NETWORK AND RF PLANNING

Introduction

Achieving maximum capacity while maintaining an acceptable grade of service and good speech quality is the main issue for the network planning. Planning an immature network with a limited number of subscribers is not the real problem. The difficulty is to plan a network that allows future growth and expansion. Wise re-use of site location in the future network structure will save money for the operator.

Various steps involved in planning procedure

Planning means building a network able to provide service to the customers wherever they are. This work can be simplified and structured in certain steps. The steps are

- System requirements
- Define radio planning
- Initial network plan
- Surveys
- Individual site design
- Implementation
- Launch of service
- On-going testing

This process should not be considered just as it is depicted, in a single flow of events. For instance, the radio planning and surveying actions are interlinked in an ongoing iterative process that should ultimately lead to the individual site design.

Planning models

Propagation in land mobile service at frequencies from 300 to 1800MHz is affected in varying degrees by topography, morphography, ground constants and atmospheric conditions. A very common way of propagation loss presentation is the usage of so called propagation curves, normally derived from some measurement formulae are

- Okumara Y. and others, for field strength and its variability in VHF and UHF land Mobile Radio Service.
- Hata. M, Empirical formula for Propagation Loss in Land Mobile Radio Services.
- Cost –207, Digital Land Mobile Radio Communication.
- Cost-231, Urban Transmission Loss for Mobile Radio in the 900 and 1800MHz bands.

Planning tools

Tools are the software packages that help for planning the network. Some of the software packages used in cellular network planning are

- Networking planning system (NPS/X)
- Network measurement system (NMS/X) developed by Nokia

Cellular planning with NPS/X is based on utilization of digitized map and measurement results. The design database includes the parameters of the base stations, antennas, propagation models and system parameters.
The basic package includes:

- Coverage area calculation
- Composite coverage area dominance
- Point to point calculation
- Interference area calculation etc.,

Planning for cellular network

For a well-planned cell network planner should meet the following requirements

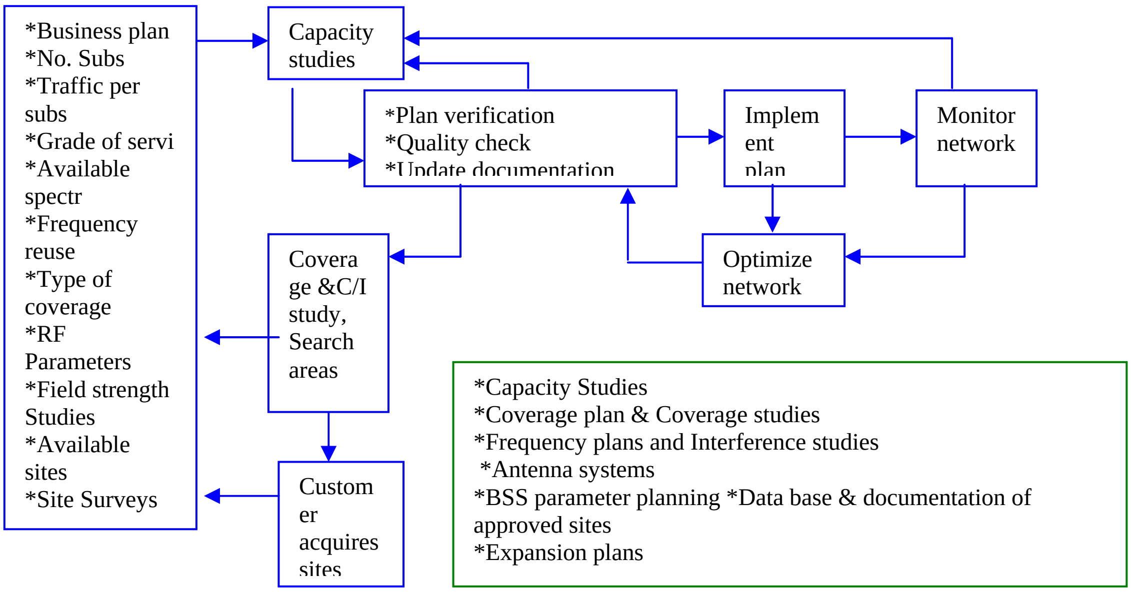
- Coverage as required and predicted.
- Co channel and adjacent channel interference levels as predicted for maintaining good quality of service.
- Minimum antenna adjustments during the optimization process.
- Maximum the network capacity (Erl/km2) with limited frequency band (MHz) by reusing the same frequencies.
- Minimum changes to the BSS parameters/database during the optimization phase.
- Facilitate easy expansion of the network with minimal changes in the system.

In general the planning process starts with the inputs from the customer. The customer inputs include customer requirements business plans system characteristics and any other constraints. After the planned system is implemented the assumptions made during the planning process nee to be validated and corrected wherever necessary through an optimization process.

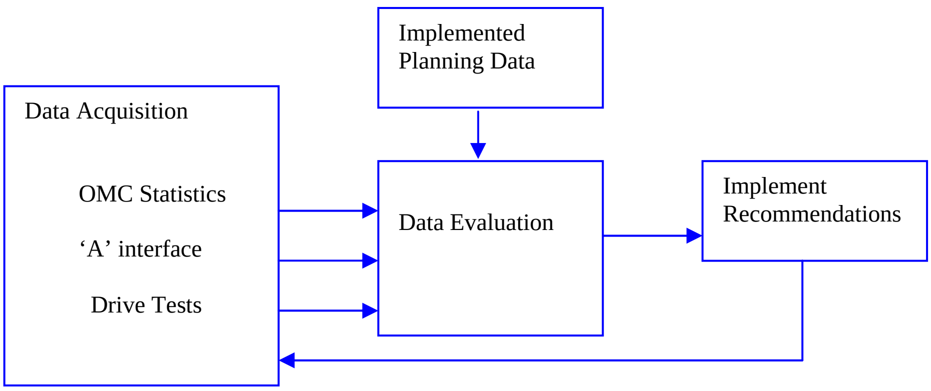
Total planning process can be divided in to four parts

