to implement all dynamic evolution for demand, installed or substituted equipments, associated operation costs, equipment life cycles and all related financial calculations. The tool selected for this case study was STEM, as described in section A 1.3 of this document due to the fact that fulfils all needed requirements. Application is based on a reference transition reference case developed by Analysys.

Network is modelled in 7 STEM resource layers for all elements with significant influence in the business parameters as follows:

- Market segments, customers and services for all demand related flows
- Radio access network for all Base Stations equipment per type of geo-scenario
- Base Station sites for the physical structure and location
- Backhaul transmission from the Base Stations to the core network
- Transport network among high level network nodes
- Core network with the MSC, HLR, RNC, SGSN, GGSN, etc.
- Interconnection to other networks

Business modelling is considered with the associated techno-economical parameters specific to the above mentioned network layers and the ones generic for all projects and country dependent. In those aspects related to new services, traffics, tariffs and trends for the 10 years period, a benchmarking has been performed with leading companies worldwide that already implemented 3G type of solutions. As an indication, a summary of both business and technical assumptions is given below:

- Voice tariffs are today over the average benchmark and are expected to decrease per year due to competition at a rate of 7%
- Data tariffs decrease due to maturity at a rate of 7% per year.
- PSTN and Internet interconnection charge with a decrease of 5% per year
- Hardware equipment costs evolving with a yearly decrease of 7%
- Business to residential customers proportion at the start of the study period is of 1:2
- Business busy hours/days per year of 250
- Residential busy hours/days per year of 360

- Voice traffic and circuit mode data flows are characterized by the traffic in erlangs and loss probability models are applied for the dimensioning of the network resources

- Proportion of traffic in the busy hour in relation to the full day of 20%

- Voice call blocking in the busy hour less or equal than 2%

- Activity user utilization rate in transmission state for the packet mode applications of 10%

- Migration to new solutions stars in the Y2 with few pilot sites in urban and suburban areas opening to the entire network since Y3.

- Churn rate from the existing GSM/GPRS technology and terminals to the 2.5G/3G scenarios is of 20% per year

A2.3.4. Evaluation Results

A high amount of results was obtained within the case study as provided by STEM for all technical, business and financial parameters and special analysis was done with the following ones:

- Evolution of mobile customers demand per main category that will grow at a Cumulative Average Grow Rate of 8%.

- Projection for multiservice traffic flow demands per service class:
    - Voice
    - Data circuit type at very low (V-low spd CS) and low rates (Low spd CS)
    - Data packet type at low (Low spd PS), medium (Medium spd PS) and high speed rates (High spd PS). This last case of high speed only feasible with UMTS technology.

- Projection for capacity requirements per flow class in Packet/s, BHCA, Mbs/s, etc.

- BS, TRX and Carriers per geo area: Urban, Suburban, and Rural

- Operation and maintenance costs

- Main projections for average tariffs

- Overall revenue projection per main user/service types

- CAPEX and OPEX projections

- Financial values and ratios: (Cash flows, NPV, IRR. Etc.)

For illustration purposes a selection of those results are included herewith in order to derive main conclusions and assessment for both scenarios: evolution to EDGE and evolution to UMTS

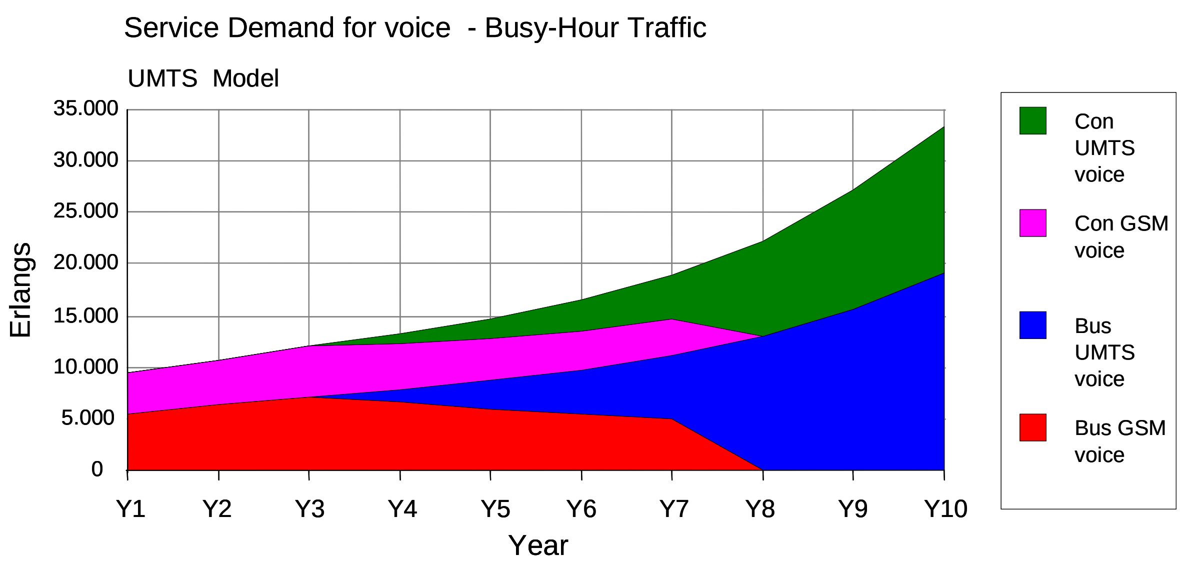


Fig:2.3.1 Service demand for voice at the Busy hour for business and consumer customers

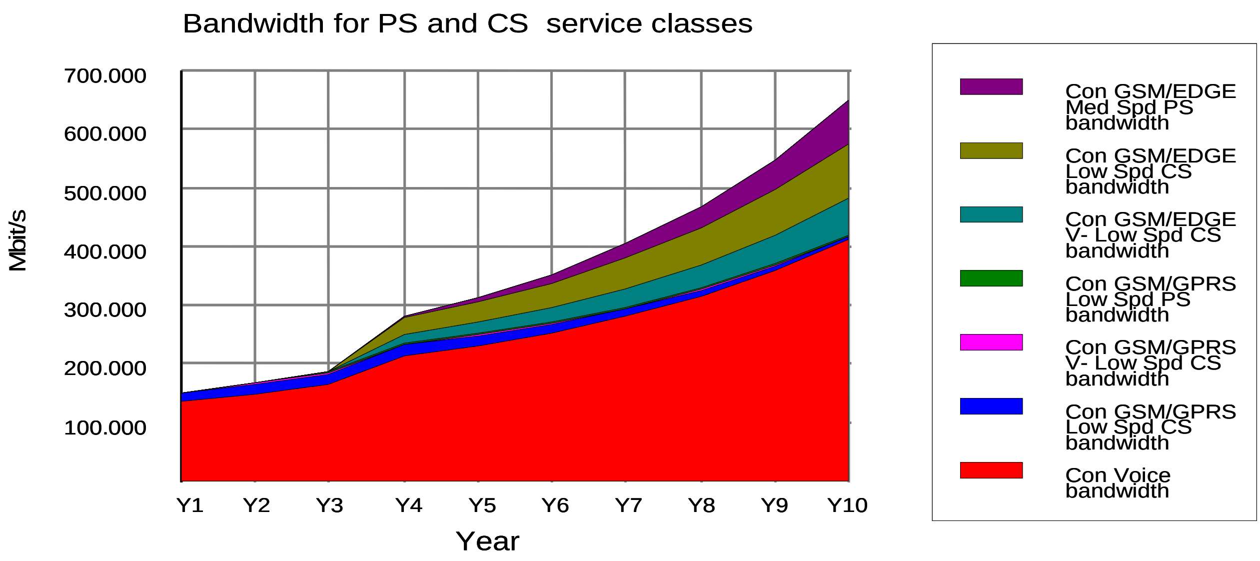


Fig:2.3.2 Bandwith evolution per service class of consumer customers in the EDGE scenario

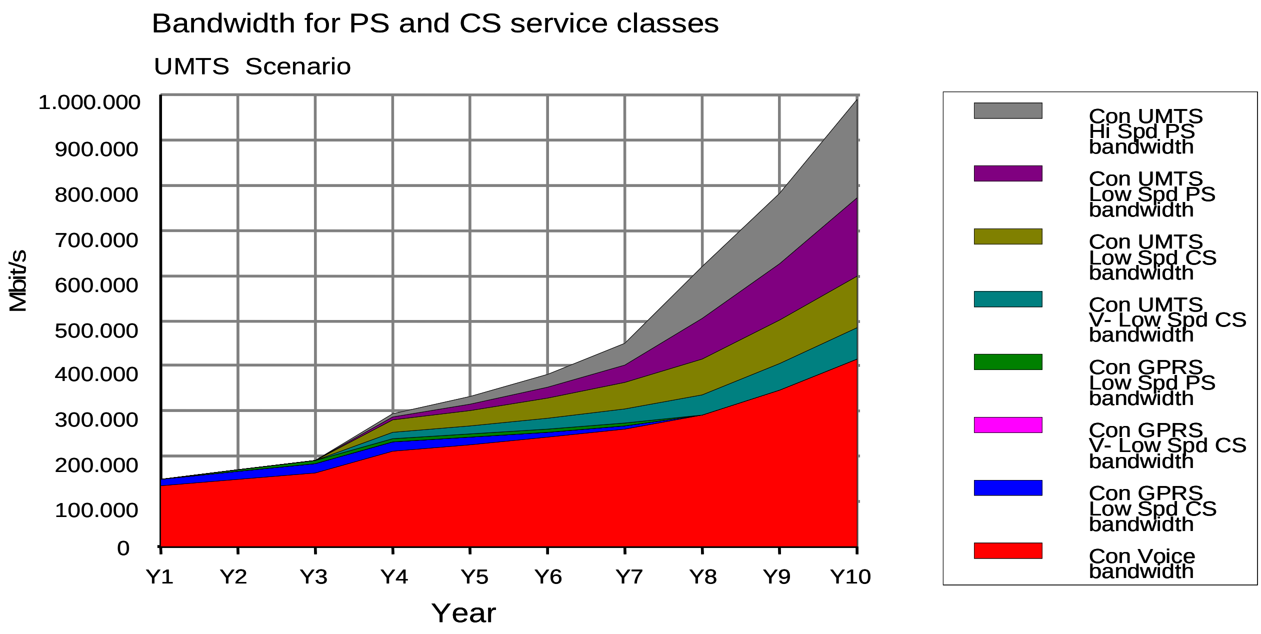


Fig:2.3.3 Bandwith evolution per service class of consumer customers in the UMTS scenario

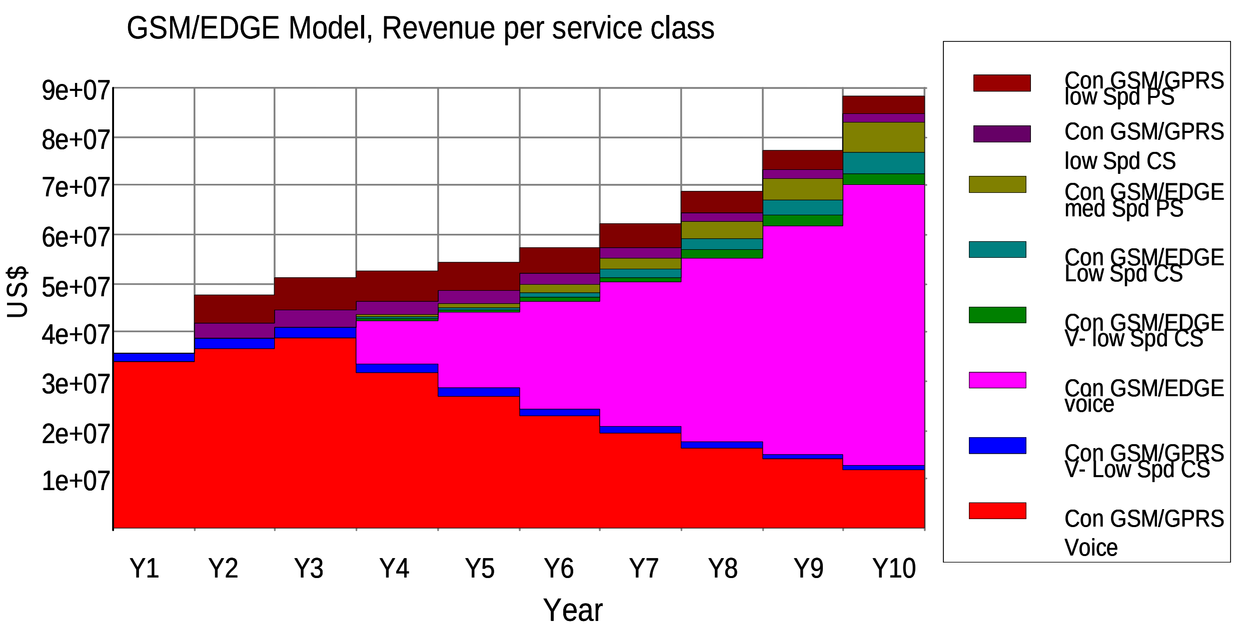


Fig:2.3.4 Service revenue evolution for consumer customers in the EDGE scenario

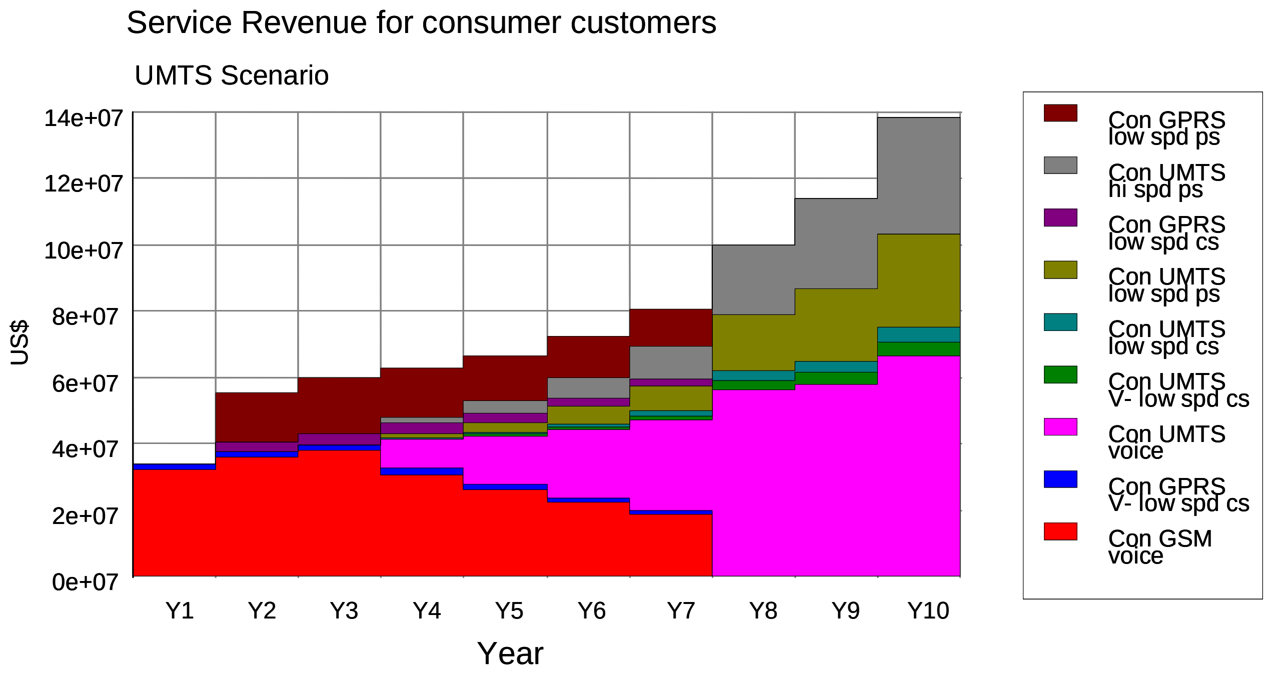


Fig:2.3.5 Service revenue evolution for consumer customers in the UMTS scenario

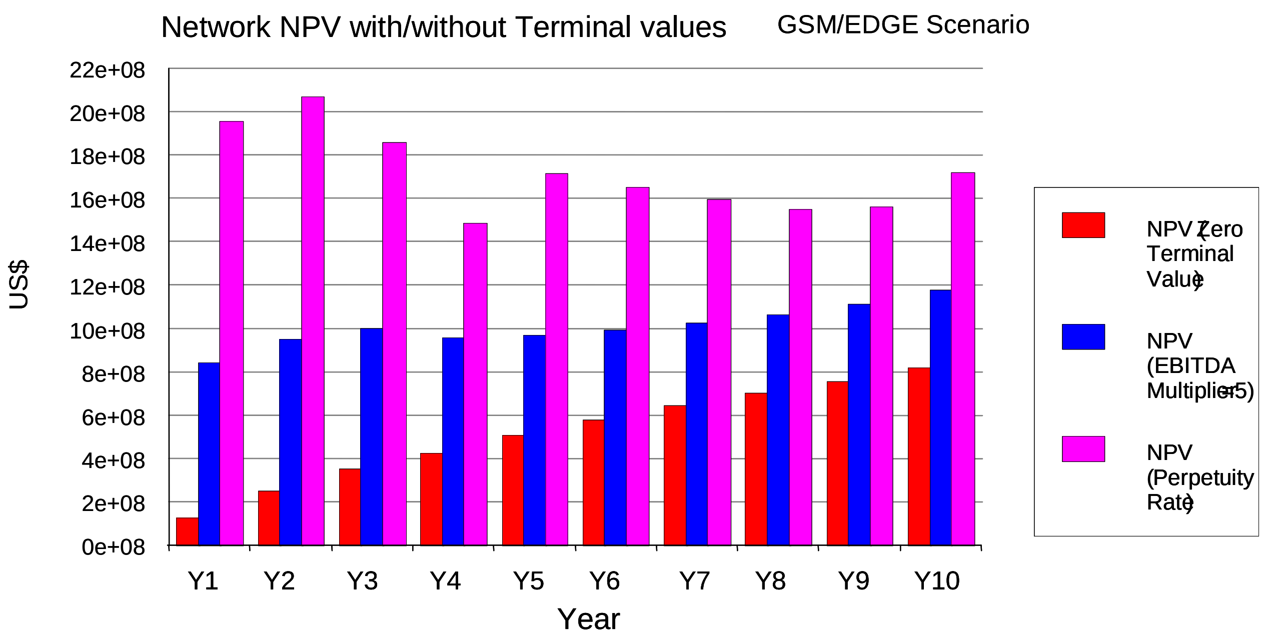


Fig:2.3.6 Net Present Value for the migration case in the EDGE scenario

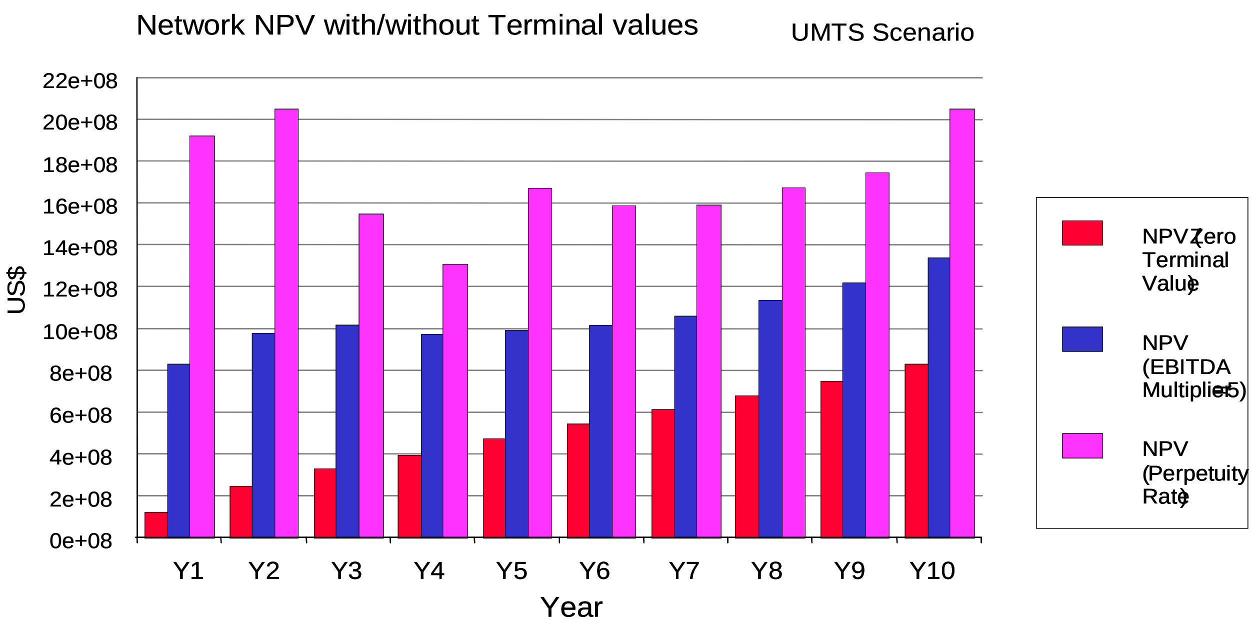


Fig:2.3.7 Net Present Value for the migration case in the UMTS scenario

A2.3.5. Results assessment

- From the analysis of the two scenarios of the study case it is derived that business is feasible in both scenarios with the corresponding economies of scale at the global country market. A simultaneous growth due to customers for better market penetration and to new services with higher bandwidth implies investments and business grow in the two dimensions: Users and Services that implies important investment in infrastructure but facilitates the business feasibility.

- For voice traffic, UMTS solution gives more spectrum efficiency and saving in number of sites for the high density areas of urban type, while EDGE requires less number of sites in the low density areas. In a more detailed observation, important differences appear between the two options from the technical and economical perspectives that are summarized as follows:

  - For data traffic, EDGE solution needs less number of sites at the suburban and mainly at rural areas at the cost of lack of provision of high speed data services and corresponding multimedia applications.

  - For multimedia services (voice+ data +video), UMTS solution facilitates a more efficient integration both at user interface and end to end network as well as an easier operational behaviour. This will favour not only to carry new high speed services but also a higher penetration of the medium speed ones.

- Network revenues at the UMTS solution start to surpass the EDGE ones after Y3 of the migration start up to an advantage of 30% at the end of the period. Profitability in relative terms has the same order of magnitude in both cases as the larger the larger revenues in UMTS are compensated by the larger investment required.

- The NPV behaviour, that provides a good complete vision along the 10 years period, shows network values for medium and long term of for UMTS are higher than for EDGE with the additional advantage of a higher generation potential is in the UMTS case and better capability to converge with other radio technologies like the DVB-H

A2.3.6. Case study summary

- A detailed modelling of the mobile network migration towards 3G was performed for a medium size country with business evaluation of the main factors in a 10 years period.

- Case study shows a series of results to support the decision making in the migration of the mobile network. The main key business factor during the period is the important increase in data services, bandwidth and revenues that will compensate the decrease in voice tariffs and support the business profitability and network modernization to be competitive and satisfy customer demands.

  - EDGE case is more conservative and appropriate for the short term with less financing needs but with less multimedia services and business potential.
  - UMTS case represents a more ambitious decision that requires more investments and operating expenses but also will incorporate more multimedia services and higher capacity to take benefits of convergence at network and access speed quality and revenues, especially at medium and long term.

  Decision to follow requires strategic considerations at each country level but will be straightforward with all provided information in this evaluation plus the consideration of financing capabilities and economies of scale at country level.