- Capacity Planning
- Coverage Planning
- Parameter Planning
- Optimization

SIMPLE PLANNING PROCESS DESCRIPTION

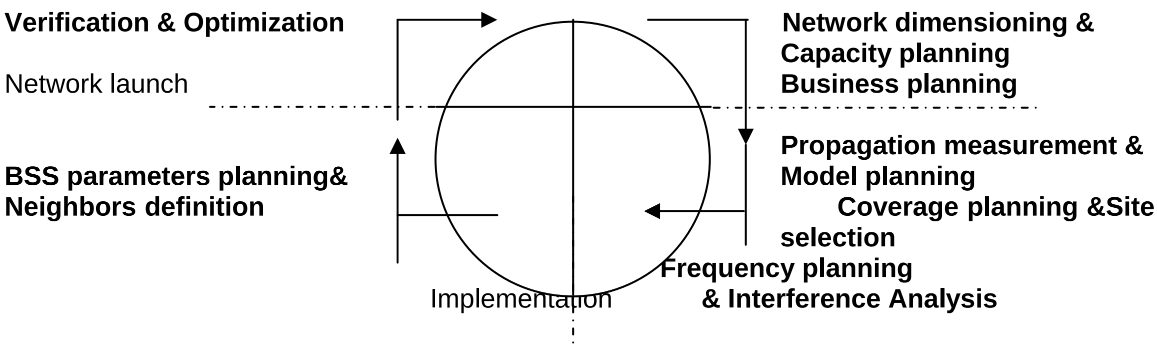


OPTIMIZATION PROCESS



<u>Recommendations:</u>
*Change Antenna Orientation/Down tilt
*Change BSS Parameters
*Dimension BSS equipment
*Add new Cells for coverage
*Interface Reduction
*Blocking reduction
*Augment E1 links from MSC to PSTN

Radio Network Planning



CAPACITY PLANNING

Network dimensioning

Network Dimensioning (ND) is usually the first task to start the planning of a given cellular network. The main result is an estimation of the equipment necessary to meet the following requirements.

- Capacity
- Coverage
- Quality

ND gives an overall picture of the network and is used as a base for all further planning activities.

Network dimensioning input

The inputs are

- Capacity related
  - Spectrum available.
  - Subscriber growth forecast
  - Traffic density map (Traffic per subs)
- Coverage related
  - Coverage regions
  - Area types information
- Quality related
  - MS classes
  - Blocking probability
  - Location probability
  - Redundancy
  - Indoor coverage.

The operator normally supplies the input data, but use of defaults is also possible. The technical parameter and characteristics of the equipment to be used are another very important part of the input. This includes the basic network modules (MSC, BSC, BTS) as well as some additional elements (antennas, cables…)

Capacity calculation

The capacity of a given network is measured in terms of the subscribers or the traffic load that it can handle. The former requires knowledge of subscriber calling habits (average traffic per subscriber) while the latter is more general. The steps for calculating the network capacity are

- Find the maximum no of carriers per cell that can be reached for the different regions based on the frequency reuse patterns and the available spectrum.
- Calculate the capacity of the given cell using blocking probability and the number of carriers.
- Finally the sum of all cell capacities gives the network capacity.

Spectrum efficiency

$$= S / (n \times A \times B)$$

S - total spectrum available
n - reuse factor
A - cell area
B - channel bandwidth

Erlang B table

To calculate the capacity of the given cell using blocking probability and the number of carriers we need the well-known Erlang B table or formulas and the no of traffic channels for different number of carriers. The result we get is the traffic capacity in Erlangs, which can easily be transferred into the number of subscribers.

Erlangs = n X t / 3600

- n = no of calls attempted
- t = total duration in seconds

Frequency reuse schemes

A cellular network can easily be drawn as a combination of hexagons or circles by the help of regular grids. One of the advantages is the possibility to try different frequency reuse patterns (clusters) and calculate the expected co-channel interference. This is required to assign a frequency reuse no (cluster size) to any of the network regions area types. It is clear that the high-density regions (big cities) are the most problematic parts of the network.

Power budget calculations

To guarantee a good quality in both directions (uplink and downlink) the power of BTS and MS should be in balance at the edge of the cell. The main idea behind the power budget calculations is to receive the maximum output power level of

BTS transmitter as a function of BTS and MS sensitivity levels, MS output power, antenna gain (Rx & TX), diversity reception, cable loss, combiner loss, etc….

The power budget calculations provides following useful results:

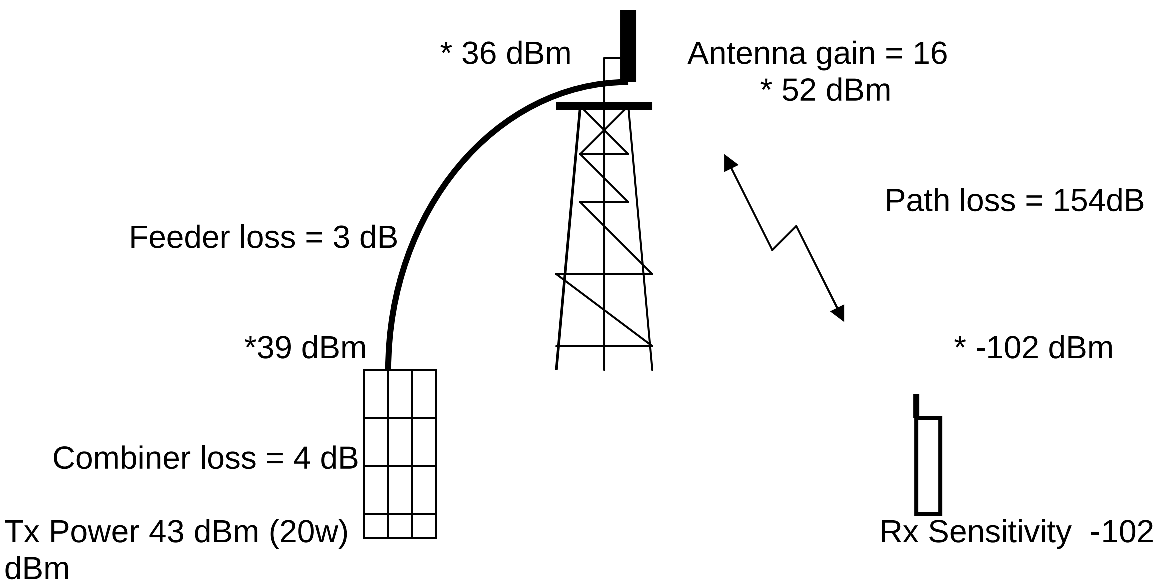
BTS transmitted power: BTS transmitted power is adjusted to provide a balanced radio link (i.e. Uplink Downlink radio link performance is the same) for given BTS and MS receiver performance, MS transmitter performance, antenna and feeder cable characteristics.

Isotropic path loss: this is the maximum path loss between BTS and MS according to given radio system performance requirements.