- Due to the high number of involved parameters, interrelations and the dynamic character of the migration, a powerful tool is required to be able to analyze scenarios and impact of decisions. In this case STEM tool was used and showed high flexibility in all the process.

  It is strongly recommended to perform periodical business and technical planning (i.e.: every two years) to adjust market assumptions, assurance of new services adaptation to country culture, quick market promotion and terminals compatibility with new applications to avoid delays in the grow of incomes and exploit business potential.

A2.4. Broadband access planning for major cities

According to the described above scenarios for evolution to NGN in the access network planning studies for introduction of xDSL equipment in the main Bulgarian cities of Plovdiv and Sofia have been carried out.

All studies are performed with specialized network planning tool, VPI AccessMaker, which has unique parameters and capabilities.

VPIaccessMaker™ quickly generates business plans and feasibility studies.

The tool captures subscriber information, models different service combinations and technologies and selects the best technology for the task, to calculate ROI, NPV, cash flow, revenue and an optimized roll out strategy.

For the city of Plovdiv it is foreseen to serve business (SOHO and SME) and limited number of residential customers with xDSL equipment.

Three categories of services are assumed - ADSL Basic (256/64 kbit/s) for residential and SOHO customers, ADSL Gold (512/128 kbit/s) and SHDSL (512 kbit/s) for SME customers.

The forecasting results for the possible customers in the period 2003 – 2007 are shown in Table A2.4.1.

Table A2.4.1.

Year	ADSL Basic	ADSL_Gold	SHDSL	Total
2003	**476**	**402**	**132**	**1010**
2004	**946**	**763**	**159**	**1868**
2005	**1416**	**1122**	**184**	**2722**
2006	**1887**	**1481**	**211**	**3579**
2007	**2357**	**1842**	**238**	**4437**

For the period 2003 – 2007 it is assumed to have:100% growth of SOHO customers, 90% growth of SME customers, 10% growth of SHDSL customers.

With the planning tool an optimization of the DSLAM locations is performed. Important condition is to use existing exchange buildings if possible.

Planning results with locations of the DSLAM equipment could be seen on Fig A2.4.1.

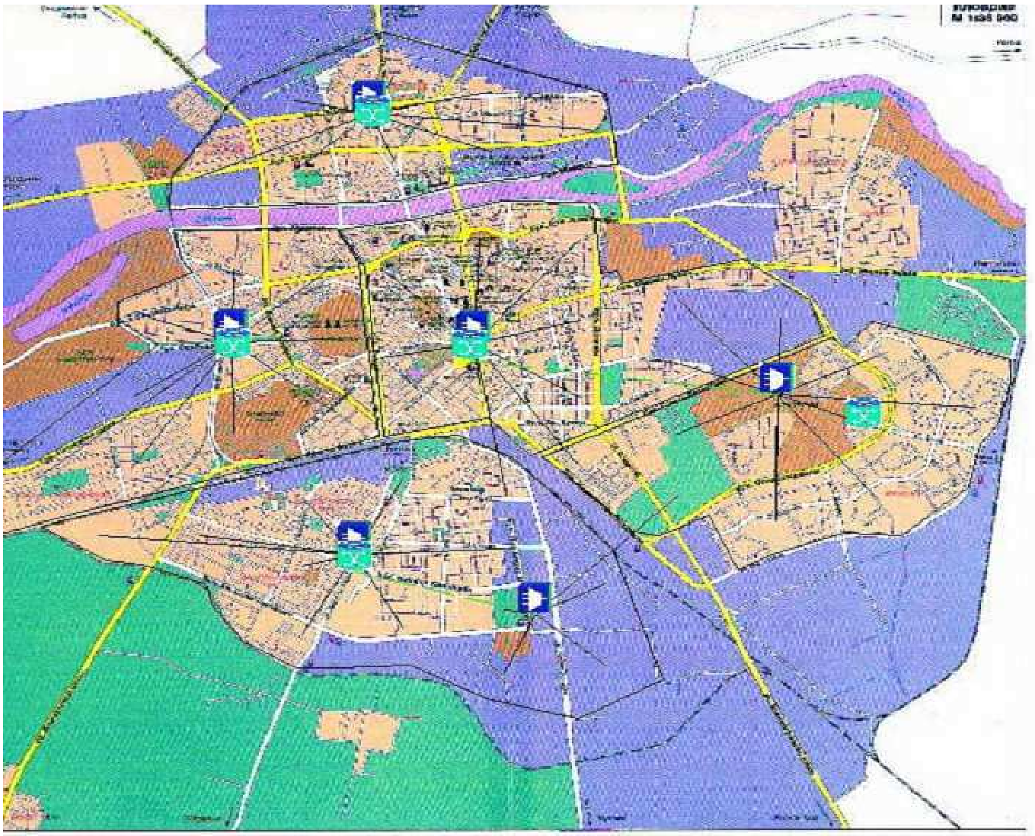
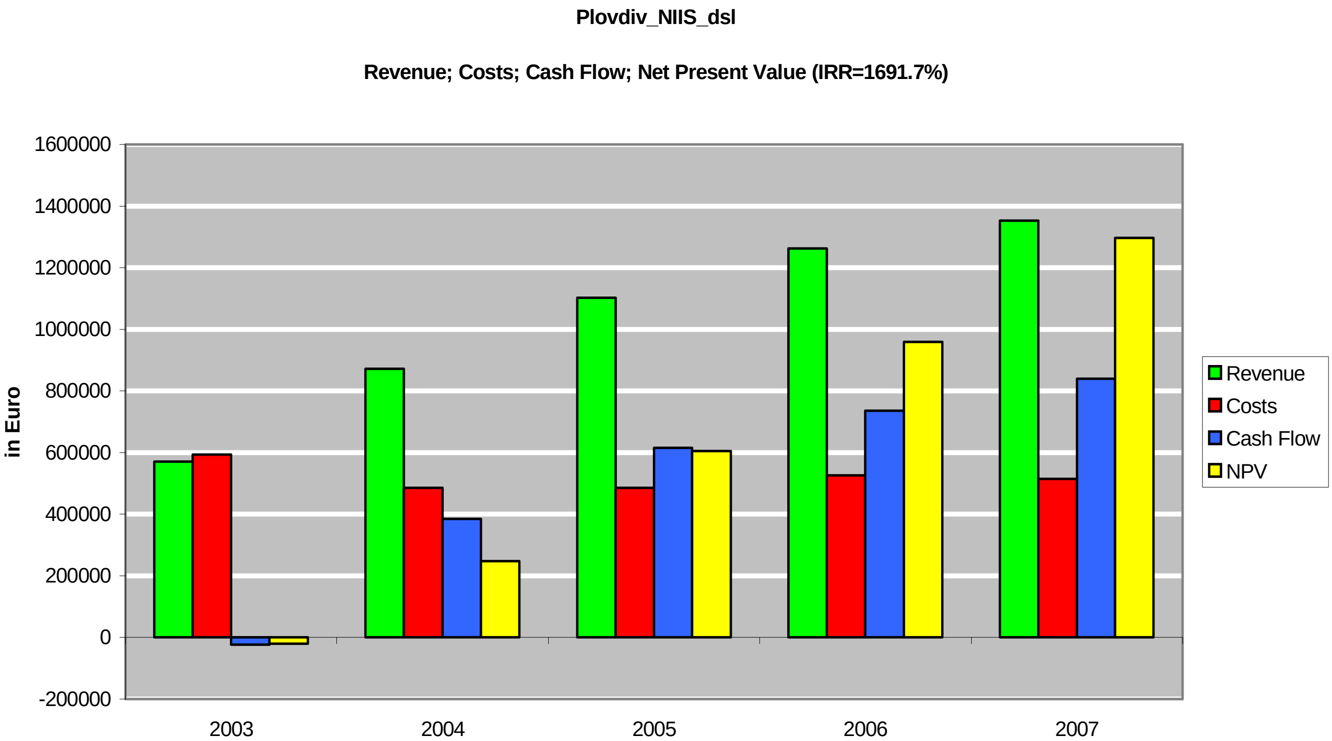


Fig. A2,4,1 Optimized DSLAM locations in Plovdiv

Optimization result shows one DSLAM for each existing exchange area, situated in the exchange building. There is one area, where a second DSLAM will be needed and its location is optimized.

Fig. A2.4.2 Economic analysis of xDSL in the access network of Plovdiv



Planning tool has produced also economic analysis with calculation of costs, revenues, cash flow NPV and IRR, which are shown on Fig. A2.4.2.

For the economic analysis it is assumed 20% decrease of the annual installation fees, 10% decrease of the annual subscription fees and 16% discount factor.

One preliminary study of the city of Sofia was also carried out.

Services to be offered were ADSL-Basic (for residential and SOHO customers), ADSL-Gold for SME customers, SHDSL for business users and FE for Large Enterprises. Forecasted services for the period 2003 - 2007 are shown on Fig. A2.4.3.

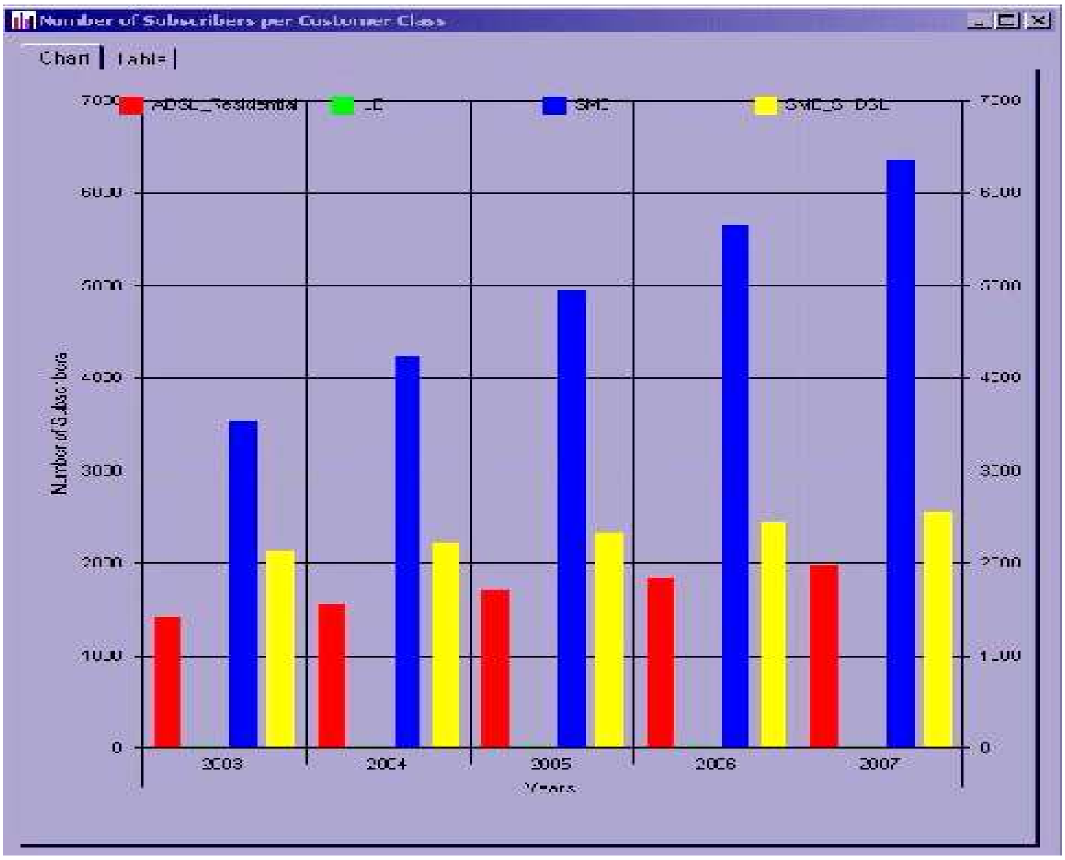


Fig. A2.4.3 Forecasted services for the period 2003 - 2007 in Sofia

Planning results for Sofia with locations of the DSLAM equipment and routers could be seen on Fig A2.4.4.

Network Design is based on xDSL technology with DSLAMs, Routers, FE, GE.

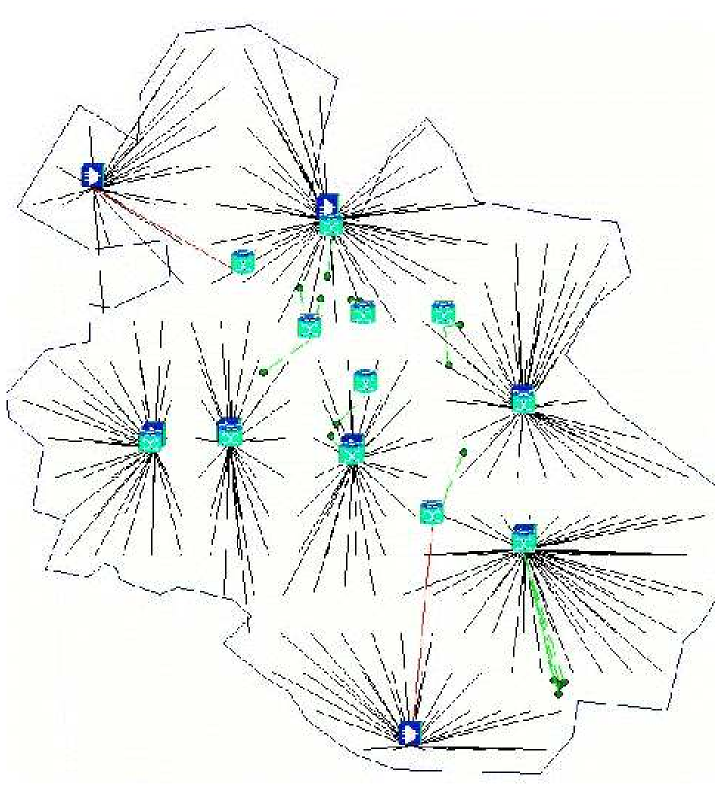


Fig. A2.4.4 Optimized DSLAM and routers locations for Sofia

The optimization result shows that eight DSLAMs could serve the city of Sofia. Locations of 12 routers are also result of the optimization.

A2.5. Voice over IP over WDM

Introduction

This example is meant to demonstrate how one can conduct an integrated network planning across multiple layers and technologies. The example is selected with the consideration that it should represent a typical network planning problem from a nationwide network provider's perspective as realistically as possible. Therefore a representative USA backbone network as shown in figure 1 is chosen as the baseline topology. This topology is used as the underlying physical network where nodes represent traffic generation/switching points and links represent fibers connectivity between nodes. Since there is a real need to model the multi-layer multi-technology complexity of today's telecommunication networks, in this exercise we would like to do a multi-layer network planning: Voice over IP over DWDM. The traffic for the voice over IP service is generated first.

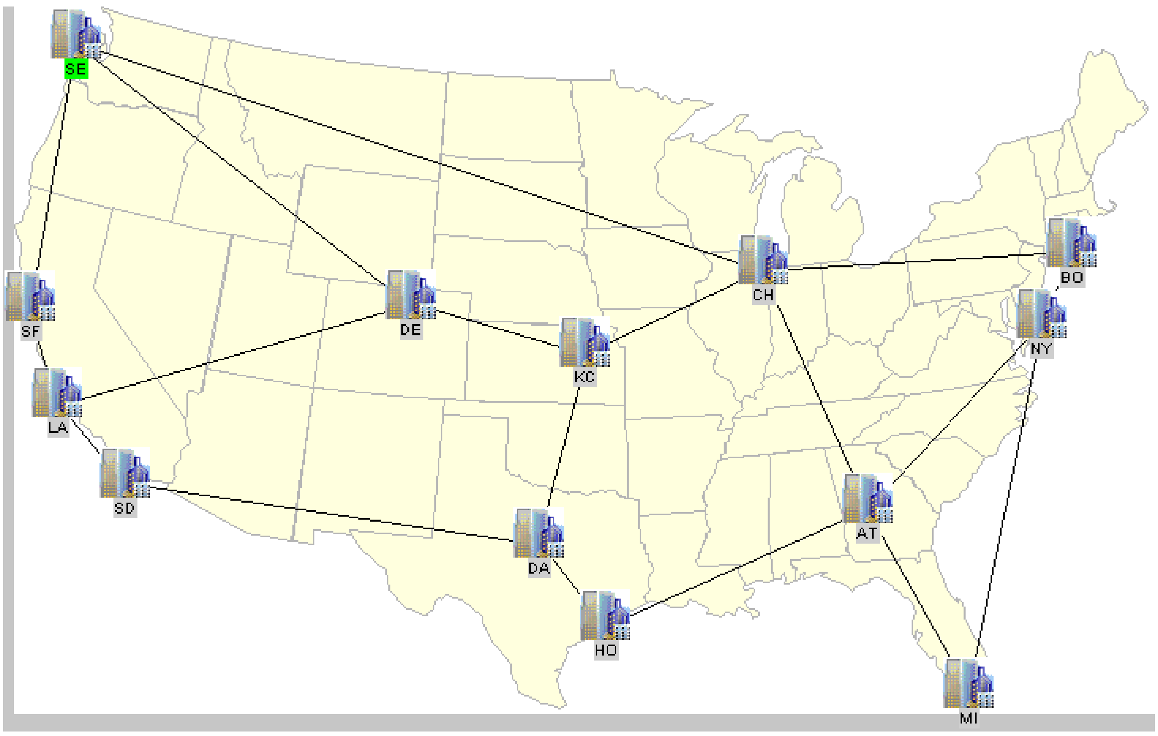


Figure A2.5.1. USA national backbone network

A high speed IP network (with OC192 links) is then planned by incorporating the voice over IP traffic and other native IP traffic such as HTTP, MAIL, FTP etc. Finally the bandwidth pipes of the IP links are viewed as point to point wavelength demands and an optical transport network is designed with switching provided by optical cross connects and multiplexing sections provided by DWDM transmission links. Now the planning of each layer and the inter-layer data exchange are described one by one using the following tools: VPIserviceMaker™IP, VPIserviceMaker™Distribution, and VPItransportMaker™. The IP network design is conducted first by assuming voice over IP traffic matrix available. Then the voice traffic design is performed by VPIserviceMaker™Distribution. Finally, the optical network design is carried out.

IP Network Planning

Since our aim is to plan an multi-layer carrier scale national backbone network, the IP layer network should represent a typical nationwide internet service provider's (ISP) network. Typical ISPs (such as AOL and AtHome) not only provide Internet connectivity services, but also content services. The Internet connectivity services can create both intra-network and inter-network traffic, while content services only create intra-network traffic between users and content servers. Estimating traffic is the first step and a key to network planning. To model the traffic characteristics of such ISPs, we need to consider the following elements:

1. Subscriber population by city.
2. Subscriber usage profile
3. Content servers
4. Intra and inter network traffic percentages.

In terms of types of traffic, we will consider the native IP services such as HTTP, EMAIL, FTP etc., as well as VoIP.

We choose a typical US ISP backbone network as show in figure A2.5.2. with reference to the physical fiber topology as shown in figure A2.5.1. The nodes of the backbone network are points of presence (POP) at all major cities. In this example there are 13 POPs, representing 13 major metropolitan areas as shown in the US map. Each POP may be composed of a number of routers of different types. Here we use only one router icon to represent each POP because what we want to model is the backbone network, not the intra POP structure.

To model subscriber population by city, we create a computer group icon for each city representing all the users served by the ISP in the city. Each computer group is named by adding the suffix NET to the city's name as the computer group also represents the regional access network. We also select a few cities as the locations of content server centers of the ISP and represented by the server icon. Similarly server names are city names followed by a suffix -SVR. To be more specific, the ISP has three web server centers: one in Los Angeles (LA-SVR), one in Denver (DE-SVR), and one in Atlanta (AT-SVR). It has two other server centers to provide other services (FTP, Email, News etc.): one in Chicago (CH-SVR) and one in Dallas (DA-SVR).

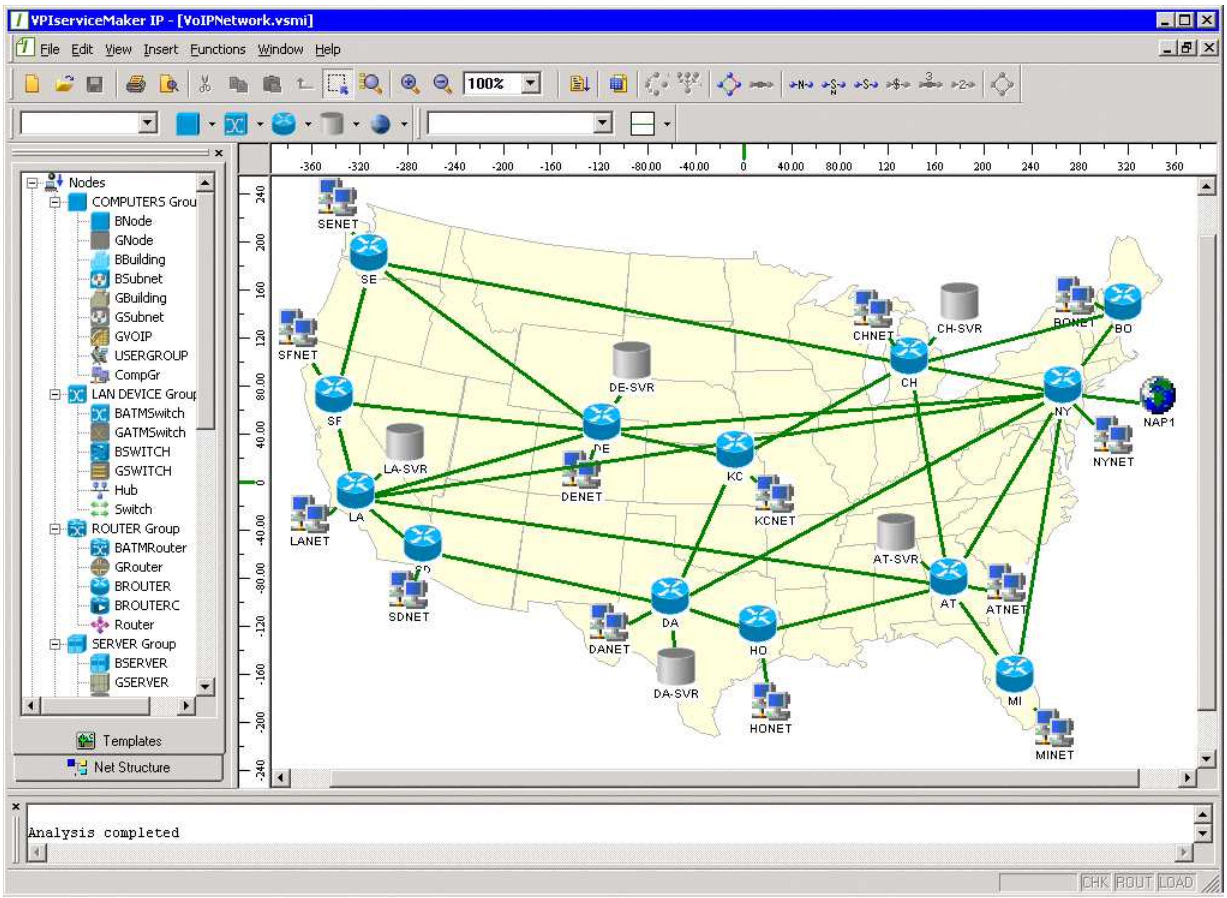


Figure A2.5.2. A Sample US Nationwide ISP Backbone Network

We assume that the network has only one gateway to the global internet and therefore the network has no transit traffic. The gateway is located at New York and is connected to other peering ISPs at a peering site named NAP1 (Network Access Point). The peering site is represented by the globe icon. Please note that the tool is only focused on the internal network of an ISP. Therefore it does model the actual locations of peering sites. In fact the globe icon represents the global internet at large. The planning scope of the tool ends at the outgoing link of each gateway. Anything beyond that is hidden into global internet. We could specify two or more gateways, such as one on the east coast and one on the west coast, by setting the routers to be AS boundary routers and connecting them to the globe icon. But in that way we need to consider transit traffic which neither originate nor terminate within the ISP's network. Since in this demo we are only interested in seeing the network planning impact by IP traffic created by the ISP's own subscribers, we consider only one gateway.