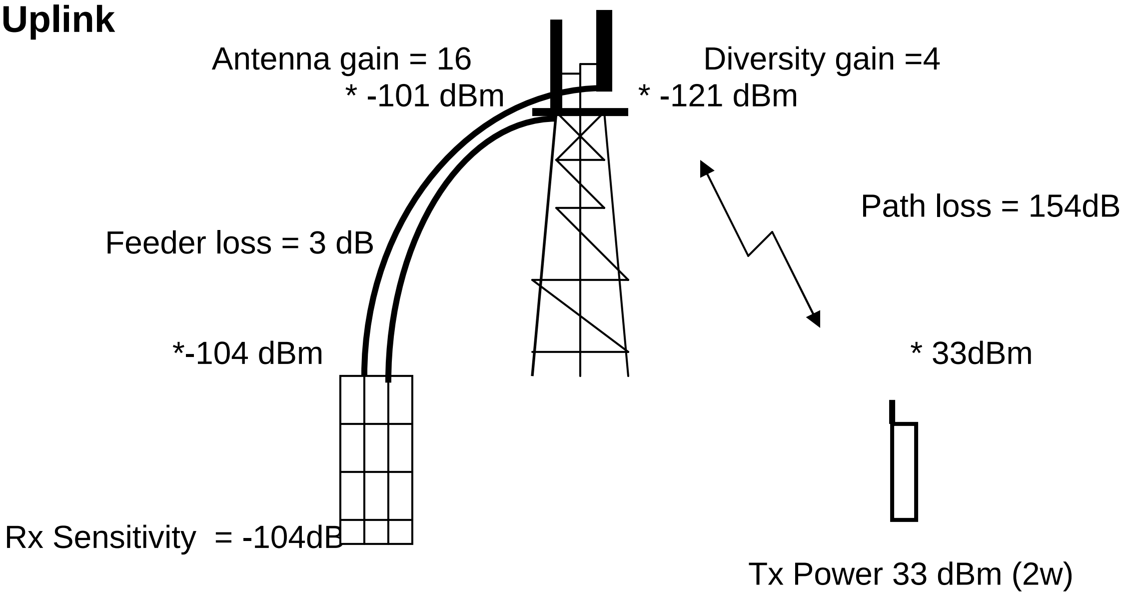
Coverage threshold: downlink signal strength at coverage area border for given location probability.

Cell range for indoor and outdoor coverage: this is a rough indication about cell range in different area types and can be used for network dimensioning. It can also be used for comparing the effect of different equipment specification and antenna heights for the cell range.

Down link



Uplink

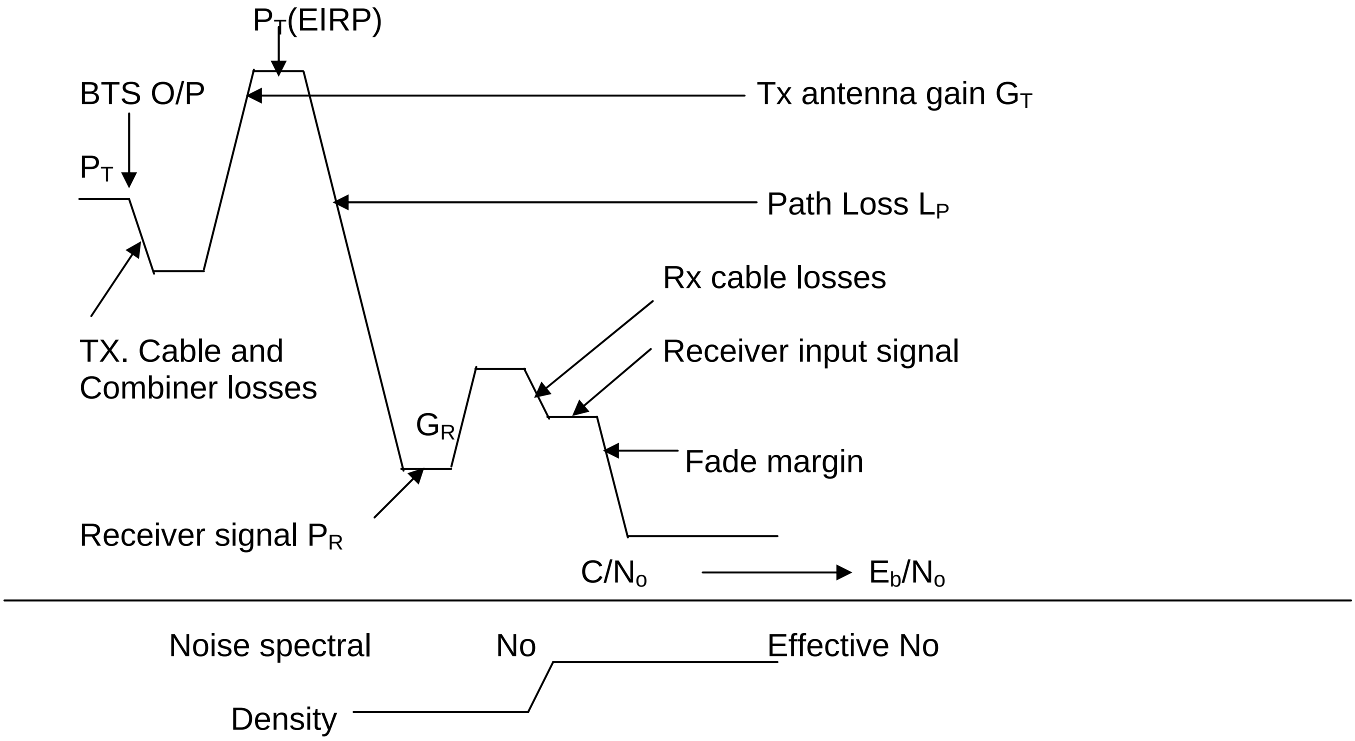


Power Budget calculation tables

Transmitting end	**MS**	**BTS**
Tx RF output power	33 dBm	43 dBm
Combiner loss	0 dB	4 dB
Feeder loss	0 dB	3 dB
Tx antenna gain	0 dB	16 dB
EIRP	33 dBm	52 dBm
	(A)	(C)

Receiving end	**BTS**	**MS**
Rx sensitivity	-104 dBm	-102 dBm
Rx antenna gain	16 dB	0 dB
Diversity gain	4 dB	0 dB
Feeder loss	3 dB	0 dB
Rx power	-104 dBm	-102 dBm
Required isotropic Rx power	-121 dBm	-102 dBm
	(B)	(D)
Maximum permissible path loss	154 dB	154 dB
	(B-A)	(D-C)

RF LEVEL DIAGRAM:



Path loss calculation

The general Path loss equation is given by (Okumara-Hata urban propagation model)