In each city, the computer group, the server (if exits) and the global gateway (if exits) are directly connected to the POP of the city.

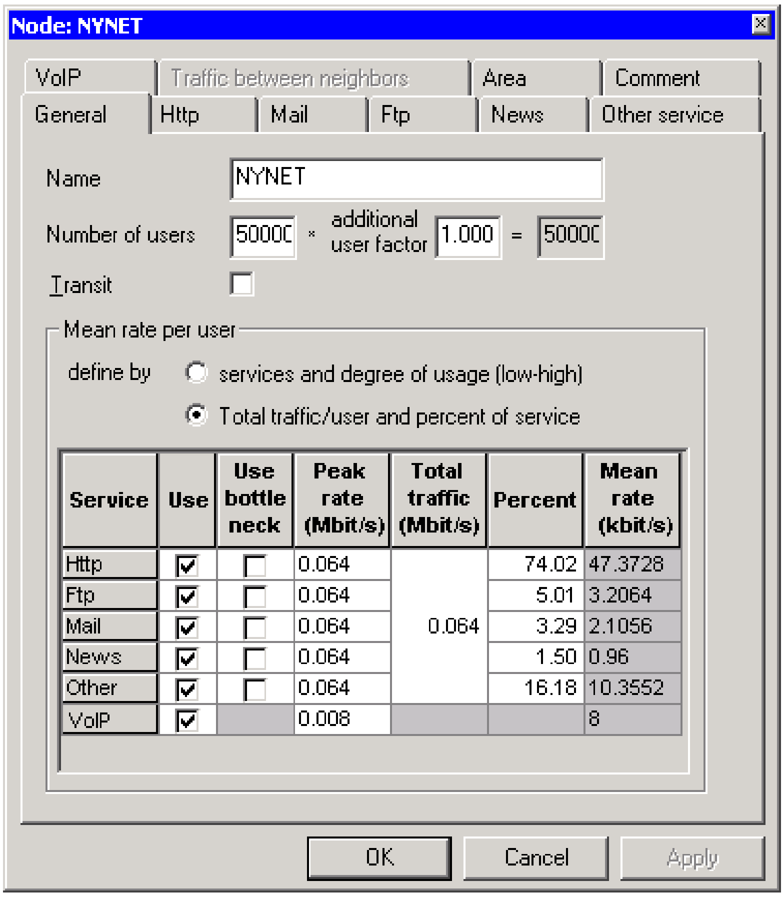
The topology shown in figure 2 is the initial set of links inter-connecting connecting POPs which we assumed based on the underlying fiber topology (shown in figure 1) and estimated traffic pattern. The IP topology normally has richer connectivity than the underlying physical network because of desirable express (logical) links connecting distant routers. Topology optimization is an iterative process. If a link is not used by the design, it should be deleted.

Similarly if a link's load is too heavy, other links should be added to off load the congested link. Since we are planning an IP over DWDM network, we assume all links are high speed links with the OC192 granularity.

The computer group representing the subscribers of each city not only enables us to model the subscriber population in the city, but also allows us to specify the usage profiles of these subscribers from which network traffic can be derived. We first need to specify subscriber population for each city by the following assumptions. Among the 13 cities, 7 of them are large cities and each of them has a subscriber population of half million: San Francisco (SF), Los Angeles (LA), Dallas (DA), Houston (HO), Chicago (CH), Atlanta (AT), and New York (NY). The other 6 cities are mid sized and each has a subscriber population of a quarter million: Seattle (SE), San Diego (SD), Denver (DE), Kansas City (KC), Boston (BO), and Miami (MI).

To set the parameters for each computer group, just double click the icon. As an example, figure A2.5.3 shows the parameter settings of computer group NY-NET. We should pay special attention to the following parameters:

- The user population, which is 500,000 for New York.
- Use of services: For all computer groups, we choose all available services including VoIP.
- Peak rate: For all cities, we assume subscribers only use telephone dial up to access the network (like AOL) and therefore the peak rate is set at 64 Kbits/s uniformly. The only exception is VoIP. Each channel of VoIP is considered as a constant bit rate connection and the bit rate is stored in the peak rate field. The VoIP bit rate is assumed to be 8 Kbits/s after taking into consideration bandwidth saving factors such as silence suppression and statistical multiplexing.
- Percent: It is a breakdown of amount of usage across all the services for an average user. For this demo example these percentages are also uniformly set for all computer groups because it is not our intention to model user behavior differences across cities. Here the only difference between cities is the one in subscriber population.
- Individual service settings (not shown): Specific settings for each individual service can be made by clicking the corresponding type. Here we set that all http traffic are equally distributed across the three servers, and a 50-50 split between internal traffic and external traffic. Similar assumptions are set for other services except for VoIP.
- For VoIP, we check the Use Voice Matrix box because VoIP traffic will be provided by a separate voice matrix which will be generated by VPIserviceMaker™Distribution. For now we just assume the voice matrix is available. The next section will describe how the matrix is created.



Service	Use	Use bottle neck	Peak rate (Mbit/s)	Total traffic (Mbit/s)	Percent	Mean rate (kbit/s)
Http	☑	☐	0.064		74.02	47.3728
Ftp	☑	☐	0.064		5.01	3.2064
Mail	☑	☐	0.064	0.064	3.29	2.1056
News	☑	☐	0.064		1.50	0.96
Other	☑	☐	0.064		16.18	10.3552
VoIP	☑		0.008			8

Figure A2.5.3. Sample Computer Group Setting

To set parameters for POPs, double click the router icons. As an example, figure A2.5.4 shows the parameter settings of NY POP. The maximal switching capacity is set to 500 Gbit/s. Currently the largest core router product available in the market place is about 100 Gbit/s. But here the switching capacity does not represent the capacity of a single router, but that of a POP which normally consists of multiple routers. For this demo we assume all the seven large POPs uniformly have a switching capacity of 500 Gbit/s and all the six medium POPs uniformly have a switching capacity of 100 Gbit/s. It should also be pointed out that for the purpose of this design the OSPF area assignment is not important. All the backbone links should be in area 0. The access networks as represented by computer groups and intra-POP networks should have other area numbers but our interest is not to model the internal structures of the access networks or POP offices. Therefore one backbone area suffices.

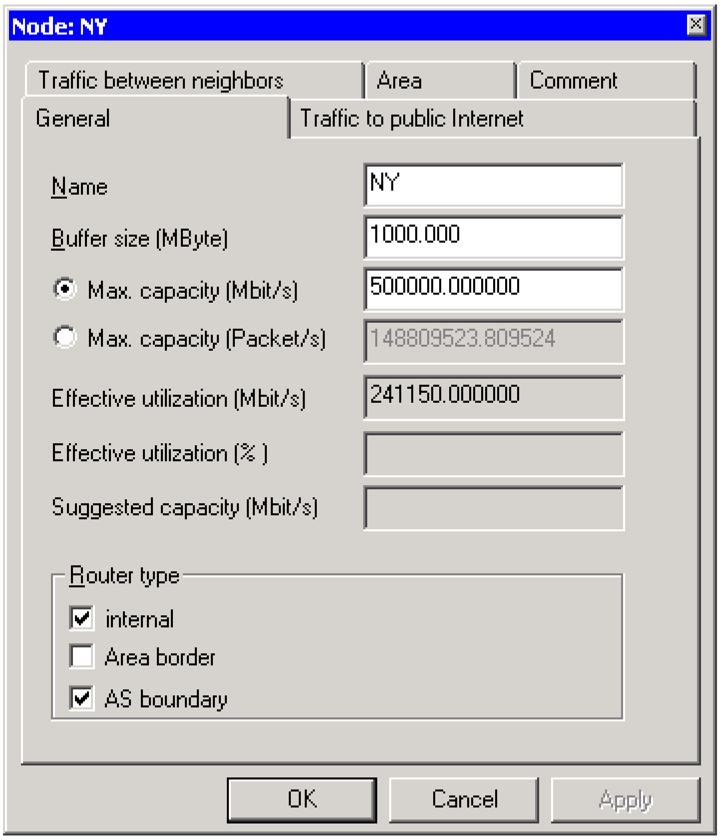
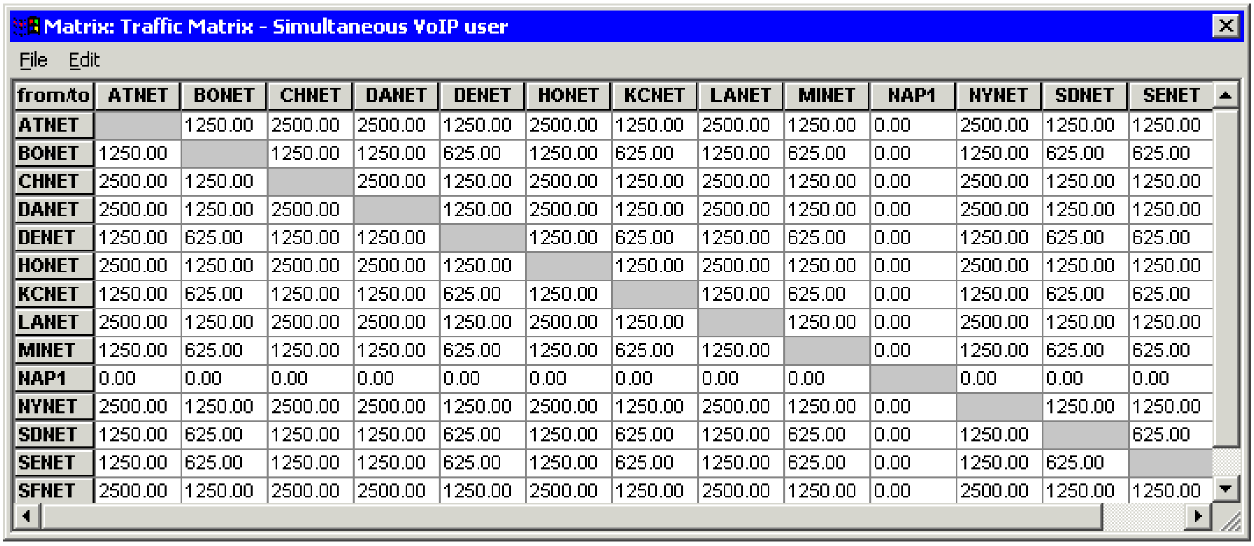


Figure A2.5.4. Sample POP Setting

Server settings are not described here because they are the simplest and can be populated in a straightforward way.

The last step of data input is to import the VoIP matrix. To do so open Edit menu and select VoIP Matrix option. A table pops up which shows the current VoIP matrix. Here only the computer group nodes which participate in VoIP service (the parameters are set) are included in the matrix. For this example all the computer groups participate VoIP.

We assume there already exists a voice matrix, which is generated by VPIserviceMaker™Distribution (to be described in the next section). To import, open the File menu of the table, select Import and choose Replace Values option, the matrix will be populated by the imported values as shown in figure A2.5.5.



Matrix: Traffic Matrix - Simultaneous VoIP user

from/to	ATNET	BONET	CHNET	DANET	DENET	HONET	KCNET	LANET	MINET	NAP1	NYNET	SDNET	SENET
ATNET		1250.00	2500.00	2500.00	1250.00	2500.00	1250.00	2500.00	1250.00	0.00	2500.00	1250.00	1250.00
BONET	1250.00		1250.00	1250.00	625.00	1250.00	625.00	1250.00	625.00	0.00	1250.00	625.00	625.00
CHNET	2500.00	1250.00		2500.00	1250.00	2500.00	1250.00	2500.00	1250.00	0.00	2500.00	1250.00	1250.00
DANET	2500.00	1250.00	2500.00		1250.00	2500.00	1250.00	2500.00	1250.00	0.00	2500.00	1250.00	1250.00
DENET	1250.00	625.00	1250.00	1250.00		1250.00	625.00	1250.00	625.00	0.00	1250.00	625.00	625.00
HONET	2500.00	1250.00	2500.00	2500.00	1250.00		1250.00	2500.00	1250.00	0.00	2500.00	1250.00	1250.00
KCNET	1250.00	625.00	1250.00	1250.00	625.00	1250.00		1250.00	625.00	0.00	1250.00	625.00	625.00
LANET	2500.00	1250.00	2500.00	2500.00	1250.00	2500.00	1250.00		1250.00	0.00	2500.00	1250.00	1250.00
MINET	1250.00	625.00	1250.00	1250.00	625.00	1250.00	625.00	1250.00		0.00	1250.00	625.00	625.00
NAP1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
NYNET	2500.00	1250.00	2500.00	2500.00	1250.00	2500.00	1250.00	2500.00	1250.00	0.00		1250.00	1250.00
SDNET	1250.00	625.00	1250.00	1250.00	625.00	1250.00	625.00	1250.00	625.00	0.00	1250.00		625.00
SENET	1250.00	625.00	1250.00	1250.00	625.00	1250.00	625.00	1250.00	625.00	0.00	1250.00	625.00	
SFNET	2500.00	1250.00	2500.00	2500.00	1250.00	2500.00	1250.00	2500.00	1250.00	0.00	2500.00	1250.00	1250.00

Figure A2.5.5. Imported VoIP matrix

Now we are ready to run the design functions. We can either do design step by step by running functions (analysis, routing and effective bandwidth calculation) one at a time, or run all of them together one clicking on the “run all the planning functions” button. In order to perform the dimensioning for all defined services select the services as indicated in figure A2.5.6.

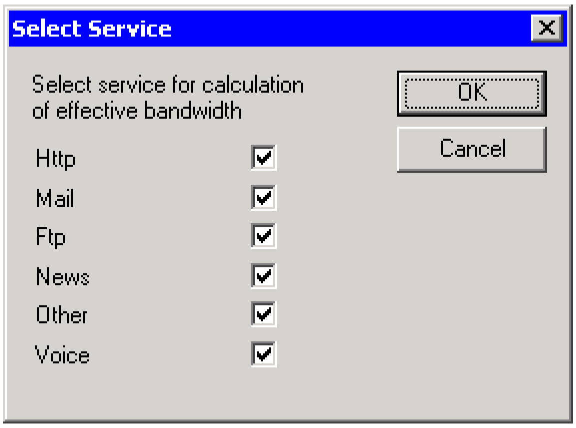


Figure A2.5.6. Select Service Dialog

The design results are compiled into a set of detailed reports. The results can also visually displayed in many different ways by selecting corresponding options under the View menu. For example, figure A2.5.7 shows the resulting IP network dimensioning. The IP network is sized in two dimensions: link bandwidth requirement and router (POP) switching capacity requirement. The number on each link indicates how many OC12s the link needs in order to carry the traffic with adequate performance. The color codes of the routers indicate the router utilization. Green and purple mean that no one is over loaded. Both routers and links can be viewed by utilization, by traffic load, and by suggested capacity.

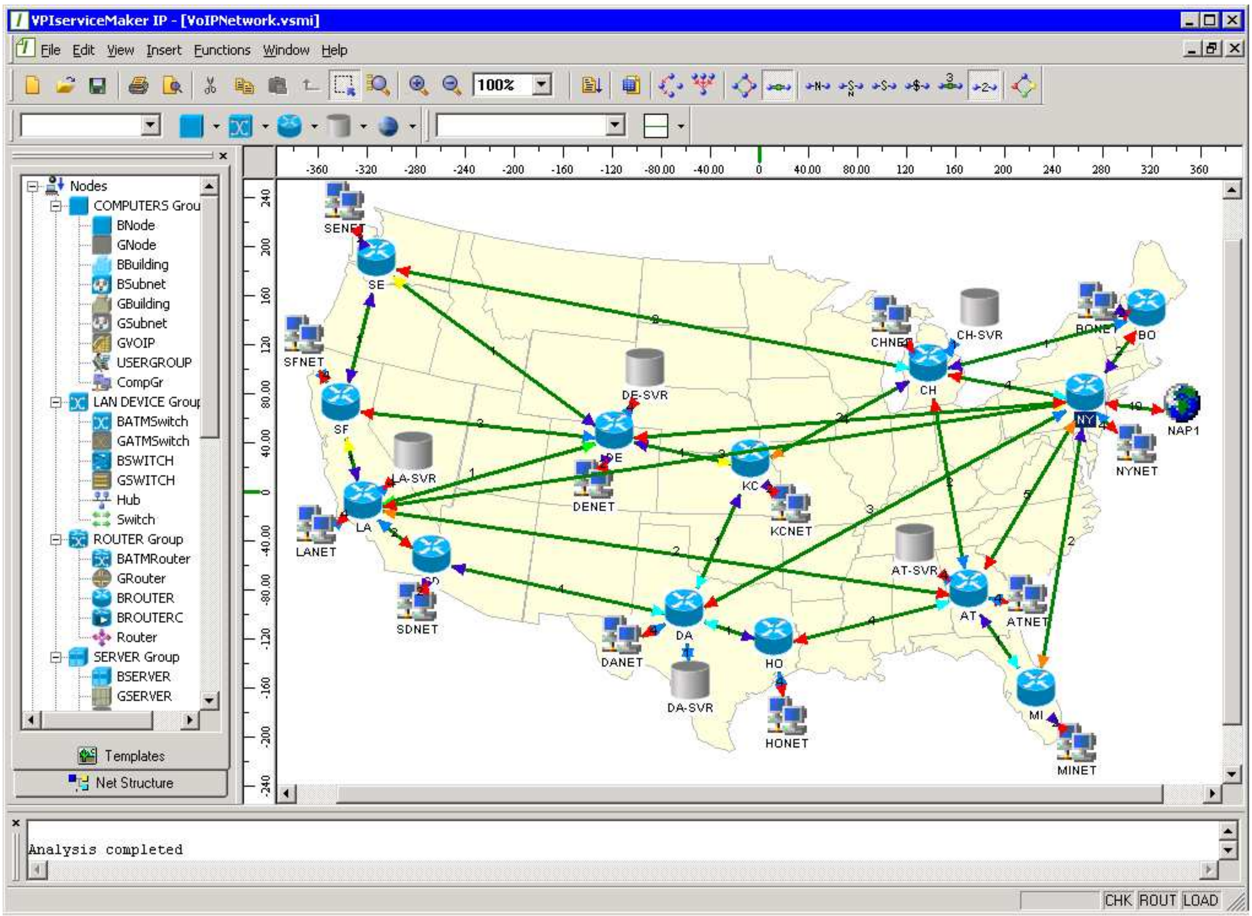


Figure A2.5.7. IP Network Dimensioning

After the design, network bottlenecks and under-utilized resources can be identified. Topology improvement can be made by simply looking at link load. For example, the link between SE and SF is very much under-utilized and can be removed. Some scenario analysis can also be conducted. To simulate the impact of a failed link, simply disable the link and rerun the tool. To project the impact of the subscriber growth at certain cities, go to the corresponding computer groups and re-set the user population, or simply use the “additional user factor” feature to scale up subscriber population.

Finally once the IP network design is satisfactory, we would like to design an underlying transport network to provide the required bandwidth for IP links. To do so the first step is to export the IP network to VPItransportMaker^{TM} using the IP tool’s export feature (Export to TransportMaker under file menu). A new TransportMaker^{TM} project will be created with IP network links being treated as a traffic matrix of point to point bandwidth demands for the transport network design.

VoIP Matrix Generation

Here we will show how to use VPIserviceMaker^{TM}Distribution to generate a matrix of point to point voice traffic as VoIP traffic for the IP network design. Normally the units of traffic quantities are Erlangs but for VoIP we interpret them as simultaneous voice channels between a pair of nodes.

Since VoIP traffic is only between computer (subscriber) groups, we do not need to consider the other nodes. The corresponding network with all VoIP relevant nodes are shown in figure A2.5.8.
The network data can be loaded from project “VoIP_Network_Dist”.

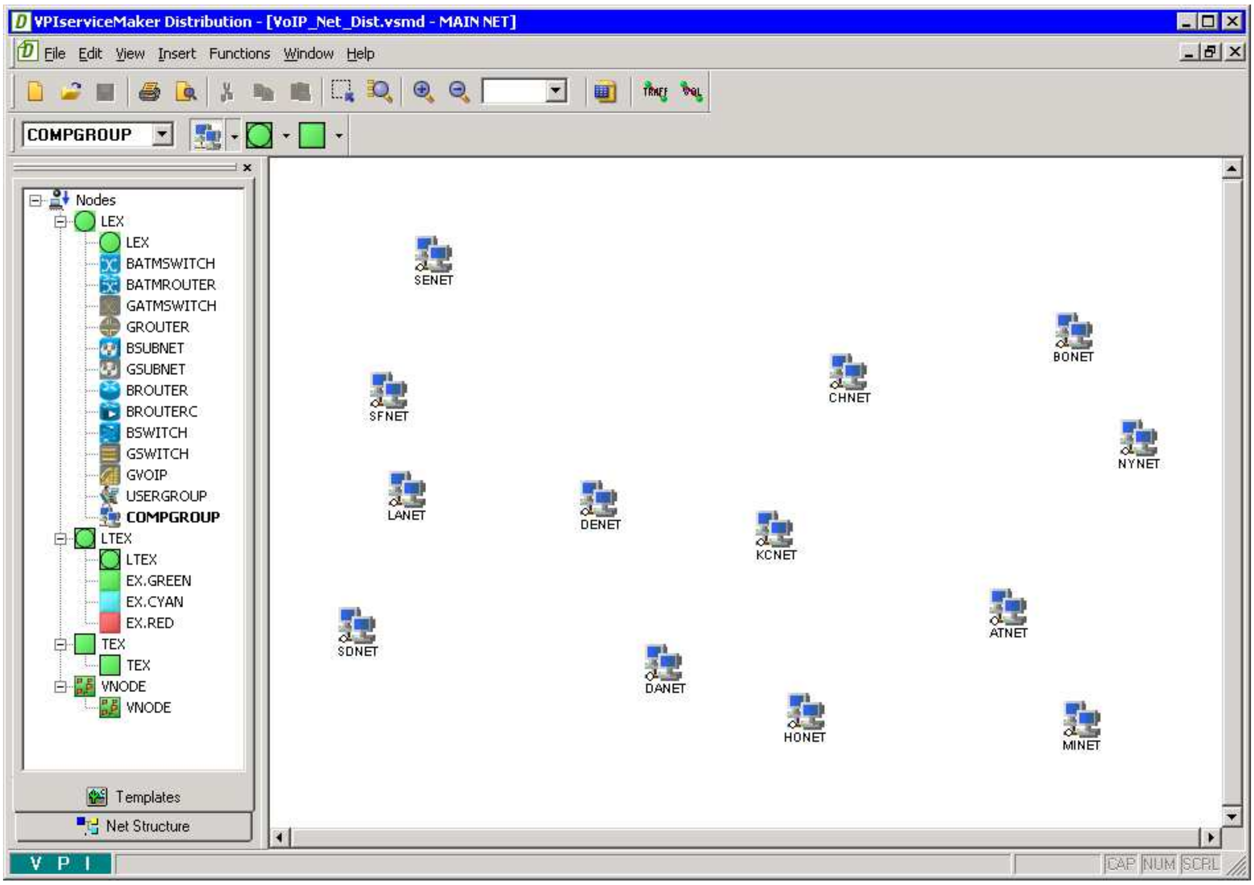
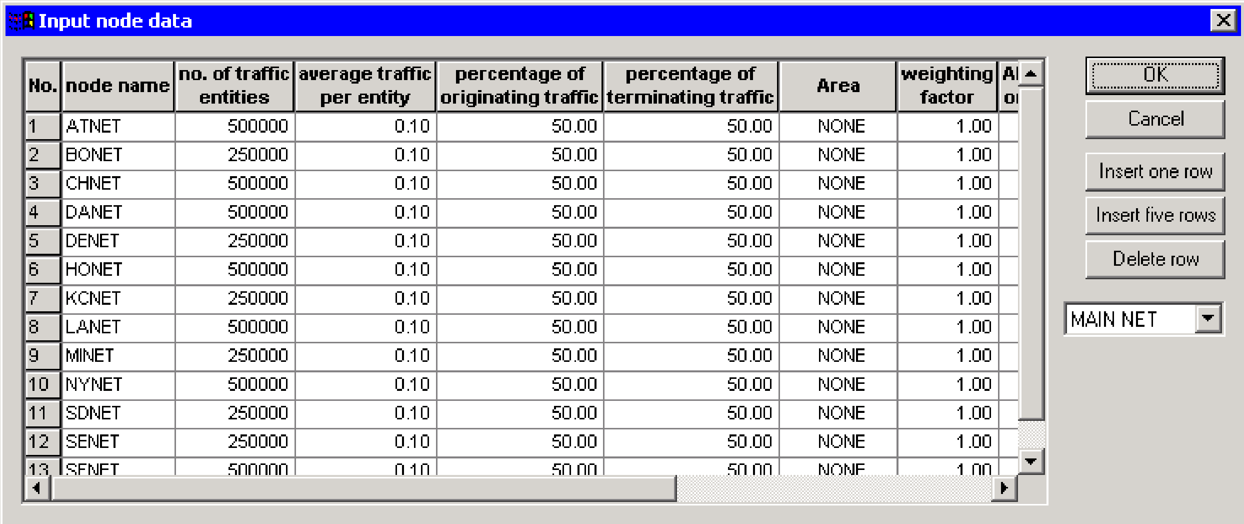


Figure A2.5.8. The set of VoIP nodes

Now we are ready to design the voice traffic. First open the Functions menu and select Input Data, an input table pops up asking for design parameters, as shown in figure A2.5.9. Since it is assumed that the amount of voice traffic between two cities is proportional to the populations of the two cities, the subscriber population for each city should be specified here. We simply use the same population numbers as those we used in the IP project. We also need to specify other parameters such as average traffic per subscriber and call originating/termination percentages which are all shown in figure A2.5.9.