L_p =Q_1+Q_2 log (f)-13.82 log (H_{bts})-a (h_m)+{44.9-6.55log(h_{bts})} log (d)+Qo

L_p =path loss in dB
f =Frequency in MHz
d =distance between BTS and the mobile (1-20 Kms)
H_{bts}=base station height in meters (30 to 100m)
a (h_m)= Correction required if mobile height is more than 1.5 meters and is given by:
a (h_m)={1.1 log (f)-0.7}h_m –{1.56 log (f)-0.8} for urban areas and
=3.2{log (11.75h_m)^2-4.97for Dense urban areas

h_m = mobile antenna hei8ght (1-10m)

Q_1 =69.55 for frequencies from 150 to 1000MHz
=46.3 for frequencies from 1500 to 2000MHz

Q_2 = 26.16 for 150 to1000 MHz
= 33.9 for 1500 to 2000 MHz

Q_o = 0 dB for urban
= 3 dB for Dense urban

COVERAGE PLANNING:

Introduction

The objective of coverage planning phase in coverage limited network areas is to find a minimum amount of cell sites with optimum locations for producing the required coverage for the target area.
Coverage planning is normally performed with prediction modules on digital map database. The basic input information for coverage planning includes:

- Coverage regions
- Coverage threshold values on per regions (outdoor, in-car, indoor)
- Antenna (tower height limitations)
- Preferred antenna line system specifications
- Preferred BTS specification

Activities such as propagation modeling, field strength predictions and measurements are usually referred to as coverage planning.

Site selection:

Coverage planning and site selection are performed on parallel with the site acquisition in interactive mode. Both network planning team and site acquisition should team have well defined responsibilities and means to communicate.

Propagation models

Propagation models are essentially curve fitting exercises. Propagation tests are conducted at different frequencies, antenna heights, and locations over different periods and distances. The receive signal data is analyzed using mathematical tools and are fitted to an appropriate curve. Formula to match these curve are then generated and used as models.
Some of the major propagation models are:

- Long-distance propagation model
- Longley-Rice model (irregular terrain model)
- Okumara
- Hata
- Cost 231-Hata (similar to Hata: for 1500-2000 MHz band)
- Wolfish-Ikegami Cost 231
- Wolfish-Xia JTC
- XLOS (Motorola proprietary model)
- Bullington
- Du Path loss model
- Diffracting Screens model

Coverage predictions

The possibilities for rough coverage calculations based on propagation curves formulas. These average values are not enough for the detailed network planning; therefore many computer-aided tools based on digital maps usage have been developed to improve the quality of the predictions.

Digital maps

There are different types of information that can be digitized and used for coverage predictions. The most important from the network planning point of view are topography (terrain heights), morphography (area types), rods traffic density.
For the micro cell modeling, which is required in a dense urban environment, more information and heighten resolution maps should be used. Information about the buildings and streets is essential, so the pixel size from 5m to 25m is reasonable. The streets can be stored and used in vector format.

Point to point and cell coverage

Using a given digital map it is not difficult to obtain the path profile between any two points, say BS and MS. Furthermore the profile can be related to the corresponding area types, thus making possible the calculation of specific propagation loss. Normally different corrections, such as the diffraction loss or mixed land-sea path correction are added to the basic propagation loss. the result of such point to point calculations can be used for cell coverage prediction. There are two basic approaches:

- Radial calculations
- Pixel by pixel calculations

The latter one gives better possibilities for the interference predictions, so the results should be transferred to the raster format even if the radial approach is used.

Field strength measurements

The field strength measurements are needed for determination of coverage areas as well as for tuning the propagation model of network planning system. In case of measurement before base station installation the site should equipped with the test transmitter. Possible test transmitter configurations are mobile station base station channel unit signal generator with power amplifier. The selection of routs to be measured depends on the purpose of the measurements. The most critical routs are typical located in urban or hilly areas. Where it is difficult to predict the field strength values with high accuracy.

During the field strength measurement, the measuring system normally takes the samples from the signal received by the antenna. The field strength samples recorded by a control computer with time, location marks. Using the samples it is possible to calculate the average values.

Propagation Model Tuning

The propagation models are not universal. The predictions must be verified by measurements and the models tuned accordingly. The model testing and tuning is a very sophisticated and challenging task, which requires detailed knowledge of the propagation nature. It should be done for every area type in a given country or region before the detailed network planning is started.

Extension of cell coverage area

<u>The cellular area extension can be done with cellular repeaters and preamplifiers.</u>

The cellular repeater amplifies the RF signal in both uplink and downlink directions, i.e. it is a device which compensates the propagation loss between the base station antenna and mobile station antenna. The cellular repeater antenna is connected between two antennas: the first antenna is pointed to the base station site and the second one (reradiating elements) is pointed to the area to be covered.

Radiating cable (leaky cable) can be used in tunnels as a reradiating element to provide homogeneous field strength inside the tunnel.
Mast Head Preamplifiers (MHPx) are---- installed at the base station antennas mast after the Rx antenna to amplify the uplink signal. The preamplifier has a low noise figure and adjustable gain to compensate the Rx antenna feeder attenuation. It can be very helpful when low-power hand portables are used in the network.

FREQUENCY PLANNING

Introduction

The main goal of the frequency-planning task is to increase the efficiency of the spectrum usage, keeping the interference in the network below some predefined level. Therefore it is always related to interference predictions. There are two basic approaches to solve the frequency assignment problem.

- Frequency reuse patterns
- Automatic frequency allocation

Some software's are used with automatic frequency allocation algorithms for finding the optimum solutions. The frequency allocation is generally guided by the following information:

- Channel requirement on cell basis according to the capacity planning
- Channel spacing limitations according to BTS specification
- Quality of service requirement which is conserved to acceptable interference probability
- Traffic density distribution over the service area
- Performance of advanced system features (frequency hopping, IUO, etc….)

The frequency allocation is based on cell-to-cell interference probability estimation according to the network topology, field strength distribution and traffic load. This results in customized frequency performance of the selected radio network elements.

The starting point of automatic frequency allocation is much better, since the exact site coordinates and BTS characteristics are available. Usage of propagation model based on digital maps, we are able to obtain interference predictions very near to reality.

Frequency Reuse

A frequency used in one cell can be reused in another cell at a certain distance. This distance is called reuse distance. The advantage of digital system is that they can reuse frequencies more efficiently than the analogue ones, i.e. the reuse distance can be shorter, and the capacity increased. A cellular system is based in reuse of frequencies. All the available frequencies are divided into different frequency groups so that a certain frequency always belongs to a certain frequency group. The frequency groups together form a cluster.

"A cluster is an area in which all frequency groups are used once, but not reused."

The frequencies can be divided into different frequency groups. This introduces the terms reuse patterns and reuse grids. The most common reuse patterns in GSM is "4/12" and "3/9".

4/12 means that the available frequencies are divided into 12 frequency groups, which in turn are located at 4 base stations sites. This assumes that the base station has three cells connected to it. The frequency groups are often assigned a number or name such as A1, B1, C1, D1, A2,…….. D3.

3/9 means that the available frequencies are divided into 9 frequency groups located at 3 sites. Problem with C/A might appear in certain parts of a cell, arising from adjacent frequencies in neighboring cells.

Example: channel assignment of 24 frequencies in a 3/9-cell plan.

Frequency Groups	A1	B1	C1	A2	B2	C2	A3	B3	C3
Channels	1	2	3	4	5	6	7	8	9
	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24			

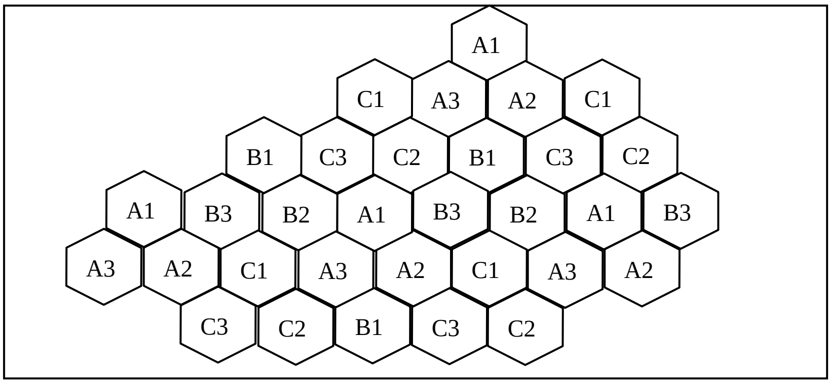


Fig: 3/9-frequency reuse pattern

Interference calculations

The reference interference ratio is defined in GSM as the interference ratio for which the required performance in terms of frame erasure, bit error rate or residual bit error rate is met. The reference interference ratios for BS and all types MSs are the following:

- Co channel interference: C/Ic <= 9 dB
- First adjacent channel interference: C/Ia1 <= -9 dB
- Second adjacent channel interference: C/Ia2 <= -41 dB

Co channel interference

The carrier to interference (C/I) ratio at a given mobile receiver can be calculated as follows:
C/I = C / (I1 + I2 + …….. +Ik)
Where k is the number of co channel interfering cells. For regular grid case it is possible to simplify the calculations by using the popular path loss expressions

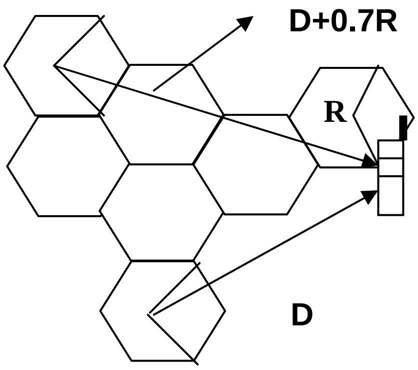
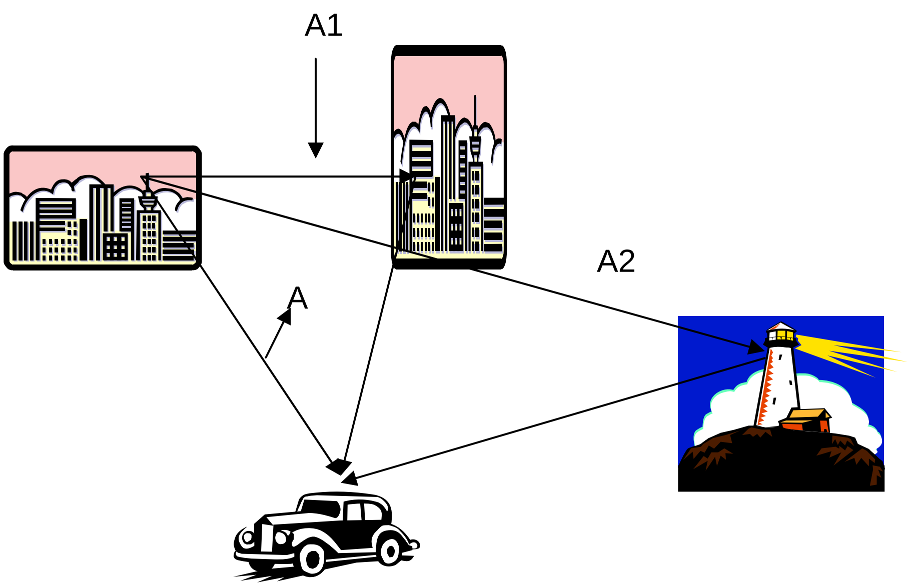


Fig: Two interferes in the sectorized network

Time dispersion

Some interference effects may be caused from the reflected signals if received outside the equalizer window. This happens only when the difference between direct path and the reflection path is larger than the equalizer window (about 4.5 km) and the reflected signal is strong enough. The reflection outside the equalizer window should be regarded as an independent co channel interferer, therefore the same reference C/I <= 9 dB should be used.



- A1+A2-A > 4.5 km
- C/I < 9 dB

Digital maps based co channel interface

From the coverage areas calculated by the help of digital maps it is quite easy to obtain the expected interference areas. Since the frequency plan is still to be done, the multiple interferences cannot be calculated. Thus the process works for every pair of BS checking the ratio between the two-signal pixels. The probability of future multiple interference can be reduced by adding some margin, say 6 dB to the reference interference ratio. If the percent of the interfered area is larger than a given predefined level (depending on the required service quality), the pair cannot operate in the same channel. The results are presented as a matrix with elements giving the minimum slowed channel difference (in this case only 0 and 1) for every pair of BSs.

Frequency hopping

Frequency hopping (FH) is changing the frequency of information signal according to a certain sequence. The transmission frequency may change at each time slot or burst and remains constant during the transmission of a burst.
FH can also decrease the overall C/I value in the network and thus improve the Quality Of Service (QOS).

Frequency hopping behavior:

Lognormal fading and Rayleigh distributed fast fading can decrease the speech quality. Rayleigh fades are the sum of a lot of reflected and phase shifted signals.