No.	node name	no. of traffic entities	average traffic per entity	percentage of originating traffic	percentage of terminating traffic	Area	weighting factor	A[illegible] o[illegible]
1	ATNET	500000	0.10	50.00	50.00	NONE	1.00	
2	BONET	250000	0.10	50.00	50.00	NONE	1.00	
3	CHNET	500000	0.10	50.00	50.00	NONE	1.00	
4	DANET	500000	0.10	50.00	50.00	NONE	1.00	
5	DENET	250000	0.10	50.00	50.00	NONE	1.00	
6	HONET	500000	0.10	50.00	50.00	NONE	1.00	
7	KCNET	250000	0.10	50.00	50.00	NONE	1.00	
8	LANET	500000	0.10	50.00	50.00	NONE	1.00	
9	MINET	250000	0.10	50.00	50.00	NONE	1.00	
10	NYNET	500000	0.10	50.00	50.00	NONE	1.00	
11	SDNET	250000	0.10	50.00	50.00	NONE	1.00	
12	SENET	250000	0.10	50.00	50.00	NONE	1.00	
13	SFNET	500000	0.10	50.00	50.00	NONE	1.00	

Figure A2.5.9. Input Data

Next choose the single matrix method by clicking the Single option and select the homogeneous matrix model, as indicated in figure A2.5.10.

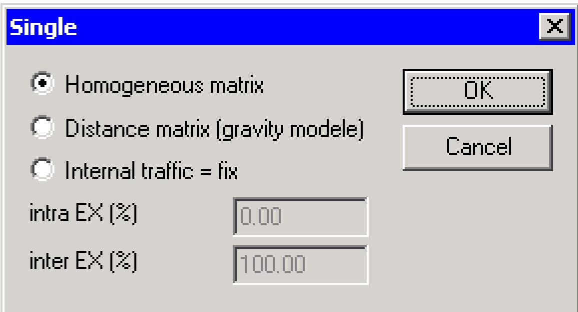


Figure A2.5.10. Input Data

The tool will create a matrix of point to point voice traffic. The traffic matrix is shown graphically in figure A2.5.11 where each line represents the voice traffic between the two end nodes and the number on the line indicate the number of simultaneous voice channels. This voice matrix is then exported to a text file in the service matrix format to be used by the IP network design, by selecting File → Export → Service Matrix.

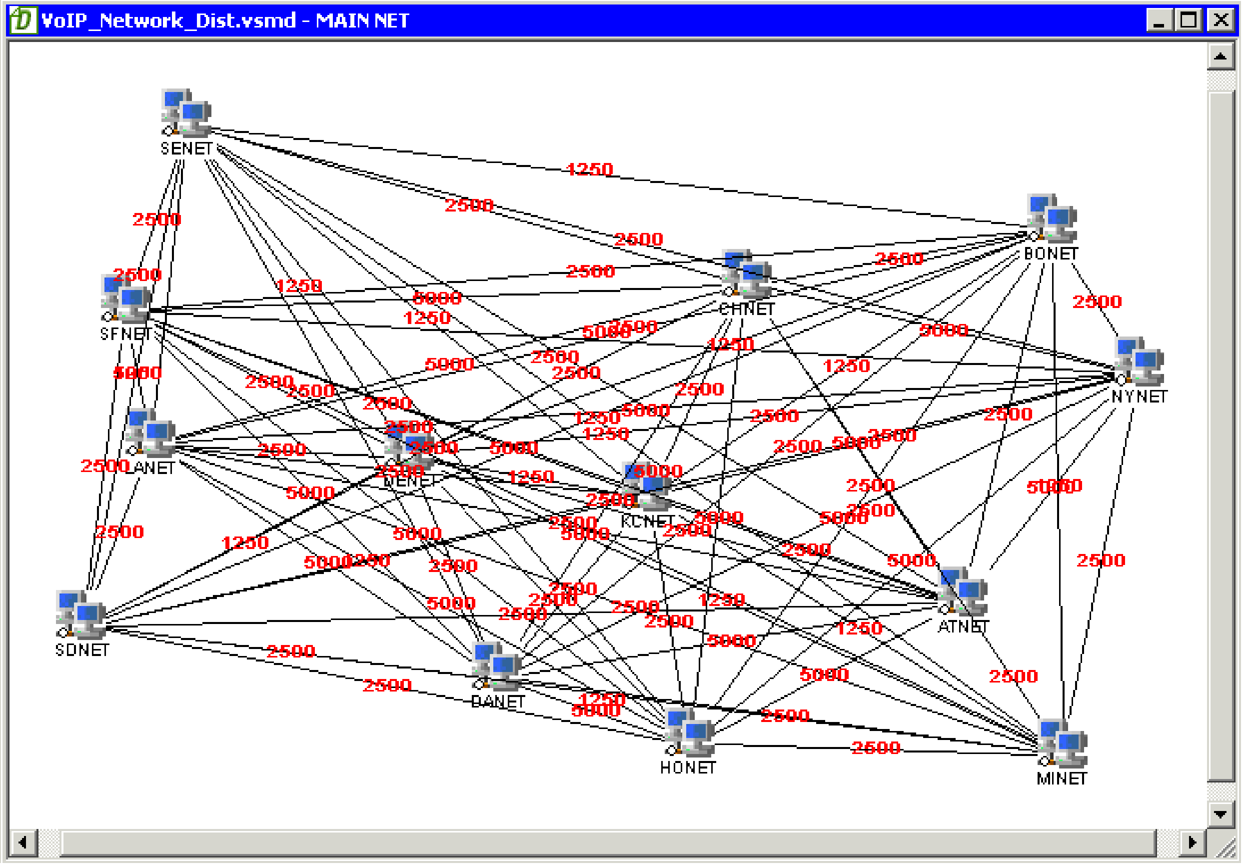


Figure A2.5.11. Voice traffic matrix

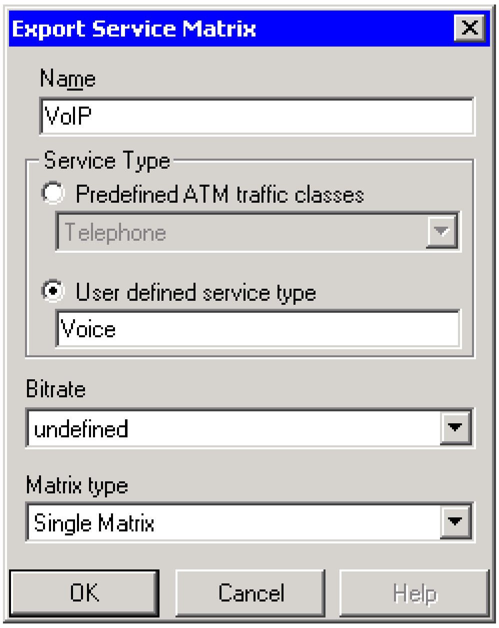


Figure A2.5.12. Export service matrix

Transport Network Planning

Figure A2.5.13 shows the newly created VPItransportMaker^{TM} project by exporting the IP network. The IP links are now grouped into a traffic matrix called STM64 (to indicate their signal rate of OC192). The server window (right) initially contains only nodes, without OMS links. The OMS links can be either manually created or imported from a topology file. The client window (left) represents graphically the traffic matrix, where each link represents a demand and the number by the link represents quantity in OC192 (STM64) units.

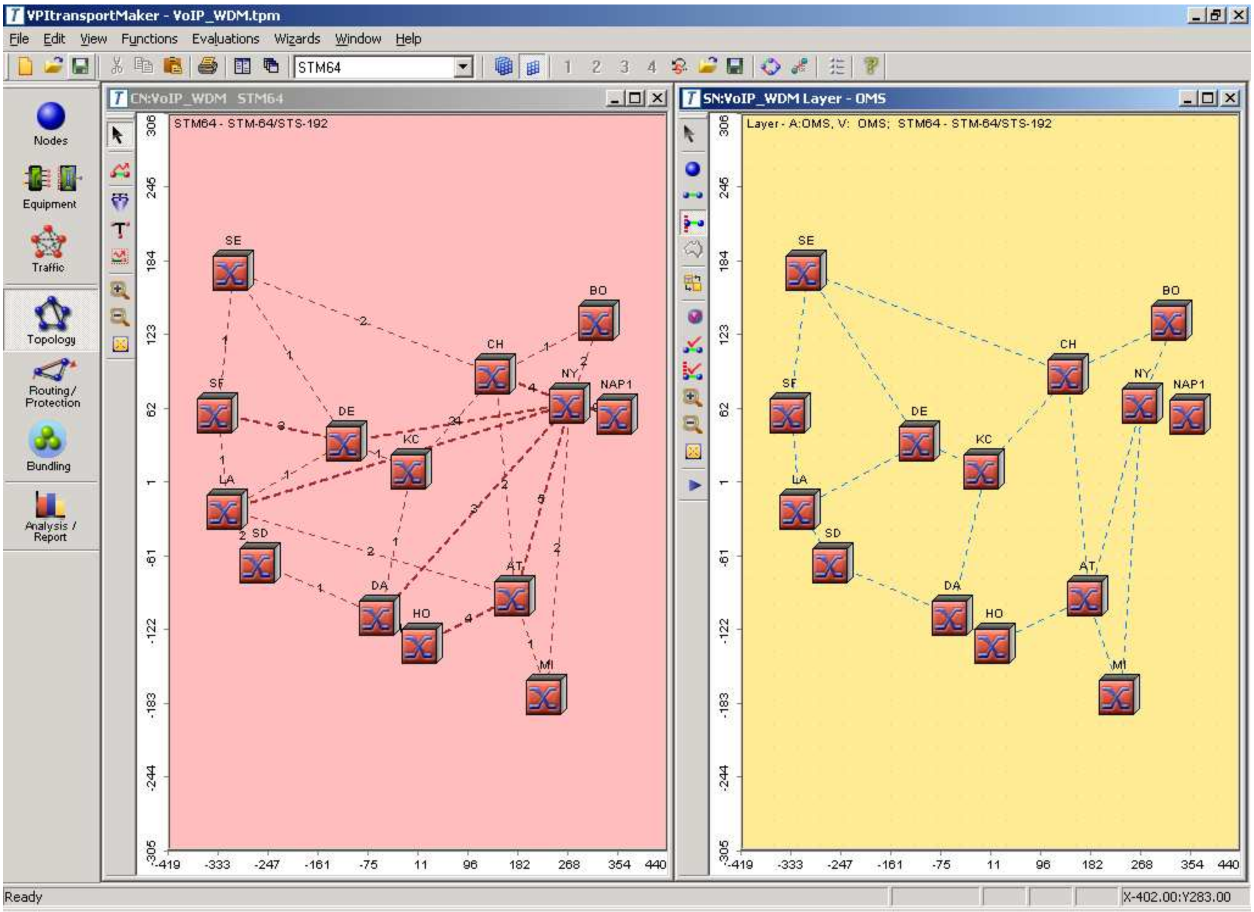


Figure A2.5.13. Transport project exported from IP

We want to plan a two layer IP over optical network. For the optical layer, we want to design a mesh network with wavelength routing and protection capabilities. Further down, DWDM systems provide point to point optical multiplexing section links. For this purpose, when we create the server layer topology (the right window), we need to specify that all links are multiplexing links at the OMS layer.

Before create the OMS links, we want to set the number of channels available to each DWDM system. We go to Bundling mode, open the Edit menu, select Set Bundling Factors option. A parameter input window shown in figure A2.5.14 appears, we set No. of Channels equals to 40 for DWDM system.

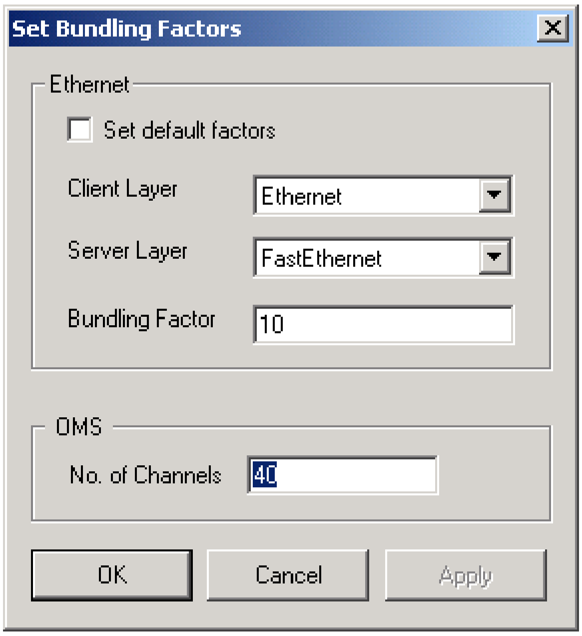


Figure A2.5.14. Set Bundling Factors

To design a wavelength routed optical network, we go to Routing/Protection mode, open the Functions menu, select the Wavelength Routing option. A parameter input window pops up as shown in figure A2.5.15. For the Algorithm Options, we choose Planning for better optimization (at the price of more computation). We select no wavelength conversion because we assume that optical cross connects are not capable of converting wavelengths based on the reality of today's technology. We also select the 1+1 path protection option because no protection is considered when we design the IP network. After the run, the design result is compiled into a report.

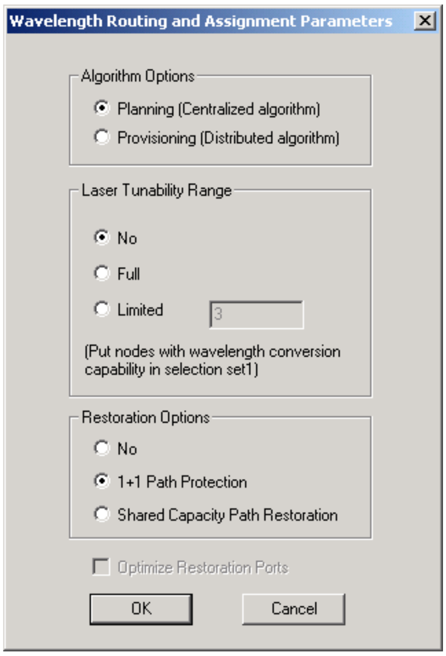


Figure A2.5.15. Wavelength routing parameters

The design can also be visually displayed on the GUI. Figure A2.5.16 shows the network of DWDM facilities where each dashed line represents one DWDM system and the number by the line indicate the number of wavelengths carried by the system. It can be seen that there is only one line over each fiber link, which means there is only one DWDM system deployed over each fiber route. This is because each DWDM system offers a capacity of 40 wavelengths (OC192s) which is more than sufficient for our traffic.

Figure A2.5.16. Wavelength load on each link

By opening the details table for each demand and select routing option, the routing of a demand can also be displayed. Figure A2.5.17 and figure A2.5.18 show the working route and the protection route of the wavelengths from Los Angeles to New York respectively.

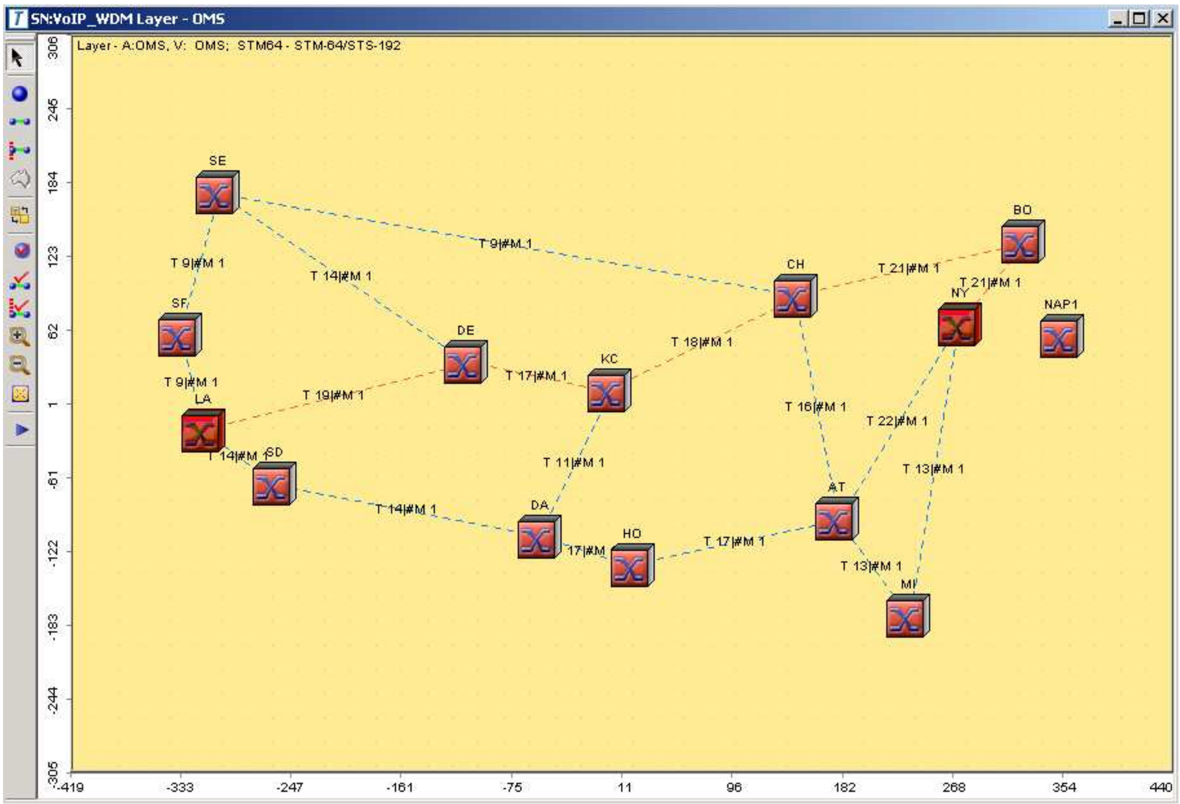


Figure A2.5.17. Working path for demand between LA and NY

Figure A2.5.18. Protection path for demand between LA and NY

Summary

In this design exercise we have shown how to leverage the VPI software and the complete suite of design tools it provides to do an integrated network planning across multiple layers. We have demonstrated a smooth end to end network planning procedure by showing how different tools can inter-work by exporting one tool's output to another tool as input.

So far in this design exercise the data flows are one way: from traffic distribution to service layer design to transport layer design. It is also possible to have a feedback process from transport layer to the service layers. For example, by looking at the spare capacity of the transport layer, one can estimate how to expand a service network, or to adjust transport bandwidths allocated to different service layer networks. Another way is to conduct what-if scenario analysis on potential impact of any service layer changes over the transport layer.

A2.6. Mobile network coverage

Case Study - GSM Network Planning Papua New Guinea

<u>Introduction</u>

The following document presents the results of a case study performed for a GSM 900 Network in Papua New Guinea. The scope of the study is to determine the number of sites needed to cover the urban area and the costal region around Port Moresby, the urban area and the catchment area of Popondetta and the connection road between these two cities (See Figure 1). Additionally the fixed network has been planned for the found radio sites. Result of the fixed network planning is the number of needed links divided into long hop- and short hop links.
The planning task has been split up in three different phases.
Please note that the case study has been based on rough mapping data and hypothetical site locations; no site survey has been done. Operational aspects like availability of power and site accessibility has not been included in the site selection process. An examination of the general economical feasibility of implementing a mobile network in the used regions (especially the connection roads and the rural areas) has not been subject of the study.

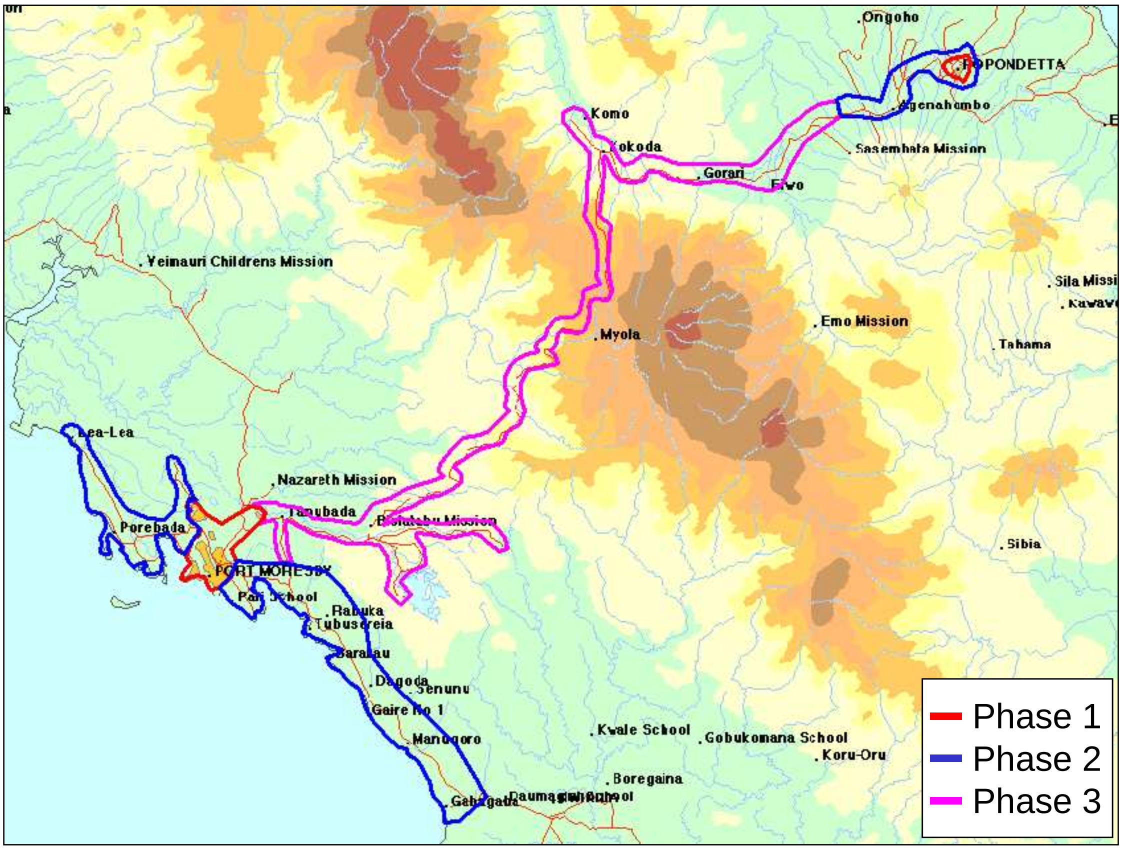


Figure 1: Rollout Phases

<u>Planning Guideline</u>

Scope of the Document

The scope of the following document is to identify and fix all technical and organizational parameters used by the planning staff during the elaboration of the GSM and Fixed network for Papua New Guinea. The document has been worked out on proposals of the experts of LS telcom based on typical system parameters achieved from vendors and ETSI / 3GPP documents.

Network Parameter Settings

Coverage Area

The coverage planning will be divided into three phases:

- During a first phase the capital of Papua New Guinea, the city Port Moresby, and the area of Popondetta in the western part of the country have to be covered. The required coverage in these regions is an acceptable indoor coverage in urban areas of Port Moresby and Popondetta.
- Goal of the second phase is to cover the catchment areas of Port Moresby and Popondetta. Aim is to achieve good outdoor coverage; focus is not set on indoor.
- In the third phase the connection road between Port Moresby and Popondetta will be covered with good outdoor coverage. At the same time indoor coverage in Port Moresby and Popondetta will be optimized if necessary.

The regions are shown in gives the different types of land use for the planning regions.

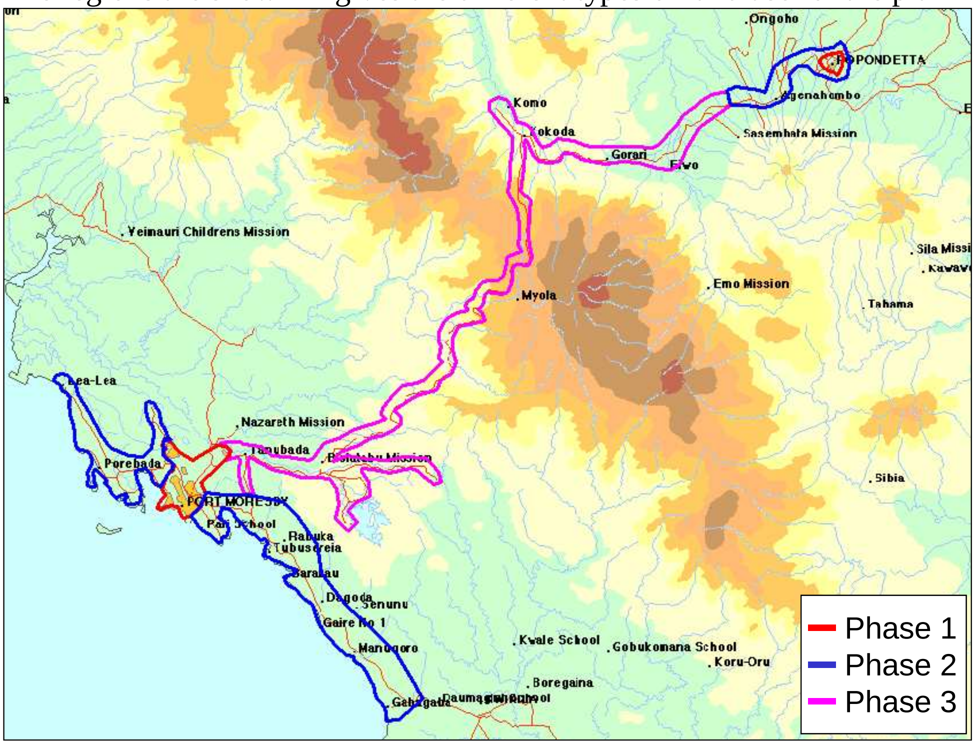


Figure 2: Phases for Rollout

Clutter Classes	**Port Moresby**	**Popondetta**	**Port Moresby Area**	**Popondetta Area**	**Inter-connection**
Urban	59.2 %	42.0 %	0.3 %	4.4 %	0.1 %

Open	14.0 %	1.8 %	47.1 %	9.0 %	41.3 %
Forest	26.5 %	56.2 %	47.6 %	86.6 %	53.8 %
Agricultural	0 %	0 %	0 %	0 %	3.0 %
Inland Water	0 %	0 %	0 %	0 %	1.8 %
Sea Water	0.3 %	0 %	5.0 %	0 %	0 %

Table 1: Land use in planning regions

Network design rules

Assumption for the design is that the network will be limited by coverage not by traffic. Therefore, base stations will be placed in a way that coverage will be maximized with a minimum number of base stations. As well as indoor coverage is expected in the urban areas of Port Moresby the focus will not be set on an overall indoor coverage. In urban areas sectorized sites with 65° antennas will be used, rural sites will use 90° antennas as default. Antenna types and antenna configuration may be adjusted to optimize site count and coverage. Coverage along roads should be achieved from sites inside build up areas. Nevertheless, green field sites will be defined where necessary.
For base station antenna height, default heights will be used for the first approach. During coverage optimization phase for selected sites, the height will be minimized in order to save cost for infrastructure.
The sites will be connected by microwave links. If necessary additional sites for fixed network repeaters will be introduced. Sites may be connected in star, loop or daisy chain configuration. No redundancy concept has been foreseen at this stage of the project.
Traffic calculations and frequency planning will not be performed.

System Parameter for Radio Access Network (GSM)

The following paragraphs gives on overview about the used parameter for the GSM radio access network.

Frequency Band

The used frequency band is 870 to 980 MHz, 200 kHz channel spacing and 45 MHz channel separation between uplink and downlink. Field strength calculations will be performed for downlink on a center frequency of 925 MHz.

Parameter for Handsets

<u>Power Classes for Handsets</u>
The calculations will be performed for GSM 900 handsets of class 4 (33 dBm, 0 dBi)

<u>Handset Antenna</u>
An isotropic antenna for the handsets with 0dBi has been assumed.

<u>Receiver Height for Handsets</u>
The used receiver height for handsets is 1.5 m

Parameter for Mobile Stations

<u>Power Classes for Base Stations</u>
The calculations will be performed for GSM900 base stations with an output power of 46 dBm.

<u>Base Station Antennas</u>
Three different types of sector antennas with horizontal beam widths of 33°, 65° and 90° and an omni-directional antenna are available. The technical parameter of the used antennas and the preferred environments are given in Table 2 Mechanical downtilt will be applied where necessary.

Antenna Type	**Antenna Gain**	**Electrical Tilt**	**Preferred usage**
Omni Antenna	11 dBi	0°	Usage in rural areas
Sector Antenna 33°	18 dBi	0°	Usage along roads
Sector Antenna 65°	17 dBi	2°	Usage in urban areas
Sector Antenna 90°	15,5 dBi	0°	Usage in rural areas

Table 2 Base Station Antenna Types

<u>Base Station Antenna Height</u>
An antenna height of 20 meters in sub-urban areas and of 30 meters in rural areas will be used.

<u>Sector Configuration</u>
The following numbers of TRX will be used as default for planning according to the land use of the coverage area of the site.
Sites in Rural area – 1 TRX for each sector
Sites in Urban area – 2 TRX for each sector
No further traffic calculations have been performed at this stage of the project.

<u>Power Budget for planned System</u>
The following tables give the power budget for uplink and downlink. As different TRX configurations are used in rural and urban areas in the latter case additional attenuation for combining has been introduced. The budgets are given for sector antennas with a gain of 17 dBi; as antennas with other gains will not change the balance between up and downlink, separate tables for each antenna type are not necessary. The link budged is done for a coverage probability of 50% without any correction factors for different types of land use. For rural areas, the system is balanced whereas in urban areas the system is limited by the downlink.

Downlink	Rural Areas (1TRX)	Urban Areas (> 1 TRX)	
BTS-Power-Output	46	46	dBm
Losses for Cabling and Combining	4	7	dB
Antenna Gain	17	17	dBi
EIRP	59	56	dBm
Mobile Rx Level	-102	-102	dBm
Antenna Gain	0	0	dBi
Isotropic Received Power at MS (50%)	-102	-102	dBm
Max Path Loss Downlink	161	158	dB

Table 3: Link Budget for Downlink

Uplink	Rural Areas (1TRX)	Urban Areas (> 1 TRX)	
Mobile-Power-Output	33	33	dBm
Antenna Gain	0	0	dBi
EIRP	33	33	dBm
BTS Rx Level	-110	-110	dBm
Antenna Gain	17	17	dBi
Losses for Cabling etc.	3	3	dB
Diversity Gain	4	4	dB
Isotropic Received Power at BS (50 %)	-128	-128	dBm
Max Path Loss Uplink	161	161	dB

Table 4: Power Budget for Uplink

<u>Design field strength values for coverage calculation</u>

The following table gives the design values for the field strength that will be used inside the planning tool to check the coverage. The field strength values are given for different classes of land usage with a coverage probability of 95 percent. For rural areas, the coverage will be optimized for outdoor usage of mobiles. For urban areas acceptable indoor coverage for class 4 mobile phones will be achieved.

	Rural	Incar	Suburban	Urban	
Minimum required Isotropic Power	-95	-85	-83	-75	dBm

Table 5: Signal Strength Design Values

System Parameters for Fixed Network

The paragraph gives an overview over the used parameter for the fixed network planning.

Frequency Band

The following frequency bands will be used according to the length of the link:
Short hops: 23 GHz
Long hops: 8 GHz

Availability

The planned availability for the links will be 99,99 %.

Network Structure

Sites can be connected in star, loop or daisy chain configuration.

Equipment

Technical parameter from Standard Equipment will be used for the planning.

Rain Rate

A rainfall intensity of 110 mm/h and a time percentage of 0.01 will be used.

Radio Network Planning Tools

Used Software

During the Planning work the following software will be used:

Radio Network Planning:	LS telcom xG-Planner	Version 4.6.0
Microwave Link Planning:	LS telcom Multilink	Version 4.3.0

Data sources

The following data sources will be used for additional information

Antenna pattern	Typical GSM-Antennas (Kathrein)
Mapping Data	LS telcom mapping department
Technical Parameter	ETSI / 3GPP and vendor documentation

Used Data Maps

The following mapping data has been available for the case study
Overview Map of Papua New Guinea

Topo Map	200m x 200m per Pixel
Morpho Map	200m x 200m per Pixel

The used rectangular coordinate system is UTM 54 Southern Hemisphere - WGS 84.

Results

In this part of the document, the results of the planning work will be discussed. The results are based on the parameters that have been fixed in the planning guideline.

Results for GSM Network

Results for Phase 1

Site Count and Site Configurations

The found network for the specified area for phase 1 in 12 sites to achieve a good coverage. All sites have three sectors. 29 of these 36 sectors are equipped with antennas with half power beam width of 65° and 17 dBi and the other 7 sectors are equipped with antennas with half power beam width of 90° and 15.5 dBi, see Figure 3.

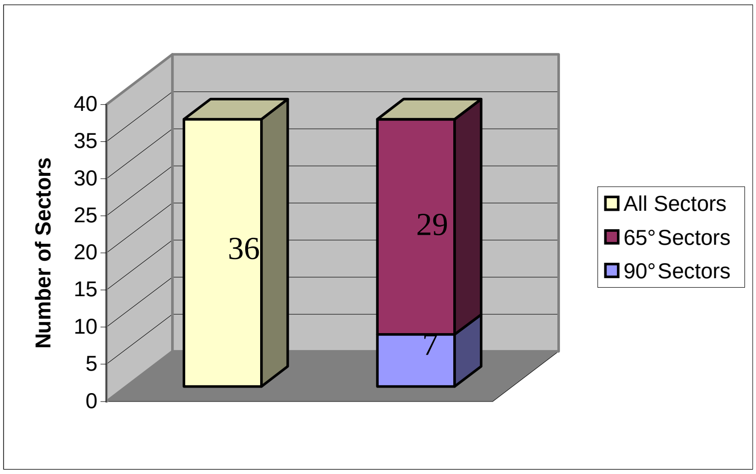


Figure 3: Number of Sectors in Phase 1

Antenna heights of 20m and 30m are used in phase 1 of the network. 24 sectors of the 36 sectors have a height of 20 m and the other sectors have a height of 30 m, see Figure 4.

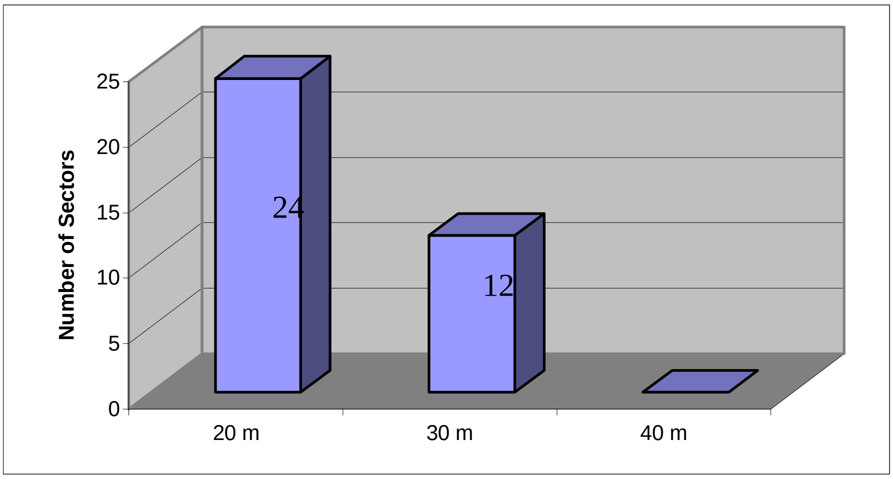


Figure 4: Sector Height Phase 1

Coverage Statistic

Table 6 shows the covered area at the end of phase 1. Values are given in percent of the overall area defined by the polygons for Port Moresby and Popondetta.

Coverage Classes	Port Moresby	Popondetta	Port Moresby Area	Popondetta Area	Inter-connection
Rural	98.7%	98.5%	40.6%	39.4%	7.9%
Incar	89.2%	90.5%	24.2%	18.5%	4.5%
Suburban Indoor	82.1%	78.8%	19.9%	12.3%	2.9%
Urban Indoor	36.5%	34.8%	8.7%	3.5%	1.4%

Table 6: Covered Area in Percent / Phase 1

Coverage Plot

The coverage at the end of phase 1 in the urban area of Port Moresby is shown in Figure 5. The goal in Phase 1 was to reach acceptable indoor coverage in the urban areas of Port Moresby and Popondetta.

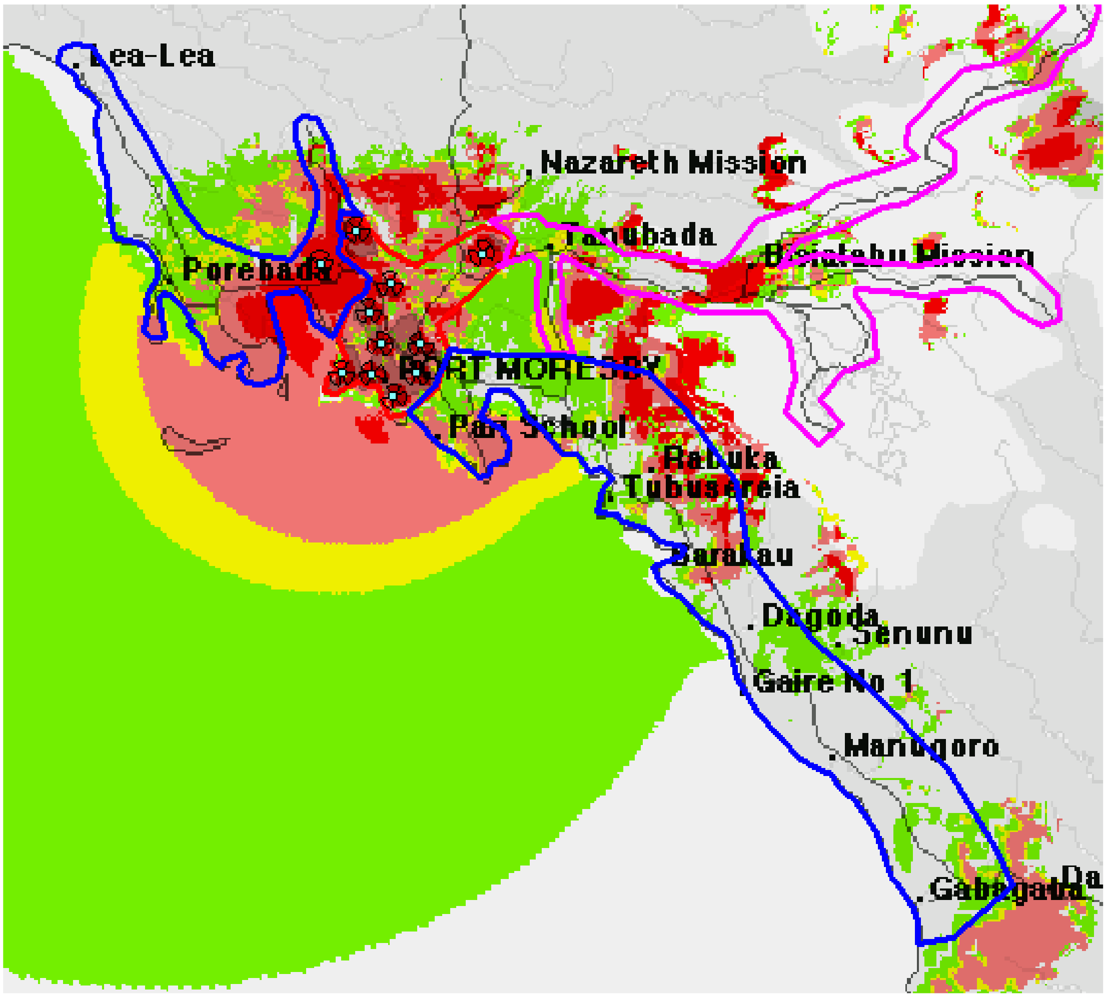


Figure 5: Coverage Phase 1 Port Moresby

The coverage for phase 1 in the urban area of Popondetta is shown in Figure 6.

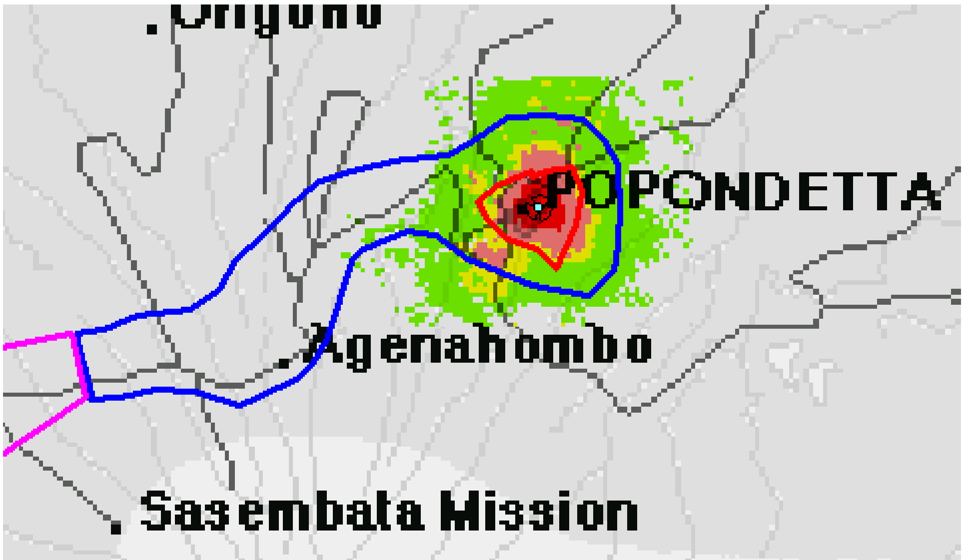


Figure 6: Coverage Phase 1 Popondetta

Site List

Table 7 lists the sites used to achieve coverage in the urban areas of Port Moresby and Popondetta. The used rectangular coordinate system is UTM 54 Southern Hemisphere - WGS 84.

Site Name	X Coordinates	Y Coordinates
Port Moresby 1	55517424.80	8952319.12
Port Moresby 2	55518426.03	8962100.94
Port Moresby 3	55520087.56	8954323.51
Port Moresby 4	55519309.62	8956522.88
Port Moresby 5	55522571.71	8952313.47
Port Moresby 6	55520973.88	8950719.43
Port Moresby 7	55522818.91	8954307.52
Port Moresby 8	55527061.18	8960542.25
Port Moresby 9	55515921.30	8959840.90
Port Moresby 10	55519467.41	8952263.32
Port Moresby 11	55520736.00	8958422.70
Popondetta1	55636991.48	9030657.05

Table 7: Site List of Phase 1

Results for Phase 2

Site Count and Site Configurations

The extension of the network in phase 2 consists of 7 additional sites with 20 sectors. All sectors are using antennas with half power beam width of 90° and gain of 15.5 dBi, see Figure 7.

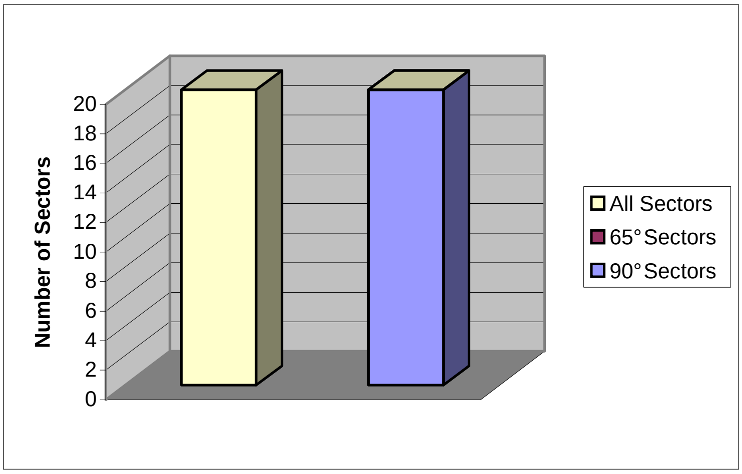


Figure 7: Number of added Sectors in Phase 2

The complete network in Phase 2 includes all in all 19 sites with 56 sectors. The antenna with half power beam width of 90° is used in 27 cases. The other 29 sectors are equipped with a 65° antenna; see Figure 8.