The fading at different frequencies is not the same and become more and more independent when the difference in frequency increases. With frequencies spaced sufficiently apart they can be considered completely independent (no correlation). Thus Rayleigh fading does then not damage all the bursts containing the parts of one code word in the same way.
When the ms moves of high speed the difference between its positions during the reception of two successive bursts of the same channel (i.e. at least 4,615 ms) is sufficient to decorrelate Rayleigh fading variations on the signal. In this case FH does not help except if there is interference.
The worst case is when ms is stationary or moves at slow speeds because the interleaved coding does not bring any benefit to reception. In this case FH “simulates ms movement” and thus the reception quality. This phenomenon is called frequency diversity.
In the other hand frequency hopping averages the interference directed towards each base station. Instead of a continuous interferer there are several interferers that affect only a short time each and with different intensity. Methods like power control and DTX (discontinuous transmission) affect only a single interference source and benefits can be distributed to the whole network by using FH. The gain, which comes from interference averaging, is called interference diversity.

Baseband hopping

Baseband hopping occurs between TRXs in BTS. The number of frequencies used in the hopping sequence is the same as the number of TRXs in the sector. Both random and cyclic hopping can be used.
The digital (baseband) and analogue (RF) parts of the TRX are separated from each other. The switching of TRXs is on a per timeslot basis ands enables a particular TCH to hop from one carrier to another.

Synthesized hopping

Synthesized hopping is available in configurations, which have at least 2 TRX per sector. It enables each TRX to change frequency on successive time slots, so that given carrier can hop quickly onto many different frequencies. The carrier on which the BCCH IS transmitted must remain at fixed frequency to enable the MS to measure correct signal strength. Both random and cyclic hopping can be used.

Discontinuous transmission (DTX)

The transmission is disconnected when no information flow happens in signal. This is done by lower speech encoding bit rate than when the user is effectively speaking. This low rate flow is sufficient to encode the background noise, which is generated for the listener to avoid him thinking that the connection is broken. The low rate encoding corresponds to a decreased effective radio transmission of one frame each 20 ms to one such frame each 480 ms. Typically transmission is effective 60% of the time, which decreases the interference.
In order to implement such a mechanism, the source must be able to indicate when transmission is required or not. In the case of speech, the coder must detect weather or not there is some vocal activity. This function is called Voice Activity Detection (VAD). At the reception side, the listener’s ear must not be disturbed by the sudden disappearance of noise and the decoder must therefore be able generate some Comfort noise when no signal is received.
DTX is an option controlled by the operator, and which may be used independently in the MS to BTS and in BTS to MS.

PARAMETER PLANNING

GSM radio path

GSM is system using time division multiple access (TDMA) frame structure. The TDMA frame has duration of 4.615 ms and consists of 8 timeslots. There is two types of logical channels carried over the timeslots: Common channels and dedicated channels.

Common channels

The common channels are used for signaling and ca be divided into broadcast channels (BCH), continuously sending information from BTS to MS, and common control channels (CCCH).

The Broadcast channels send information on the cell properties such as synchronization, frequency correction, used frequencies and power levels, neighboring cells. There are three different broadcast control channels (BCCH).

The common control channels are used when establishing a signaling connection between the MS and BTS. The paging channel (PCH) is used when BTS wants to contact the MS. The MS requests a signaling channel on a random access channel (RACH). The signaling channel is allocated to the MS by using Access grant channel (AGCH)

Dedicated channels

The dedicated channels are divided into dedicated control channels and traffic channels. Call set up signaling and location updating procedures are performed on stand-alone dedicated control channel (SDCCH). In case of a call setup the connection is transferred into a traffic channel (TCH).
Both SDCCH and TCH have a parallel slow associated control channel (SACCH) which is used for transfer of measurement results from MS to BTS and power control commands from BTS to MS. During the short messages are transmitted over SACCH channel, while the fast associated control channel (FACCH) is used to transmit the handover commands to the MS.

Radio path measurements

The radio path measurements are used to keep the connection in good quality and therefore to trigger power changes and handover if needed. Both MS and BTS measure signal level and quality (bit error ratio). In addition to that MS measures the signal levels of all adjacent BCCH frequencies even though it is able to report only six best measurements.

Power control and handover

The BTS sends the raw measurement results received from the MS (downlink) and the results of its own measurements (uplink) to the BSC every SACCH multiframe period. The BSC does not support the measurement preprocessing in the BTS.
The BSC does the preprocessing of the measurement samples namely the book keeping and the averaging. The BSC is able to maintain a table of maximum 32 measurements results for up to 32 adjacent cells per call. After the averaging the BSC makes comparisons with the thresholds related to both power control (PC) and hand over (HO) algorithms.
The BSC determines the RF output power of the MS and the BTS on the basis of the results received from the pc threshold comparison process.
The HO decision is based in signal strength (RXLEV), quality (RXQUAL) and distance measurements. Another possible criterion is the power budget (PBGT) or umbrella condition fulfillment from an adjacent cell. The HO command is given over FACCH, which uses TCH temporally. Handovers can be done to TCH and SDCCH. The intra BTS handover can occur either to a timeslot in a new carrier or to a different timeslot in the same carrier. The intra-BSC handover to performed autonomously by the BSC. If there is an inter-BSC handover to be performed, the BSC sends the list of performed cells to the MSC and MSC performs the handover according to that list.

Handover strategies and parameters

The HO decision process may be triggered in different situations. Similarly to the pc it is controlled by the level (RXLEV) and quality (RXQUAL) in both UL and DL. In addition to these it depends in the distance and some periodic checks (PGBT, UMBRELLA). Only one type of periodic can be used per cell. The main principle when making HO caused by radio criteria is that the new server should be better than the current one.
The parameters, averaging and threshold comparison for level, quality and distance are similar to PC but only one threshold associated. The periodic checks occur every power budget (HO period PGBT) or umbrella (HO period Umbrella) period. In order to be performed the periodic checks require some data for the neighboring cells: the comparison process uses the calculated PGBT (n) or AV_RXLEV_NCELL (n) for neighboring cells instead of fixed thresholds.
Like with PC it is possible by changing the HO related cell parameters to affect the HO algorithm at all stages: preprocessing, threshold comparison, decision making.

BSS Parameters

The following figure showing the example of general parameters on how the structure of the network is defined

BTS	
BS identity code (ncc&boc)	0…..7s
BTS ID	1…...128
Cell ID	1……65535
Location Area ID	mcc 0…999 lac0…65535
Number Of Blocks For Access Grant	0……7
No Of Multiframes Between Paging	2…….9
Number Of Retransmission	1,2,4,7
No Of Slot Spread Trans	3-12,14,16,20,25,32,50
Max Queue Length	0……100%
Time Limit Call	1……30s
Time Limit Handover	1……30s
Queuing priority call	1……14
Queuing priority handover	1……14
Ms Priority Used In Queuing	Y/N
Queue Priority Used	Y/N
Radio Link Timeout	4……64
IMSI Attach Detach	Y/N

NETWORK VERFICATION AND OPTIMZATION

This is the last step of the network planning procedure. It can start during the network trial period and continues after opening the commercial service and during the network expansion.
The aim of this process is to evaluate and maximize the quality of service in the network with the corresponding set of quality criteria.