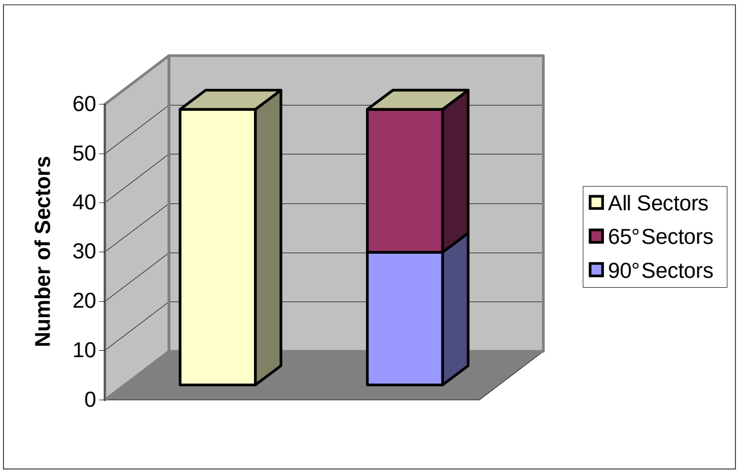


Figure 8: Number of Sectors in complete Phase 2

Mainly antenna heights of 30 m are used. In 6 cases a height of 40 m was selected. The antenna heights of the additional sites in phase 2 are shown in Figure 9.

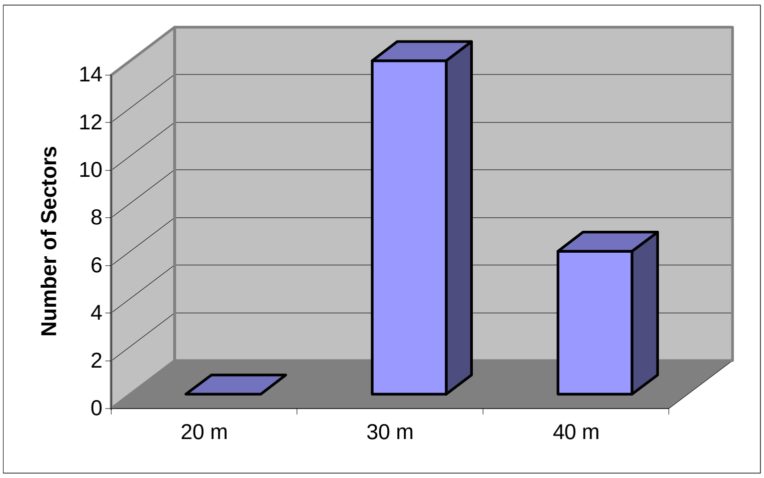


Figure 9: Sector Heights of added Sites / Phase 2

The number of sectors for each antenna height for the complete phase 2 is shown in Figure 10.

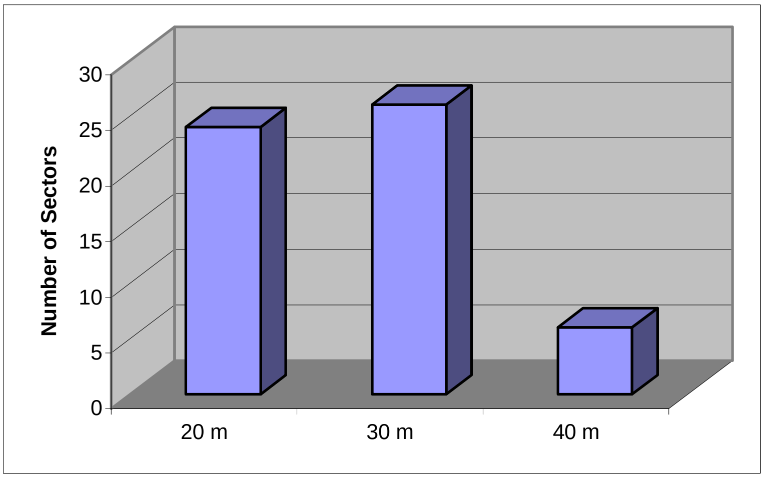


Figure 10: Sector Heights of complete Sites in Phase2

Coverage Statistic

Coverage Classes	**Port Moresby**	**Popondetta**	**Port Moresby Area**	**Popondetta Area**	**Inter-connection**
Rural	98.7%	100%	95.9%	96.6%	9.8%
Incar	89.2%	90.5%	65.7%	48.9%	4.6%
Suburban Indoor	82.1%	78.8%	56.7%	37.1%	3.0%
Urban Indoor	36.5%	34.8%	25.4%	15.3%	1.4%

Table 8: Covered Area in Percent / Phase 2

Coverage Plot

The coverage at the end of phase 2 in the rural area of Port Moresby is shown in Figure 11. The goal in this phase was to achieve good outdoor coverage; focus was not set on indoor.

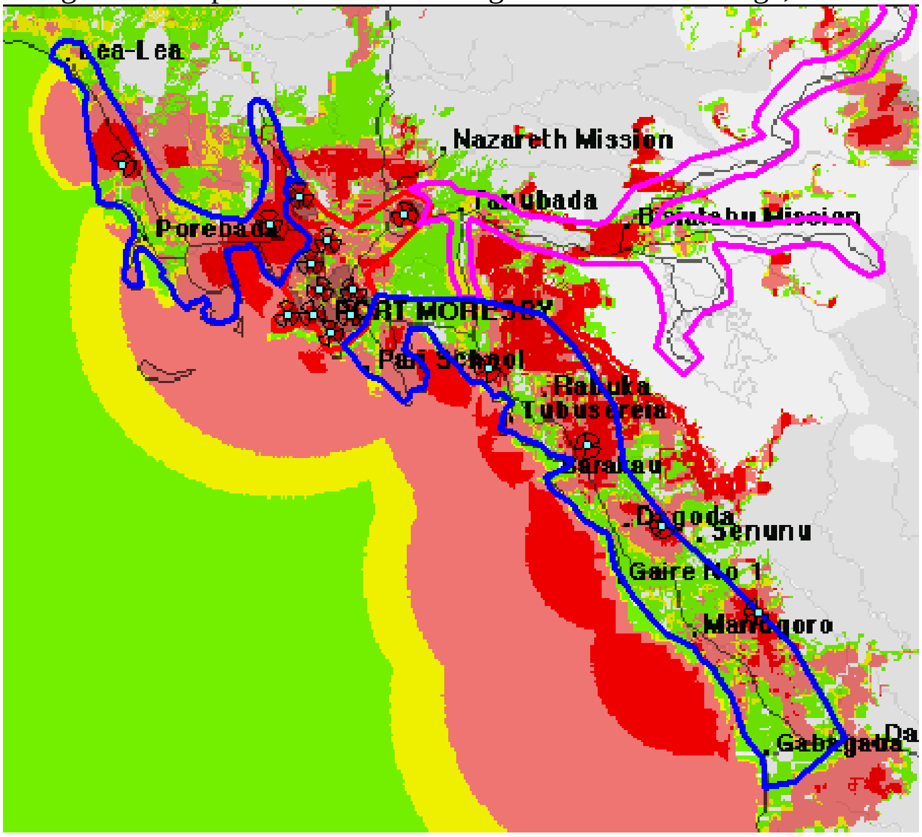


Figure 11: Coverage Phase 2 Port Moresby Area

The coverage of phase 2 in the rural area of Popondetta is shown in Figure 12.

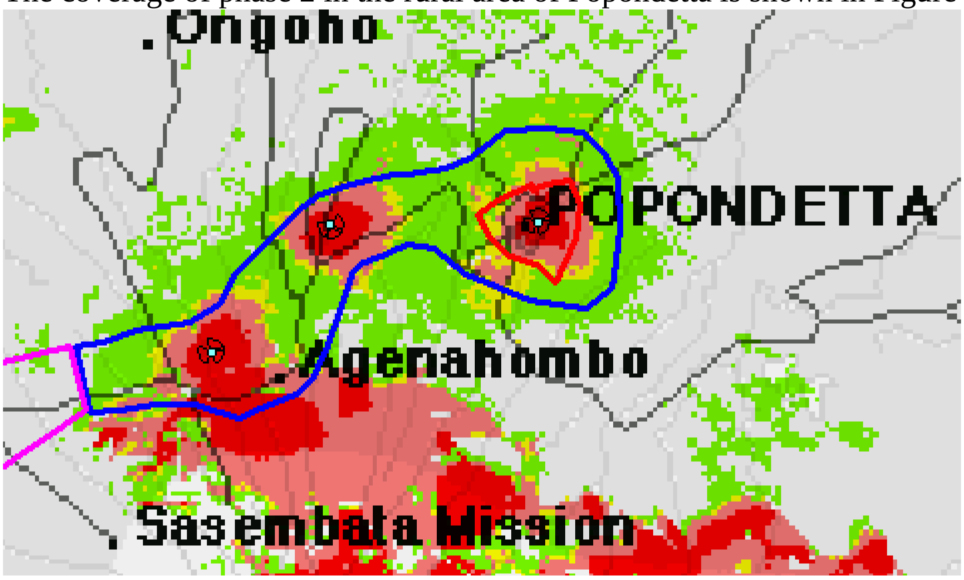


Figure 12: Coverage Phase 2 Popondetta Area

Site List

The following table shows the sites added during phase 2 to cover the rural area of Port Moresby and Popondetta. The used rectangular coordinate system is UTM 54 Southern Hemisphere - WGS 84, see Table 9.

Site Name	X Coordinates	Y Coordinates
Port Moresby Area 1	55503779.78	8964730.75
Port Moresby Area 2	55556409.37	8927602.40
Port Moresby Area 3	55534019.80	8947773.39
Port Moresby Area 4	55542259.83	8941408.50
Port Moresby Area 5	55548507.64	8934821.32
Popondetta Area 1	55628561.14	9030545.94
Popondetta Area 2	55623712.66	9025382.31

Table 9: Site List of Phase 2

Results for Phase 3

Site Count and Site Configurations

In the third and last network phase, 13 sites with 28 sectors were added. In 23 cases, the antenna with a half beam width of 33° was used to cover the interconnection area between the Port Moresby and Popondetta. In 5 cases the sectors were equipped with the 90° antenna, see Figure 13.

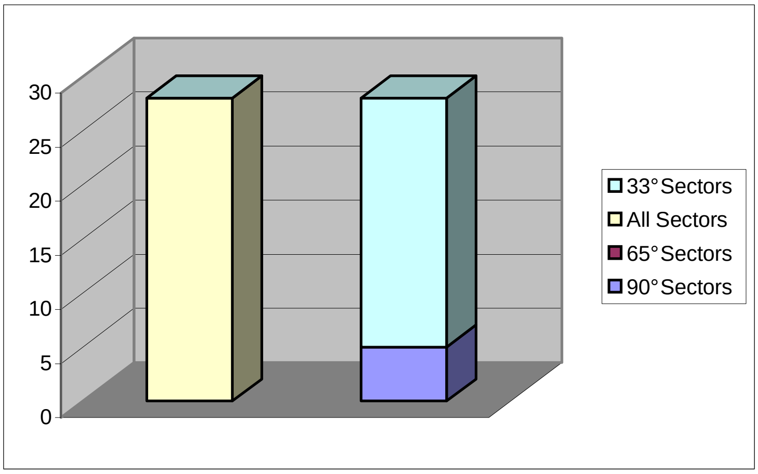


Figure 13: Number of added Sectors in Phase 2

At the end of phase three, the network consists of 32 sites with 84 sectors. Three different antenna types are used. Figure 14 shows the distribution of the antenna types for the sectors. The 33° antenna was used in 23 cases, the 65° antennas in 29 cases and the 90° antenna in 23 cases.

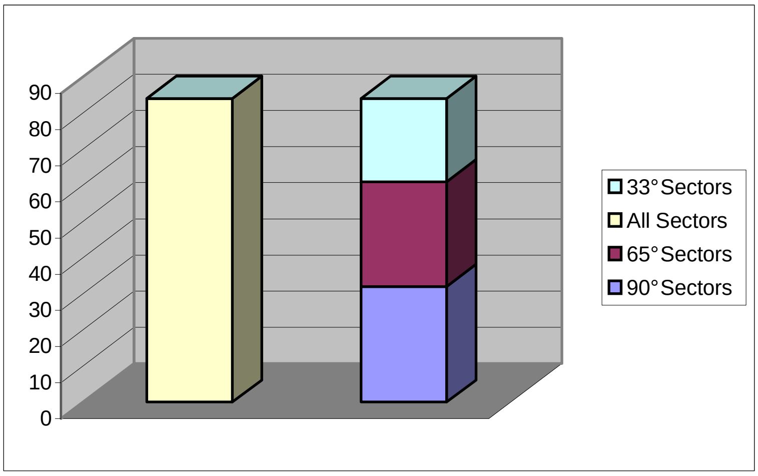


Figure 14: Number of Sectors in complete Phase 3

During the third planning phase only two times an antenna height of 40 m was used. The remaining 26 sectors are having a height of 30 m, see Figure 15. Antenna heights below 30 m has shown to be ineffective in the hilly terrain of the interconnection route between the areas of Port Moresby and Popondetta.

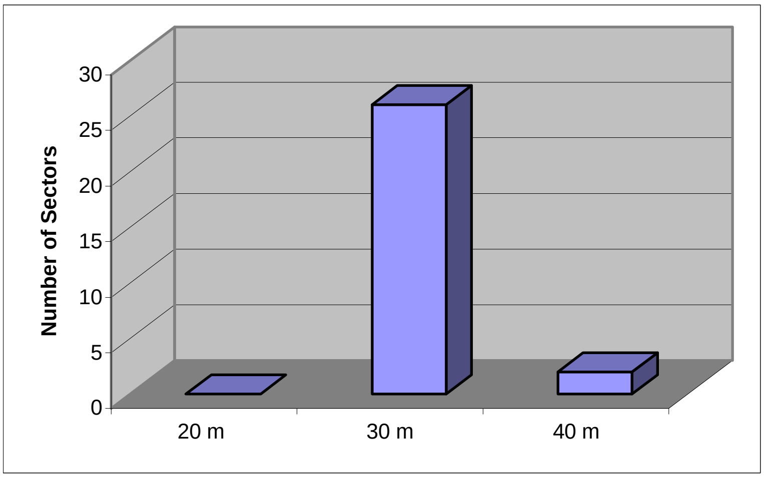


Figure 15: Sector Heights of added Sites / Phase 3

Three different antenna heights were used during the whole planning phases. Figure 16 shows the distribution of the antenna height. Roughly, two thirds of the sectors were using the height of 30 m. 24 sectors are 20 m high and 8 sectors 40 m.

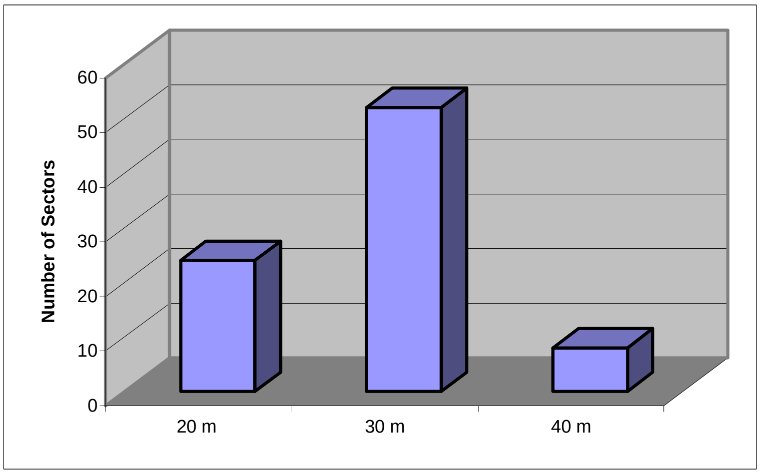


Figure 16: Sector Heights of complete Sites in Phase 3

Coverage Statistic

Table 10 shows the covered area in percent for the result network in phase 3.

Coverage Classes	**Port Moresby**	**Popondetta**	**Port Moresby Area**	**Popondetta Area**	**Inter-connection**
Rural	99.1%	100%	95.9%	97.8%	87.9%
Incar	89.8%	90.5%	65.7%	48.9%	57.8%
Suburban Indoor	82.6%	78.8%	56.7%	37.1%	51.1%
Urban Indoor	36.5%	34.8%	25.0%	15.3%	29.6%

Table 10 Covered Area in Percent / Phase 3

Coverage Plot

The coverage plot shows the achieved coverage for the network after phase 3, see Figure 17:

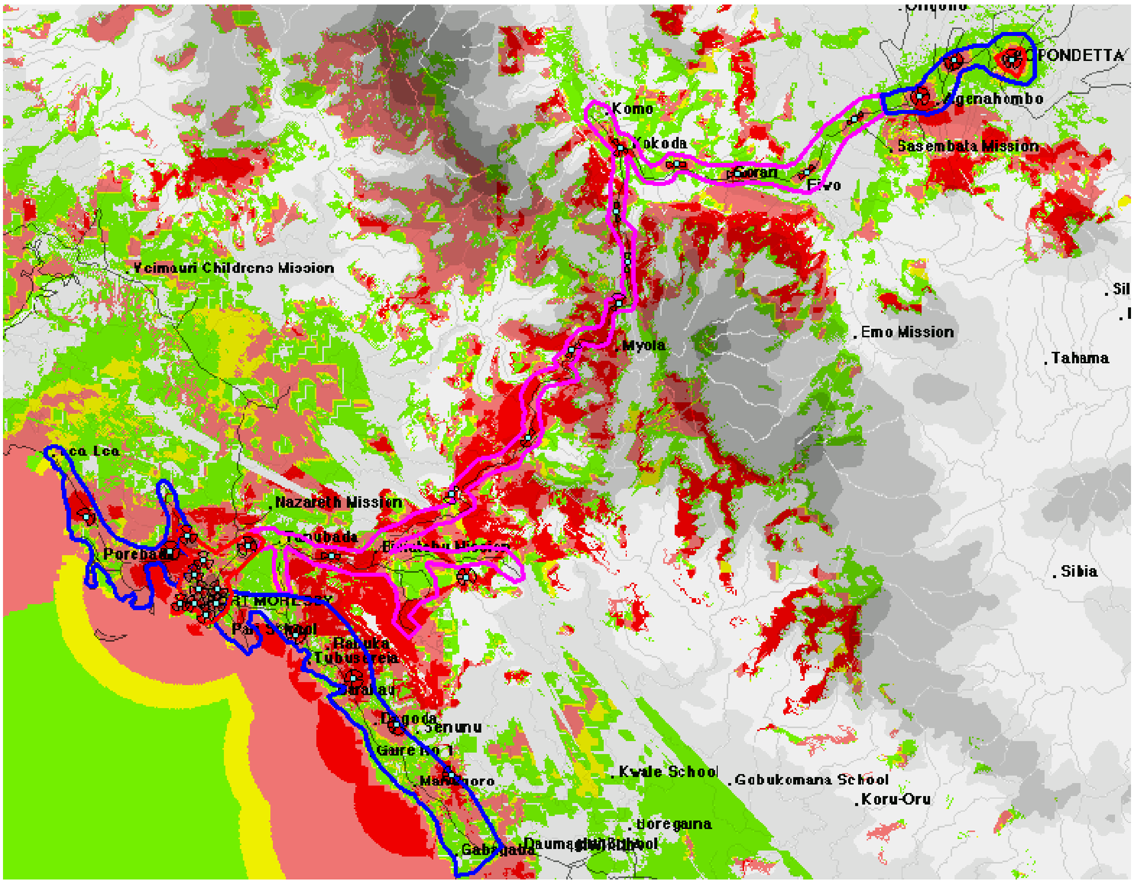


Figure 17: Coverage Phase 3

<u>Site List</u>

The following table shows the used sites needed to achieve the coverage in the interconnection area between Port Moresby and Popondetta. The used rectangular coordinate system is UTM 54 Southern Hemisphere - WGS 84.

Site Name	X Coordinates	Y Coordinates
Interconnection 1	55614358.80	9022109.60
Interconnection 2	55607492.18	9014330.90
Interconnection 3	55597409.24	9014145.95
Interconnection 4	55588740.65	9015527.77
Interconnection 5	55580654.80	9018000.50
Interconnection 6	55580104.05	9008776.11
Interconnection 7	55580392.44	8995565
Interconnection 8	55581685.96	9001492.51
Interconnection 9	55567382.71	8976130.13
Interconnection 10	55558457.45	8956070.41
Interconnection 11	55556385.70	8967977.59
Interconnection 12	55573709.59	8988901.21
Interconnection 13	55539063.00	8959142.60

Table 11: Site List of Phase 3

Results for Fixed Network
- - to be finalized --

Results for Phase 1

Link Count and Link Configuration

Plot with links

Link List

Results for Phase 2

Link Count and Link Configuration

Plot with links

Link List

Results for Phase 3

Link Count and Link Configuration

Plot with links

Link List

Summary

A2.7. Case study from developing country

BROADBAND ACCESS & BACKBONE SOLUTIONS.

CASE STUDY FROM PAPUA NEW GUINEA (PNG)

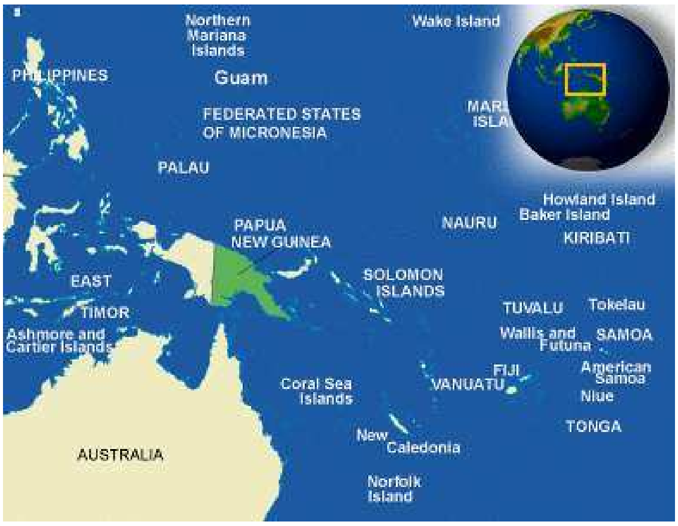
TELECOMMUNICATIONS INDUSTRY IN PNG

The Telecommunication Industry in Papua New Guinea is a regulated industry. The sole provider of telecommunication services is Telikom PNG Limited (TPNG) that is a fully state owned Company. Plans are currently underway to partially privatize it. Independent Consumer and Competition Commission (ICCC) is the super regulator (economic and social regulator) while PANGTEL is the sole Technical Regulator.

The telecommunications industry in PNG has a potential for 1.038 million additional subscribers for basic telecommunications services, current connection capacity of 96,000 lines and 150,000 mobile cellular (GSM) capacities with 67,000 telephone subscriber lines connected and 54,000 mobile subscribers connected. A teledensity of 13 lines per 1000 people and mobiledensity of 11 mobiles per 1000 people.

In the past two years, the Telecommunication industry has been under going a number of new reforms. Some of these reforms are to regulate the industry by providing a legislative framework where TELIKOM PNG LTD will be a regulated entity by way of a regulatory contract. PANGTEL will retain responsibility for the technical aspects of the telecommunications industry.

SOCIO-ECONOMIC ASPECTS



Papua New Guinea is an Island country comparable to but slightly larger than the city of California, USA and borders the main island of New Guinea with Indonesia on the west. It has a land area of 452,860 sq.km of 0.084 sq.km. per person. It has a population of 5.4 million people. The country's population density is 11.92 persons per sq.km. Its terrain is mostly mountains with coastal lowlands and rolling foothills.