Network verification

The purpose of the network verification (NV) is to evaluate an independent and objective quality of service (QOS) inside a given service area. This is done with network measurement system. Some OMC traffic measurements are dine in parallel to provide a statistical data and to complete the network picture.

The network verification procedure consists of the following steps:

- Planning of the measurement resources (including tools), reference network, schedule and test route(s)
- Setting of the network performance objectives and quality criteria
- Measurement execution and analysis of the statistical results
- Reporting to the customer the results of analysis
- Agreement on possible corrective actions if the set quality criteria is not met

The field verification takes place after successful completion of site acceptance. It should be repeated before and after any major network hardware/software changes to verify their affect on the network quality.
The service area, or the part of the network to be verified, is defined as a group of cells giving continuous coverage. It is always connected with a selection of test routes; the all verification and optimization activities are based in recurrent measurements over the same routes.

Network quality criteria

The quality objectives are specified according to the capacity requirements and customer's QOS strategy which se agreed with the customer.
Some examples
Number of successful mobile originating (MO)
Call attempts with normal cell releases **:**90-95%

Minimum overall downlink quality **:**value 0-5 in 90-95%

Minimum overall downlink level on street **:**>37dBuV/m in 90-95%
level for 2W mobile minimum

Minimum successful rate for handovers (HO) **:**90-905%

Maximum system response time **:**0-7 s in 90-95%

(Time for TCH assignment)

One basic requirement for Network quality survey is to monitor continuously QOS and Hp behavior, compare the network against other similar network and present the result in such a way that they are easy to understand for non-technical parts of the operator’s organization as well. To be capable of doing that requires additional metrics that are sensitive enough and very easy to understand.

Analysis of the Results

The main result of the verification procedure is the statistical quality sheet generated by the NPS/X or similar system
In addition to the statistical quality sheet the network element availability statistics from the OMC also form part of the network verification results. These results are collected either on a monthly or weekly basis and they concern the network elements as a whole or by unit basis. The statistics of unit restarts and the availability of transceiver units are reported.
The congestion level of each BTS is obtained from the OMC traffic statistics and reported together with other network Verification results as the Network Verification report

Network Optimization

Network Optimization can be defined as a continuous process of improving overall network quality. Looking at network quality two different views should be considered . The customers (subscribers) view and the more comprehensive operators view **fig. 1** overall network quality is illustrating this. Usually a subscriber is not interested in site leasing or maintenance socts. As long as his service is not affected things like spectrum efficiency and network traffic are of no interest to him. For the operator these fig are of fundamental importance.

Network optimization service and more general the Nokia Quality cycle service package are designed to support the operator in the most efficient way to improve all different aspects of network quality. Nokia tools experts with detailed system knowledge and the global network of experience provide the operator with the most sophisticated services.

BSS Default Parameter Assessments

Proper BSS default parameter settings are needed to ensure the best possible performance of the network. The parameter sets are based on experience from optimized networks.

BSS Configuration Analysis Module

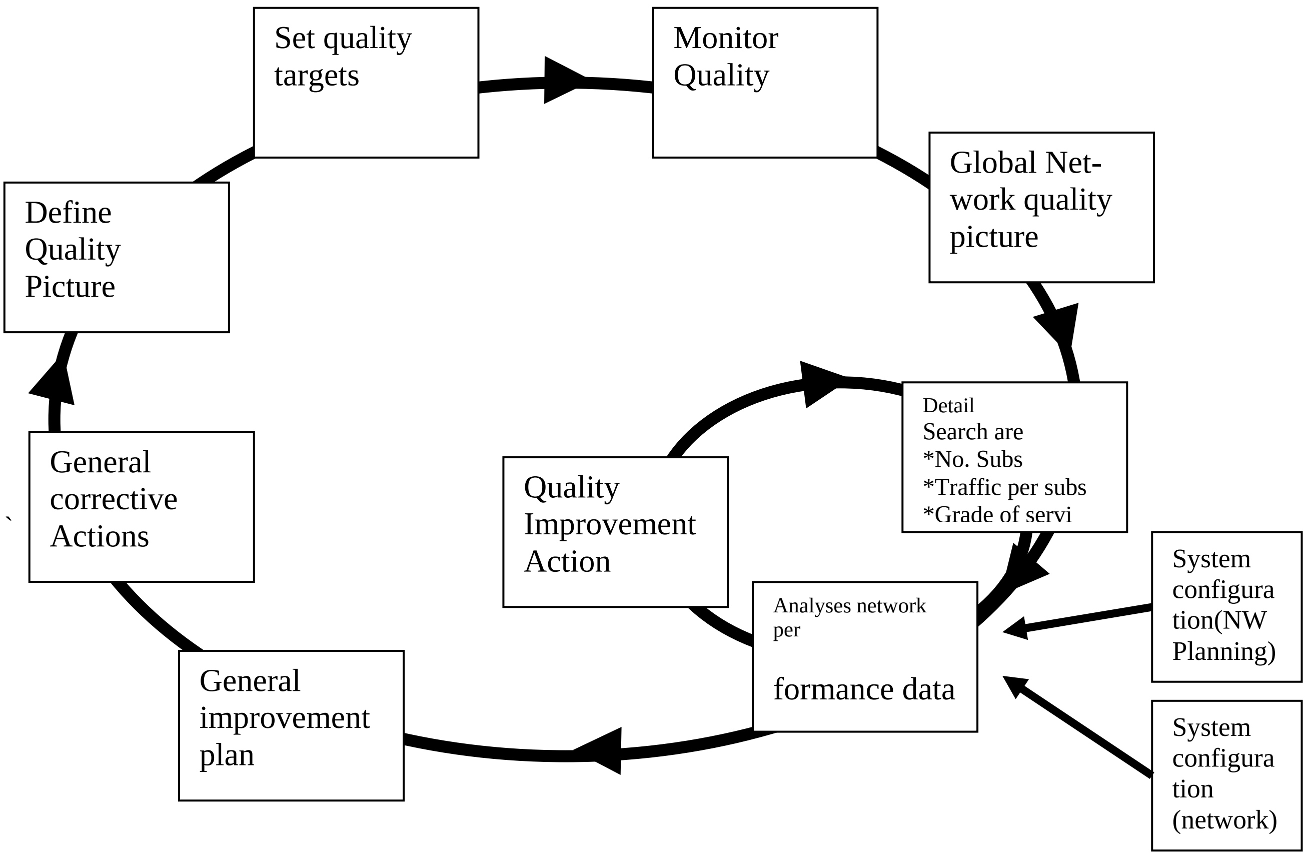
Network configuration Analysis is the smallest possible service module of network optimization. With this service the system configuration as existing in the real network (system configuration network) is compared against the system configuration as provided by network planning. This task ensures consistency between different system configuration databases and therefore is the basis of all following tasks. Basic configuration analysis should be repeated on a regular basis. Nokia can support with improving or designing and implementing procedures for regular consistency checks.

Basic Network Optimization Module

Field-tests OMC measurements and customer complaints are the three main sources to provide a detailed network quality picture.(e.g. call and handover success rates, problems reported by customer and field test personnel) the network performance data analysis together with single quality improvement actions raise network quality on a case by case basis. These tasks are combined in the Basic Network Optimization Module.

Full Optimization Service

As network optimization has to be seen as part of a bigger process, which is embedded in the operator's organization, Nokia is offering services and consultancy in the area of quality definition monitoring and improvement. This service sis called Full Optimization service and contains the small quality cycle as described in the previous chapter.



As the small quality cycle is required to monitor and improve quality on a more or less problem-by-problem basis a more global approach of quality monitoring and improvement is required.

Global quality reporting on regional and network level is required for management marketing and network planning. Global quality monitoring is similar to quality monitoring as required for Basic network optimization but it is reporting on a more general level (field tests, OMC and customer complaints) Global quality reporting allows
To monitor the impact of major changes in the network (e.g. frequency changes, BSS default parameter changes or massive traffic increase)
Quality definition and quality target setting are needed for agreements between different departments (e.g. Planning and marketing) As a conclusion from global quality reporting and experience from the small quality cycle work general improvement actions (e.g. testing new system features) and general corrective actions (e.g. major frequency change , capacity extension , introduction of micro cells or IUO)might follow.

In all phases of the network quality cycle Nokia is supporting with consultancy tools and training

Optimization Tools

Nokia is providing a variety of tools for network optimization. NMS/X, Nokia network measurement system for GSM/DCS and NMT network quality survey, network tracing and for multi channel field strength measurements covers all demands for field measurements. A portable version allows indoor measurements.

NPS/X, Nokia network planning system, is also a powerful tool for network optimization. Its features for down and uploading data from the OMC, the GSM/DCS simulator, the link to the measurement system NMS/X and many other features provide the optimization personnel with an advanced tool.

Examples For Basic Cell Planning
Input from the customer

Total subscribers 10000 at 25 mE traffic
Total Traffic 250 E (10000 X 25 mE)
Grade of service 2 %
Operating frequency 900 MHz
Hypothetical distribution of traffic is:

Area type	%Traffic	Traffic
Urban high density	20	50E

Urban	30	75E
Industrial	15	37.5E
Suburban	25	62.5E
Highways	5	12.5E
Total	100	250 E

Case 1: for specified number of sites

- 1/1/1 sites (350 subs per site)……..7000 subscribers.
- 2/2/2 sites (990 subs per site)……..19800 subscribers

Case 2: for specified capacity requirement (10000)

- 1/1/1 sites…….. 10000/350….. 30 sites
- 2/2/2 sites…….. 10000/990…...11 sites

Deciding Factors - Planning

- We may choose 2/2/2 sites for first 3 area types and 1/1/1 sites for the rest.
- What is the area of coverage needed?
- How many sites are required for this area?

(cell radius of 1 km means an approximate coverage area of 3 Sq.kms).

- Do we need so many sites?
- Can some sites be bigger?
- Decide number of sites based on capacity and coverage requirements.
- Divide city into clutter types such as:
    1. Urban
    2. Suburban
    3. Quasi open
    4. Open
    5. Water
- Identify "search areas" covering all clutter types.
- Customer selects a few sample sites
- Survey sites with reference to
    1. Clutter heights
    2. Vegetation levels
    3. Obstructions
    4. Sector orientation
    5. Building strengths and other civil requirements.
- Prepare power budgets.
- Conduct propagation tests.
- Calculate coverage probabilities based on the drive test results.
- Verify power budget sensitivity against drive test results modify planning tool parameter
- Prepare final coverage map.

RF planning starts with the preparation a power budget for the up link and the downlink for all sites.

Assume

Frequency 900MHzs
Cell radius 5 Kms
BTS antenna height 30m
Mobile antenna height 3m
Required receiver
Sensitivity (RSS) -104 dBm (BTS) and –102 dBm (MS)

So path loss for above inputs is **147.23 dB** (calculated using Okumara-Hata urban propagation model)

Transmitting end	**MS**	**BTS**	
TX RF output power	30 dBm	40 dBm	k
Combiner loss	0 dB	4 dB	l
Feeder loss	0 dB	3 dB	m
TX antenna gain	0 dB	12 dB	n
EIRP	30 dBm	45 dBm	O =k-l-m+n
	(A)	(C)	

Receiving end	**BTS**	**MS**	
Rx sensitivity	-104 dBm	-102 dBm	a
Rx antenna gain	12 dB	0 dB	b
Diversity gain	4 dB	0 dB	c
Feeder loss	3 dB	0 dB	d
Rx power	-104 dBm	-102 dBm	e = f+b+c-d
Required isotropic Rx power	-117 dBm	-102 dBm	f = a-b-c+d
	(B)	(D)	
Maximum permissible path loss	147 dB	147 dB	
	(B-A)	(D-C)	

Area type	%Traffic	Traffic	1/1/1	2/2/2
Urban high density	20	50E	6	2
Urban	30	75E	10	3
Industrial	15	37.5E	5	2
Suburban	25	62.5E	7	3
Highways	5	12.5E	2	1
Quasi open	5	12.5E	2	1

Total	100	250E	32	12

Hint : please refer Erlangs B table

We know In 1 TRX, 7 channels for traffic and 1 channel for signaling
From Erlang B Table
1 TRX (7 Channels) with 2%grade of service, handle 2.94E
2 TRX (14 channels) with 2% grade of service, handle 8.2E
From this, in above example for Urban high density at 50E Traffic **we require**
If 1/1/1 configuration - 6sites {2.94E X 3 cells X 6 sites = 52.92E} **or**
If 2/2/2 configuration - 2 sites {8.2 X 3cells X 2sites = 49.2E}