The language is Melanesian pidgin as lingua franca, English spoken by 1-2% and is the language of commerce and business with motu in the coastal region. Life expectancy is 64.56 years. Port Moresby is the largest and the capital city and has the largest population of 325,000 people.

Its natural resources are gold, copper, silver, natural gas, timber, oil and fisheries. PNG is richly endowed with natural resources but exploitation has been hampered by rugged terrain and high cost of developing infrastructure. Agriculture provides a subsistence livelihood for 85% of the population. Minerals deposits including oil, copper, gold account for 72% of export earnings.

PNG receives 7.2% of GDP as aid, has budget expenditures (Total Expenditure US$1.35 billion) of US$996.8 million including capital expenditures of US$344 million and total revenue of US$1.33 billion. The economy has improved over the past two years after a prolonged period of instability. Australia annually supplies US$240 million in aid which accounts for 20% of the national budget. Challenges facing the country include further gaining investor confidence, privatizing government assets and balancing relations with Australia the former colony. The current exchange rate is one Kina = 3.2225 USA dollar. PNG income category is low income. The population level below poverty line is 37%.

TELECOMMUNICATIONS SERVICES & COMMUNICATIONS

Fixed services

TPNG's Public Switched Telecommunications Network services include:

- Switched telephone international services

- Switched telephone domestic (local and national distance) services
- Public pay phones
- Leased circuit services
- Packet switched data
- Outstation HF radio services
- Public radio-communications services (coastal radio services/maritime and aeronautical services).
- Other services provided include mobile satellite services and paging.

Mobile services

Mobile network and services are provided by Pacific Mobile Communications Ltd (PMC), a wholly owned subsidiary of TPNG. Like the fixed services, mobile services are currently provided on an exclusive basis.

PMC has replaced the old AMPS analogue system with the “second generation” GSM technology. The GSM system now services 6 major urban towns and is expanding due to its preference over fixed phones by customers. The service is provided with pre-paid option.

The demand and preference for mobile phones over fixed phones saw the customer base (150,000) exceed the fixed phone customer base (96,000) recently and is growing. With more and more demand for the service, the network is currently experiencing significant congestion. The congestion was caused by a number of factors including:

- Insufficient call handling capacity of the mobile exchange;
- Insufficient capacity of the prepaid billing platform;
- Insufficient transmission capacity between the mobile exchange and TPNG prepaid billing platform;
- Insufficient transmission between the mobile exchange and TPNG fix line exchange;
- Insufficient radio capacity on the mobile base station network; and
- Network not being optimised.

System optimisation to be completed by end of August 2005 with the mobile network upgrade.

Internet gateway service

TPNG also provides Internet Gateway Service to five (5) Internet Service Providers (ISP’s). ISP’s are not licensed as Value Added Service providers however they operate under an agreed arrangement with TPNG. One ISP is currently providing email service, which makes use of HF radio, particularly in the rural areas. The satellite link provides an aggregate bandwidth of 8 Mbps while the cable network has a capacity of 2.0 Mbps.

Private Communication Networks

The demand for ICT and broadband applications from various sectors in PNG can not be emphasised enough. So much so that certain entities, have installed and are operating their own Very Small Terminal Aperture (VSAT) based communication systems..

Radio broadcasting services

AM and SW Broadcasting services are provided by the government operator, National Broadcasting Corporation (NBC). A non-commercial community SW radio service commenced operation in June2005.
There are also two nationwide commercial FM radio networks while in the main city and towns. Four FM radio stations (commercial and non-commercial) also operate locally as well, two of which broadcast in the Pidgin and Motu languages. A number of non-commercial community FM radio stations operate in remote rural locations, which use the local language of the serviced area to broadcast its programs.

Television and Multi-channel Multi-Distribution System (MMDS)

There is only one nationwide TV broadcaster and a 27-channel Pay TV service, which operates only in Port Moresby, the national capital, using Microwave Multipoint Distribution System. At least two major Cable TV networks serve Port Moresby and other major towns.

DEVELOPMENT OF TELECOMMUNICATIONS SERVICES

Government Policy & Privatisation

The government has also commenced privatization of state-owned entities including Telikom PNG. The objectives of this exercise include;

- Improving the provision of essential services in accordance with priority policy objectives
- Promoting economic efficiency and encouraging competition, and
- Improving the performance of state-owned enterprises.
- Future Plans for Information Communications

With the privatization of Telikom PNG, the government is including the Community Service Obligation (CSO) in the sale process as a major condition. This would constitute a deed of agreement between the State and the privatized Telikom PNG binding it to provide accessibility of basic telecommunication services to the rural sector in which 80% of the total population are based. The main objective is raising the current access level to the ITU USO acceptable levels as much as possible.

Major Set-Backs and Hurdles to Development of Telecommunications

The diversity of culture/languages, scattered villages, the rural based population and the rugged terrain of the country is a major hurdle to the development of the Telecommunications in PNG. Natural disasters and theft also have a part to play in the already very difficult area.

Rural Based Population

One major barrier in the development of the industry is that the vast majority (80%) of the total population of PNG is rural based and depend heavily on subsistence farming. The rural populations do not really see the need to own a phone and even if they are in the vicinity of an access point will not afford a phone. Due to this, Telikom PNG does not see such an exercise as profitable.

Scattered Villages

In PNG, the definition of a village would differ from the village in other countries. The villages in PNG are small and are scattered making it very difficult to extend the current PSTN network out to the rural areas. Even if an access point were located in one of the PNG villages, the inhabitants of the other villagers would have to travel kilometers just to have access to a telephone. The targets as set by the USO are very difficult to meet in such a scenario.

Rugged Terrain

The natural terrain of PNG makes the provision of service difficult and the extensive use of radio a necessity with radio repeaters often being sited on inaccessible mountain peaks serviceable only by helicopters. High compensation demands by landowners for land on which repeaters are located has forced Telikom to introduce satellite system to provide a more efficient and reliable network that is very costly.

PNG NETWORK PLANNING CASE STUDIES

The organisation of the PNG case study was in two parts:

1. Broadband solution for the capital city of Port Moresby,
2. Backbone solution for the whole country.

The case studies were performed and run with highly professional Network Planning Tools provided by VPISystems. Other companies' tools partners of the ITU in NP programs in NetWORKS, LSTelcom were supposed to be used but unfortunately were not run or study performed using them.

1 Broadband Solution Study of Boroko suburban area in Port Moresby.

Figure 1: Boroko commercial area. The Study Area is on the top right hand of the picture.

Figure 2: Service areas of Boroko, Business, Residential and Government according to Distribution Areas (DA).

The customer classes were segmented into the following:

- Business customers_ Bus
- Residential POTS_ Res_POTS
- Residential Low_Res_Low
- Coin Boxes_CB

The services respectively were:

- ADSL Business/ 512Kbps
- POTS/64kbps
- ADSL Residential / 128kbps
- Payphones / 64kbps

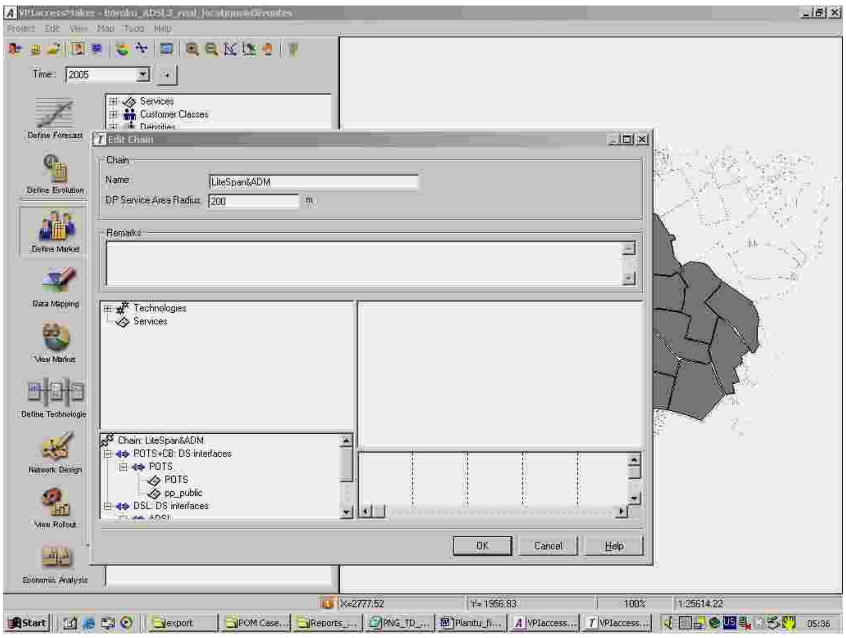


Figure 3: The VPIAccessMaker^{TM} Tools is used to study the potential and distribution of the new services.

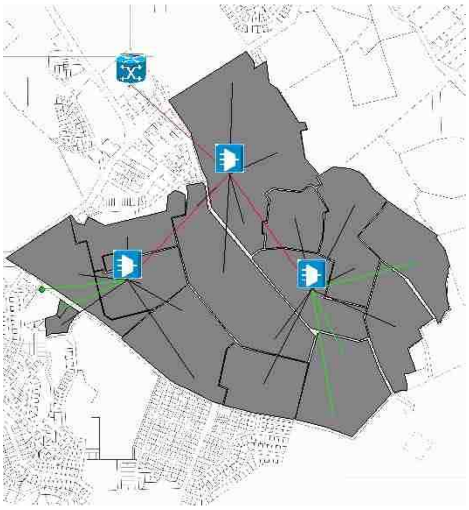


Figure 4: The Optimised DSLAM & Router locations in Boroko. Only three DSLAM with one Router at the exchange is needed.

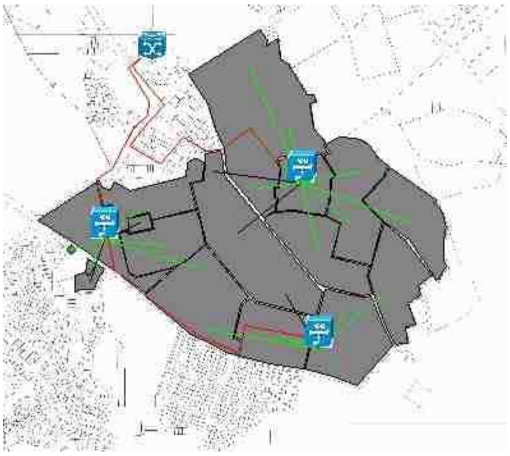


Figure 5: The Optimised Location within existing buildings with optical fibre links.

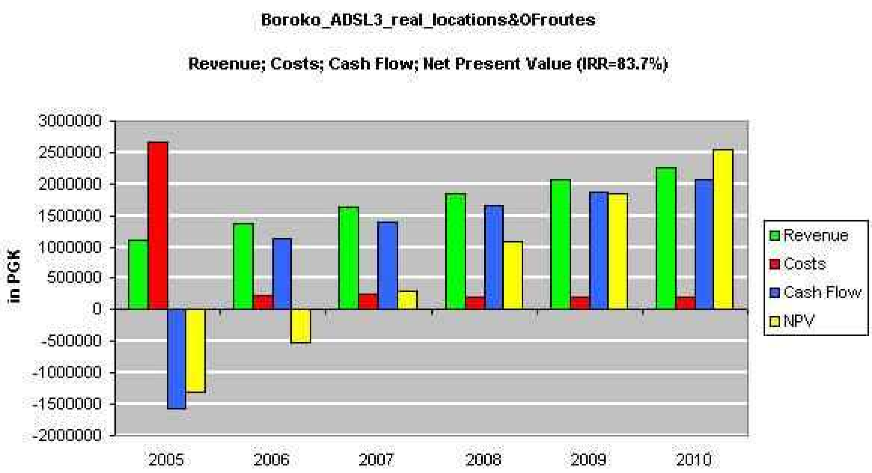


Figure 6: Economic Analysis of ADSL in the access network of Boroko

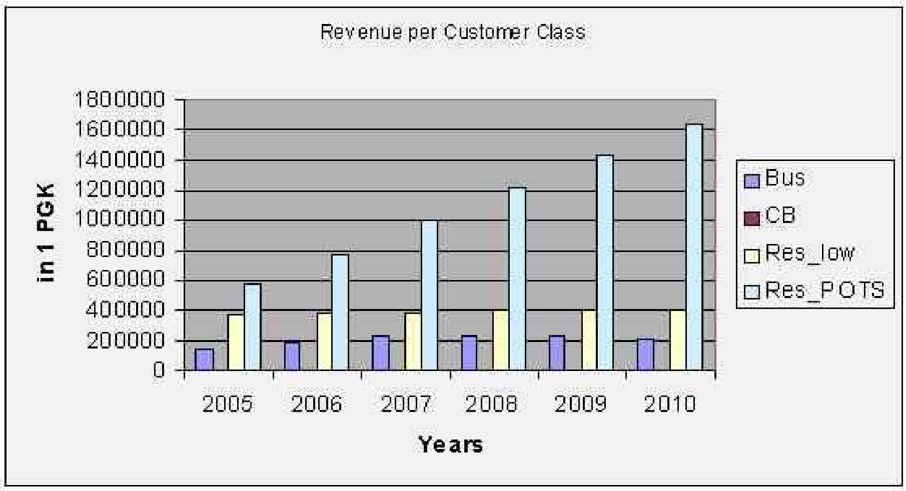


Figure 7: The forecasted revenue of the services. The POTS segment of the services will provide most of the revenue

2 Backbone Solution for the Whole Country.

The backbone solution study was to optimize the routing and dimensioning of the network. The numbers of exchanges of 27 were used in the study.

The transmission medium used in the networks are Radio, Satellite, Fibre optic and cable. About 90% of the links are radio and satellite transmission systems covering the whole country. Apart from diversity on satellite it also provide means to counter demands for compensation using vandalism and forceful disruptions to service by the local land owners on whom the repeaters are installed . The Data network is over lay on the PSTN. The satellite links are for diversity and for oil, copper, gold mines were radio links are not covered or inaccessible due to rugged terrain.

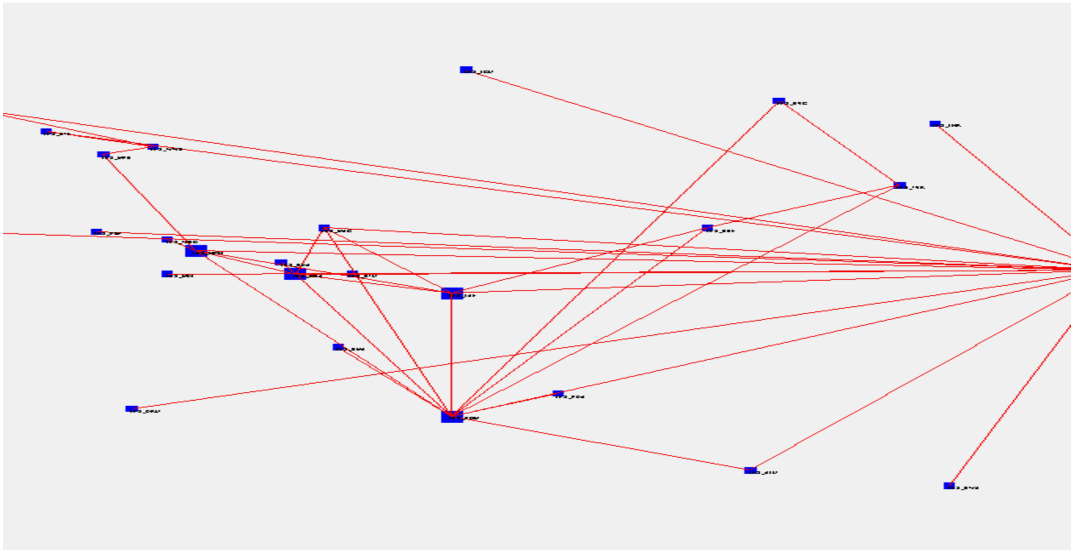


Figure 8: Physical Links of the Papua New Guinea Telecommunications Networks showing Satellite and Radio links.

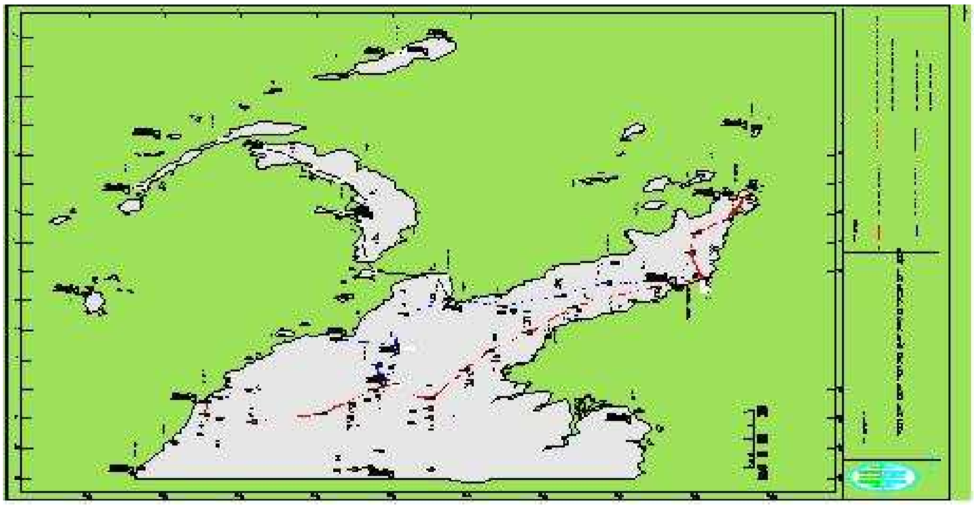


Figure 9: PNG National Microwave Trunk Network.

The complete digitization of the transmission network is undergoing completion by 2005/2006 planning period.

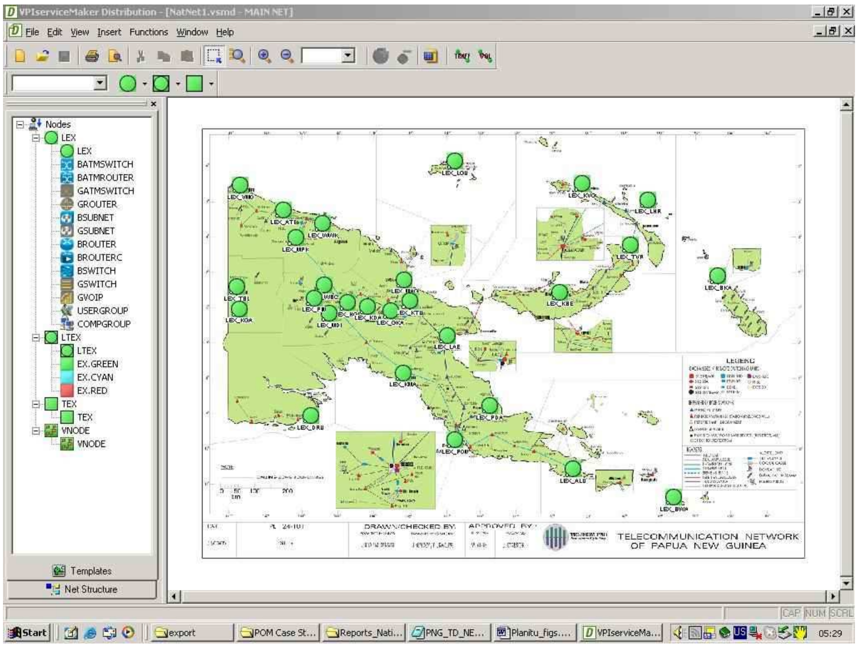


Figure 10: The Switching Network of Papua New Guinea showing existing exchange nodes locations.

The Telikom Switching Network is presently comprised of a five level hierarchical structure as follows;

- International Switching Centers – Port Moresby & Lae
- Sector Primary Exchanges
- District Local/Transit Exchanges
- Remote Switching/Concentrator Units

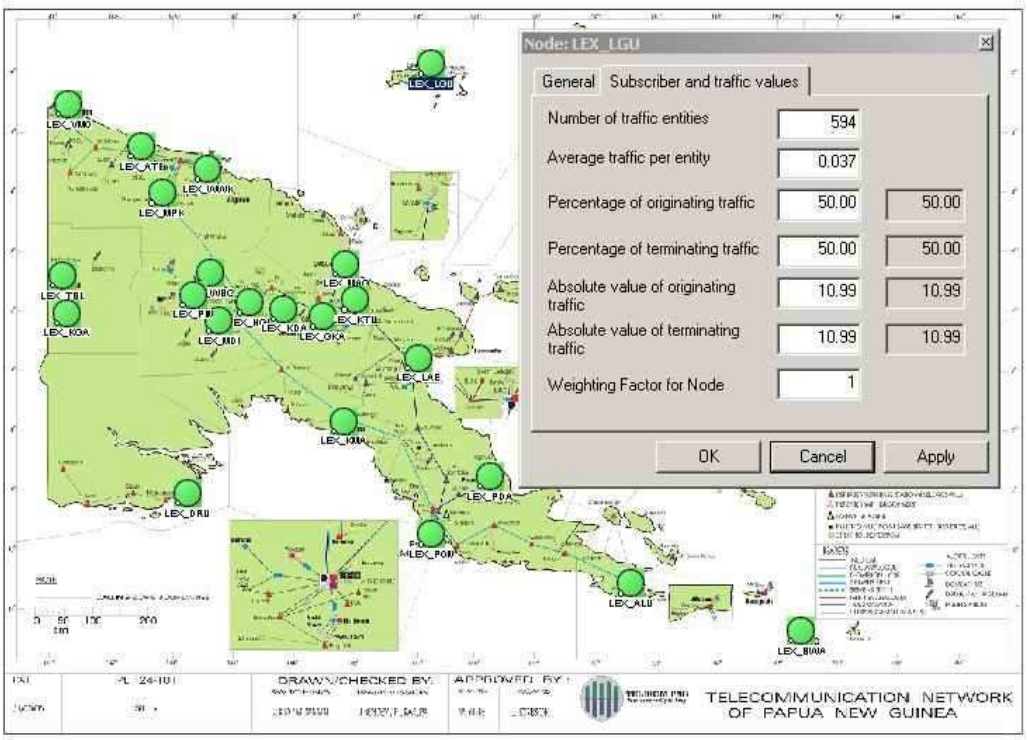


Figure 11: The specialised Network Planning tool of VPIserviceMaker™ Distribution was used to perform traffic forecast and distribution. The generated traffic distribution matrix for the network is below. The parameters were required:

- Subscriber numbers for each of the 27 nodes,
- Average traffic outgoing for national network from the 27 nodes
- Proportion of traffic terminating and originating from the 27 nodes

MM	LEX_ALU	LEX_ATE	LEX_BKA	LEX_BWA	LEX_DRU	LEX_GKA	LEX_HGN	LEX_KBE	LEX_KDA	LEX_KGA	LEX_KMA	LEX_KTU	LEX_KVG	LEX_LAE	LEX_L
LEX_ALU	0.00	0.10	0.19	0.07	0.19	0.93	1.36	0.67	0.13	0.14	0.11	0.12	0.33	3.77	(
LEX_ATE	0.10	0.00	0.03	0.01	0.03	0.17	0.25	0.12	0.02	0.03	0.02	0.02	0.06	0.69	(
LEX_BKA	0.19	0.03	0.00	0.03	0.06	0.32	0.46	0.23	0.04	0.05	0.04	0.04	0.11	1.29	(
LEX_BWA	0.07	0.01	0.03	0.00	0.03	0.13	0.18	0.09	0.02	0.02	0.02	0.02	0.05	0.51	(
LEX_DRU	0.19	0.03	0.06	0.03	0.00	0.32	0.47	0.23	0.05	0.05	0.04	0.04	0.12	1.31	(
LEX_GKA	0.93	0.17	0.32	0.13	0.32	0.00	2.33	1.14	0.22	0.24	0.19	0.21	0.57	6.46	(
LEX_HGN	1.36	0.25	0.46	0.18	0.47	2.33	0.00	1.67	0.33	0.35	0.28	0.31	0.84	9.43	(
LEX_KBE	0.67	0.12	0.23	0.09	0.23	1.14	1.67	0.00	0.16	0.17	0.14	0.15	0.41	4.62	(
LEX_KDA	0.13	0.02	0.04	0.02	0.05	0.22	0.33	0.16	0.00	0.03	0.03	0.03	0.08	0.90	(
LEX_KGA	0.14	0.03	0.05	0.02	0.05	0.24	0.35	0.17	0.03	0.00	0.03	0.03	0.09	0.97	(
LEX_KMA	0.11	0.02	0.04	0.02	0.04	0.19	0.28	0.14	0.03	0.03	0.00	0.03	0.07	0.78	(
LEX_KTU	0.12	0.02	0.04	0.02	0.04	0.21	0.31	0.15	0.03	0.03	0.03	0.00	0.08	0.85	(
LEX_KVG	0.33	0.06	0.11	0.05	0.12	0.57	0.84	0.41	0.08	0.09	0.07	0.08	0.00	2.32	(
LEX_LAE	3.77	0.69	1.29	0.51	1.31	6.46	9.43	4.62	0.90	0.97	0.78	0.85	2.32	0.00	1
LEX_LGU	0.23	0.04	0.08	0.03	0.08	0.40	0.58	0.28	0.06	0.06	0.05	0.05	0.14	1.60	(
LEX_LHR	0.24	0.04	0.08	0.03	0.08	0.40	0.59	0.29	0.06	0.06	0.05	0.05	0.14	1.63	(
LEX_MAG	1.13	0.21	0.38	0.15	0.39	1.93	2.82	1.38	0.27	0.29	0.23	0.25	0.69	7.81	(
LEX_MDI	0.16	0.03	0.06	0.02	0.06	0.28	0.40	0.20	0.04	0.04	0.03	0.04	0.10	1.12	(
LEX_MPK	0.07	0.01	0.02	0.01	0.02	0.12	0.17	0.08	0.02	0.02	0.01	0.02	0.04	0.48	(
LEX_PDA	0.31	0.06	0.11	0.04	0.11	0.54	0.79	0.38	0.08	0.08	0.07	0.07	0.19	2.18	(
LEX_PIM	0.10	0.02	0.03	0.01	0.03	0.17	0.25	0.12	0.02	0.03	0.02	0.02	0.06	0.68	(
LEX_POM	12.21	2.22	4.17	1.65	4.25	20.93	30.53	14.97	2.92	3.14	2.53	2.75	7.50	84.61	5
LEX_TBL	0.54	0.10	0.19	0.07	0.19	0.93	1.36	0.67	0.13	0.14	0.11	0.12	0.33	3.77	(
LEX_TVR	1.24	0.23	0.42	0.17	0.43	2.13	3.11	1.52	0.30	0.32	0.26	0.28	0.76	8.62	(
LEX_VMO	0.22	0.04	0.07	0.03	0.08	0.37	0.54	0.26	0.05	0.06	0.04	0.05	0.13	1.50	(
LEX_WBG	0.12	0.02	0.04	0.02	0.04	0.21	0.31	0.15	0.03	0.03	0.03	0.03	0.08	0.86	(
LEX_WWK	0.66	0.12	0.23	0.09	0.23	1.13	1.65	0.81	0.16	0.17	0.14	0.15	0.41	4.58	(
Debit	25.90	4.72	8.85	3.49	9.01	44.40	64.75	31.74	6.20	6.66	5.37	5.84	15.91	179.45	10
sum TERM	25.3562	4.6970	8.7827	3.4831	8.9433	42.8014	61.3499	30.9249	6.1639	6.6241	5.3467	5.8144	15.7049	153.3302	10.8
Corr	0.9790	0.9962	0.9928	0.9972	0.9927	0.9640	0.9475	0.9742	0.9950	0.9946	0.9957	0.9953	0.9871	0.8544	0.9
Delta	0.0210	0.0038	0.0072	0.0028	0.0073	0.0360	0.0525	0.0258	0.0050	0.0054	0.0043	0.0047	0.0129	0.1456	0.0

OK
Cancel
Update Debit
Calc Single
IT-Factor
Target Factor
Fix matrix
gen TAM
Int Matrix
Undo Int Matrix
Kruithof
MinQS

Figure 12: The Network Traffic Matrix generated by the VPIserviceMaker™ Distribution Planning Tool for originating, terminating and total traffic in the Network.

The Dimensioned & Routing of the Network

The Dimensioning of traffic routes and routing for the whole network is performed by the PLANITU Planning Tool..

PNG National Telecoms Network 2005 Tr&D new 2005- 7-22 21
Statistics for Circuits & Traffics

Exchange #	Name	Circuits Inc	Circuits Outg	Peak Traffics Inc	Peak Traffics Outg	Transit
1	LEX_ALU	60	60	38.	38.	0.
2	LEX_ATE	30	30	7.	7.	0.
3	LEX_BKA	30	30	13.	13.	0.
4	LEX_BWA	30	30	5.	5.	0.
5	LEX_DRU	30	30	13.	13.	0.
6	LEX_GKA	90	90	65.	65.	0.
7	LEX_HGN	600	600	95.	95.	291.
8	LEX_KBE	60	60	46.	46.	0.
9	LEX_KDA	30	30	9.	9.	0.
10	LEX_KGA	30	30	10.	10.	0.
11	LEX_KMA	30	30	8.	8.	0.
12	LEX_KTU	30	30	8.	8.	0.
13	LEX_KVG	60	60	23.	23.	0.
14	LEX_LAE	540	540	258.	258.	139.
15	LEX_LGU	30	30	16.	16.	0.
16	LEX_LHR	30	30	16.	16.	0.
17	LEX_MAG	120	120	79.	79.	0.
18	LEX_MDI	30	30	11.	11.	0.
19	LEX_MPK	30	30	5.	5.	0.
20	LEX_PDA	60	60	22.	22.	0.
21	LEX_PIM	30	30	7.	7.	0.
22	LEX_POM	1140	1140	613.	613.	140.
23	LEX_TBL	60	60	38.	38.	0.
24	LEX_TVR	360	360	87.	87.	133.
25	LEX_VMO	30	30	15.	15.	0.
26	LEX_WBG	30	30	9.	9.	0.
27	LEX_WWK	60	60	46.	46.	0.

Total traffic offered : 1562.
Total traffic lost : 3.

Table 1: Optimised Dimensioning results from PLANITU Planning Tool. The results show that the Total Network Traffic generated is 1562 erlang, and 3 Erlang of traffic lost implying no congestion in the Network.

27 exchanges

LEX_ALU	1	0.0	0.0	1	2	2	22	0.	0.
LEX_ATE	2	0.0	0.0	1	2	2	7	0.	0.
LEX_BKA	3	0.0	0.0	1	2	2	22	0.	0.
LEX_BWA	4	0.0	0.0	1	2	2	22	0.	0.
LEX_DRU	5	0.0	0.0	1	2	2	22	0.	0.
LEX_GKA	6	0.0	0.0	2	2	2	0	0.	0.
LEX_HGN	7	0.0	0.0	2	2	2	0	0.	0.
LEX_KBE	8	0.0	0.0	1	2	2	22	0.	0.
LEX_KDA	9	0.0	0.0	1	2	2	6	0.	0.
LEX_KGA	10	0.0	0.0	1	2	2	22	0.	0.
LEX_KMA	11	0.0	0.0	1	2	2	22	0.	0.
LEX_KTU	12	0.0	0.0	1	2	2	22	0.	0.

LEX_KVG	13	0.0	0.0	1	2	2	22	0.	0.
LEX_LAE	14	0.0	0.0	2	2	2	0	0.	0.
LEX_LGU	15	0.0	0.0	1	2	2	22	0.	0.
LEX_LHR	16	0.0	0.0	1	2	2	22	0.	0.
LEX_MAG	17	0.0	0.0	1	2	2	14	0.	0.
LEX_MDI	18	0.0	0.0	1	2	2	22	0.	0.
LEX_MPK	19	0.0	0.0	1	2	2	7	0.	0.
LEX_PDA	20	0.0	0.0	1	2	2	22	0.	0.
LEX_PIM	21	0.0	0.0	1	2	2	22	0.	0.
LEX_POM	22	0.0	0.0	2	2	2	0	0.	0.
LEX_TBL	23	0.0	0.0	1	2	2	22	0.	0.
LEX_TVR	24	0.0	0.0	1	2	2	22	0.	0.
LEX_VMO	25	0.0	0.0	1	2	2	22	0.	0.
LEX_WBG	26	0.0	0.0	1	2	2	7	0.	0.
LEX_WWK	27	0.0	0.0	1	2	2	7	0.	0.

Table 2: The Routing policy from PLANITU with all other exchanges routing traffic to the regional four transits.

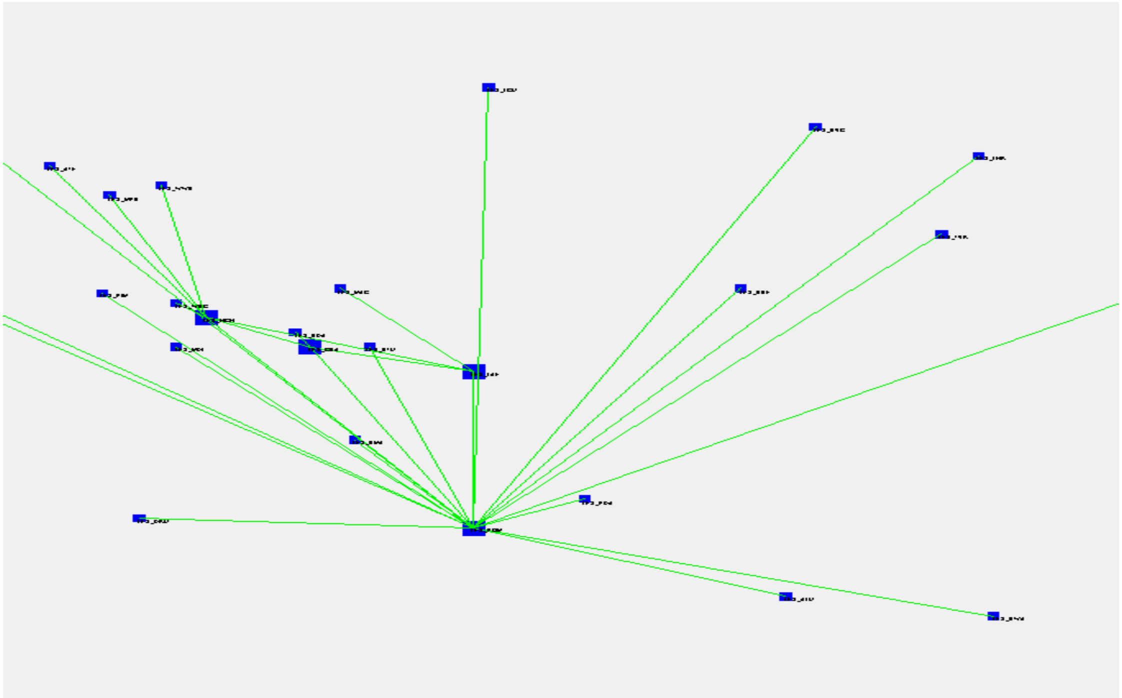


Figure 13: Optimised Traffic Routing from using PLANITU Planning Tool.

The Optimised routing transforms the routing into a three level hierarchical routing from a four level national network of the following;

- National Transit – Located in Port Moresby
- Regional Transits – Port Moresby, Lae, Mt.Hagen and Tomavatur
- Local Transits/Local Exchanges.

CONCLUSIONS

PNG as a developing country is faced with the following challenges of migration of present network, anticipated competition and regulation, and increased planning complexity. Critical planning issues and aspects of network development are needed to be addressed in transmission, signalling, routing, traffic management and quality of service.

The following case studies have addressed the need for attention to be given to the use of planning tools as compulsory if it is required to implement new, better and recognized methods for improving planning methods.

The development of telecommunications strategy for evolving of present networks and the transition to Next Generation Networks (NGN) is facilitated by the role of planning tools. The PNG Case studies show this by using specialised tools as the VPIsystems AccessMaker™ and VPIsystems ServiceMaker™ and for specific planning cases for broadband access solutions and backbone routing optimisation and dimensioning, using PLANITU.

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A3.3. ABBREVIATIONS/GLOSSARY

The list of abbreviations is intended to include all those used in these Reference Manual.

The list will be further completed and updated

#	
1G	First Generation Mobile Communications
2G	Second Generation Mobile Communications
3G	Third Generation Mobile Communications
3GPP	Third Generation Partnership Project
4G	Fourth Generation Mobile Communications
A	
AAA	Authentication, Authorization and Accounting
ACGF	Access Gateway Control Function
ADM	Add/Drop Multiplexer
ADSL	Asymmetric Digital Subscriber Line
AGW	Access Gateway
ALG	Application Level Gateway
AMPS	Advanced Mobile Phone System
AN	Access Network
ANI	Application Network Interface
ANSI	American National Standards Institute
API	Application Programming Interface
AS	Application Server
ATM	Asynchronous Transfer Mode
B	
B&B	Branch and Bound
BC	Bandwidth Constraint
BGCF	Breakout Gateway Control Function
BGF	Border Gateway Function
BGP	Border Gateway Protocol
BIS	Bump in the Stack
BLER	Block Error Rate
BS	Base Station
BSC	Base Station Controller
BSS	Business Support Systems
BT	Burst Tolerance
BW	Bandwidth
BWA	Broadband Wireless Access
C	

C4	Class 4 switch
C5	Class 5 switch
CAC	Call Admission Control
CAPEX	Capital Expenditure
CAPS	Call Attempts per Second
CATV	Cable Television
CBMS	Converged Broadcast Mobile Services
CDMA	Code Division Multiple Access
CDV	Cell Delay Variation
CDVT	Cell Delay Variation Tolerance
CF	Cash Flow
CIR	Committed Information Rate
CLASS	Custom Local Area Signaling Services
CLR	Cell Loss Rate
CN	Core Network
CoS	Class of Service
CPE	Customer Premises Equipment
CR	Constraint Based Routing
CRM	Customer Relations Management
CS	Circuit Switching
CSCF	Call Session Control Function
D	
DECT	Digitally Enhanced Cordless Telephone
DBM	Digital Building Model
DEM	Digital Elevation Model
DLC	Digital Loop Carrier
DLCI	Data Link Connection Identifier
DOCSIS	Data Over Cable Service Interface Specifications
DP-1	Dimensioning Problem -1
DSCP	DiffServ Code Point
DSLAM	Digital Subscriber Line Access Multiplexer
DSM	Digital Surface Model
DSTM	Dual Stack Transition Mechanism
DTM	Digital Terrain Models
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting-Handheld
DVB-T	Digital Video Broadcasting- Terrestrial
DWDM	Dense Wavelength Division Multiplexing
E	
EBIT	Earnings Before Interest and Taxes
EBITDA	Earnings Before Interest and Taxes, Depreciation and Amortisation
ECMP	Equal Cost Multi-Path
EDGE	Enhanced Data Rate for GSM Evolution
EF	Expedited Forwarding
EN-FE	Edge Node-Functional Entity
EPG	Electronic Program Guide
ERT	Equivalent Random traffic

ESBR	Equivalent Sustained Bit Rate
ESS	Engineering Support System
ETNO	European Telecommunication Network Operators association
ETSI	European Telecommunication Standards Institute
EVA	Economic Value Added
F	
FDD	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
FEC	Forward Equivalence Class
FH	Frequency Hopping
FITL	Fiber In The Loop
FMC	Fixed Mobile Convergence
FO	Fiber Optics
FR	Frame Relay
FTTC	Fiber To The Curb
FTTH	Fiber To The Home
FPLMTS	Future Public Land Mobile Telecommunication Systems
FTTO	Fiber To The Office
FTTU	Fiber To The Unit
FV	Future Value
G	
GFP	Generic Framing Procedure
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GW	Gateway
H	
HDSL	High bit Rate Digital Subscriber Line
HFC	Hybrid Fiber Coax
HLR	Home Location Register
HSS	Home Subscriber Server
HTML	HyperText Markup Language
I	
IAD	Integrated Access Device
IBCF	Interconnecting Border Control Function
ICD	Intelligent Control Delivery
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
IGP	Interior Gateway Protocol
IM	Instant Messaging
IMS	Internet protocol Multimedia Subsystem
IMT-2000	International Mobile Telecommunications
IMT-DS	International Mobile Telecommunications Direct Spread
IMT-FT	International Mobile Telecommunications Frequency Time
IMT-MC	International Mobile Telecommunications Multi Carrier
IMT-TD	International Mobile Telecommunications Time Division

IN	Intelligent Network
INAP	Intelligent Network Application Part
INMD	In Service non- intrusive Measurement Device
IP	Internet Protocol
IPDV	Internet Protocol Packet Delay Variation (jitter)
IPER	Internet Protocol Packet Error Ratio
IPLR	Internet Protocol Packet Loss Ratio
IPTD	Internet Protocol Packet Transfer Delay
IPTV	Internet Protocol Television
IPv4	Internet Protocol version four
IPv6	Internet Protocol version six
IRR	Internal rate of return
ISATAP	Intra-Site Automatic Tunnel Addressing Protocol
ISDN	Integrated Services Data Network
ISO	International Standards Organization
ISUP	ISDN User Part
IT	Information Technology
ITC	International Teletraffic Congress
ITU	International Telecommunication Union
ITU-D	International Telecommunication Union – Development Sector
ITU-R	International Telecommunication Union – Radiocommunication Sector
ITU-T	International Telecommunication Union – Telecommunication Sector
J	
K	
L	
LBS	Location Based Services
LCAS	Link Capacity Adjustment Procedure
LDP	Label Distribution protocol
LE	Large Enterprise
LER	Label Edge Routers
LEX	Local Exchange
LIB	Label Information Base
LFIB	Label Forward Information Base
LMDS	Local Multipoint Distribution System
LOS	Line Of Sight
LP	Linear Programming formulation
LSC	Label Switch Controller
LSP	Label Switched Path
LTP	Long Term Planning
M	
MAC	Medium Access Control
MAN	Metropolitan Area Network
MCR	Minimum Cell Rate
MCTD	Maximum Cell Transfer Delay
MDI	Medium Dependent Interface
MGCF	Media Gateway Control Function
MGF	Media Gateway Function

MIP	Mixed Integer Programming problems
MM	Multimedia
MMS	Multimedia Message
MOS	Mean Opinion Score
MPLS	Multi Protocol Label Switching
MRF	Multimedia Resource Function
MRFC	Multimedia Resource Function Control
MRFP	Multimedia Resource Function Processor
MS	Mobile Station
MSC	Mobile Switching Center
MSS	Mobile Satellite Services
MTP	Medium Term Planning
N	
NAT-PT	Network Address Translation-Protocol Translation
NAS	Network Access Server
NE	Network Element
NGN	Next Generation Network
NGSS	Next Generation Support Systems
NM	Network Management
NMT-450	Nordic Mobile Telephone -450
NO	Network Operator
NPV	Net Present Value
NWA	Network Wireless Access
O	
OADM	Optical Add-Drop Multiplexer
OASIS	Organization for the Advancement of Structured Information Standards
O&M	Operation and Management
OIF	Optical Interworking Forum
OPEX	Operational Expenditure
OSPF	Open Shortest Path First
OSA	Open Service Architecture
OSS	Operational Support System
OTN	Optical Transport Networking
OXC	Optical cross-connect
P	
P2P	Peer to Peer
PAN	Personal Area Network
PBS	Presence Based Services
PCS	Physical Coding Sublayer
PCR	Peak Cell Rate
PDA	Personal Directory Assistant
PDSN	Packet Data Serving Node
PDSN	Public Data Switched Network
PE	Provider Edge
PESQ	Perceptual Evaluation of Speech Quality
PHBs	Per Hop Behaviors
PHY	Physical Layer Service

PIM	Protocol Independent Multicast
PKI	Public Key Infrastructure
PLMN	Public Land Mobile Network
PMA	Physical Medium Attachment
PMD	Physical Medium Dependent
PNNI	Private Network-to-Network Interface
POP	Point of Presence
POTS	Plain Old Telephone Service
PS	Packet Switching
PSTN	Public Switched Telephone Network
PTM	Point To Multipoint
PtS	Push to Speak
PTP	Point To Point
PV	Present Value
PVC	Permanent Virtual Connection
Q	
QoS	Quality of Service
R	
RACE	Research for Advanced Communications in Europe
RACF	Resource Acceptance Control Function
RAN	Radio Access Network
RFP	Request for Proposal
RGW	Residential Gateway
RNC	Radio Network Controller
ROCE	Return on Capital Employed
ROI	Return on Investment
RPR	Resilient Packet Rings
RRM	Radio Resource Management
RSU	Remote Service Unit
RSVP	Resource Reservation Protocol
S	
SBle	Service Blending
SCCP	Signaling Connection Control Part
SCR	Sustainable Cell Rate
SDH	Synchronous Digital Hierarchy
SDMA	Space Division Multiple Access
SDSL	Symmetrical Digital Subscriber Line
SGSN	Serving GPRS Support Node
SIP	Session Initiation Protocol
SIR	Service Integration Radio Access
SIIT	Stateless IP/ICMP Translation
SLA	Service Level Agreement
SLF	Subscriber Location Function
SME	Small Medium Enterprises
SMS	Short Message Service
SOA	Service Oriented Architecture
SOHO	Small Office Home Office

SS	Signaling System
SSW	Softswitch
STEM	Strategic Telecom Evaluation Model
STM	Synchronous Transfer Module
STP	Short Term Planning
T	
TACS	Total Access Communication Systems
TB	Tunnel Broker
TCAP	Transaction Capabilities Application Part
TCBH	Time Consistent Busy Hour
TCM	Trellis Coding Modulation
TCP	Transmission Control Protocol
TDMA	Time Division Multiplexing Access
TE	Traffic Engineering
TEX	Transit Exchange
TISPAN	Telecoms & Internet converged Services & Protocols for Advanced Networks
TMN	Telecommunications Management Network
TRC-FE	Transport Resource Control Functional Entity
TRX	Transceiver
TTL	Time To Live
U	
UE	User Equipment
UMS	Unified Messaging System
UMTS	Universal Mobile Telecommunication System
UN	User Network
UNI	User Network Interface
V	
VC	Virtual Channel
VC-12	Virtual Channel/Virtual Container
VCI	Virtual Channel Identifier
VDSL	Very high Digital Subscriber Line
VNO	Virtual Network Operator
VOD	Video On Demand
VoDSL	Voice over Digital Subscriber Loop
VoIP	Voice Over IP
VP	Virtual Path
VPI	Virtual Path Identifier
VPN	Virtual Private Network
W	
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexing
Wi-Fi	Wireless Fidelity
WiMAX	World wide Interoperability for Microwave Access
WIP	Wireless Internet Protocol
WL	Wireline
WLL	Wireless Local Loop

WLAN	Wireless Local Area Network
X	
xLAN	Generic Local Area Network
xDSL	Generic Digital Subscriber Line
Y	
Z	