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GSM NETWORK PERFORMANCE MANAGEMENT AND SYSTEM OPTIMISATION

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3. Network Characteristics and Problem Types

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Course Objectives and Structure

Course Objectives

- Understand the types of problems experienced in a GSM network and why they occur.
- Understand the variety of different tools available to the optimisation engineer.
- Develop and explain an optimisation process for GSM networks.
- Identify suitable KPI's which could be used to highlight poorly performing cells.
- Use statistics to identify hardware problems in the BSS.
- How to identify service affecting BSS database and neighbour relation issues.
- Optimise GSM networks with a view to Multi-Service deployment.
- Understand alternative capacity enhancement techniques.
- Optimise frequency hopping networks for maximum capacity and quality.
- Know how non-BSS issues can affect the network and be identified.

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Course Outline

1. Review of GSM Principles
2. Introduction to Performance Management
3. Network Characteristics & Problem Types
4. Network Performance Metrics
5. Measuring Network Performance - Drive Testing
6. Measuring Network Performance - OMC Statistical Data
7. Introduction to Optimisation
8. Evaluating Performance Data
9. Optimisation Activities
10. Optimising Networks for New Services

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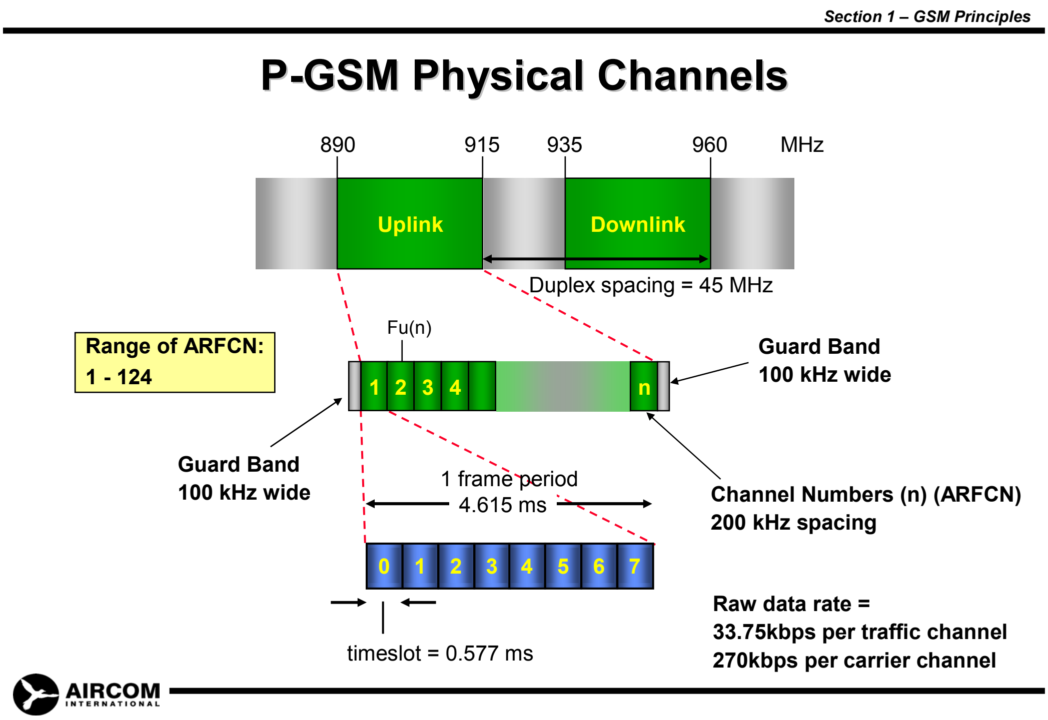
1. Review of GSM Principles

1.1 Introduction

This first section of these notes reviews some of the basic principles and operations within a GSM network. It is intended to provide a short refresher of these concepts in order to provide a more complete understanding of the Performance Management and Optimisation concepts introduced in this course.

1.2 GSM Physical Channel Structure

1.2.1 GSM BANDWIDTH ALLOCATION



GSM uses Frequency Division Duplexing (FDD) where the uplink and downlink of each channel operates on a different frequency. Therefore, two frequency bands were allocated to GSM, separated by 20 MHz.

The following frequency bands were initially allocated to GSM (now known as Primary GSM):

Uplink sub band: 890 MHz to 915 MHz
Downlink sub band: 935 MHz to 960 MHz

1.2.2 GSM FDMA STRUCTURE

Each band is divided into a number of frequency channels (or carriers), each carrier having a 200kHz bandwidth. Therefore 124 carriers are available within each of the up and down link bands, allowing for 2 x 100kHz guard bands.

The up and down-link frequency channel pair allocation has been arranged such that the two frequencies comprising a channel pair are 45Mhz apart.

Each of these frequency pairs is identified by an 'Absolute Radio Frequency Carrier Number '(ARFCN) in the range 1-124 for P-GSM.

Up and downlink channel frequencies can be calculated as follows:

Uplink frequencies: $Fu(n) = 890 + 0.2\ n \quad (1 <= n <= 124)$
Downlink frequencies: $Fd(n) = Fu(n) + 45$

1.2.3 GSM TDMA STRUCTURE

Each GSM carrier channel is subdivided by time into 8 timeslots. Timeslots are repeated in frames, each frame comprising 8 timeslots. The duration of a single timeslot is 0.577ms. Therefore each TDMA frame repeats every 4.615ms. These timeslots are known as 'physical channels'.

Within each timeslot, a radio 'burst' is transmitted. This burst comprises 156.25 bit periods. Therefore a frame comprises 8 x 156.25 = 1250 bit periods. If a frame is transmitted every 4.615ms, the raw data rate over the carrier channel is (1/4. 615ms) x 1250 = 270kbps. The corresponding physical ((timeslot) raw data rate is 270/8 = 33.75kbps.

1.3 GSM Logical Channel/Multiframe Formats

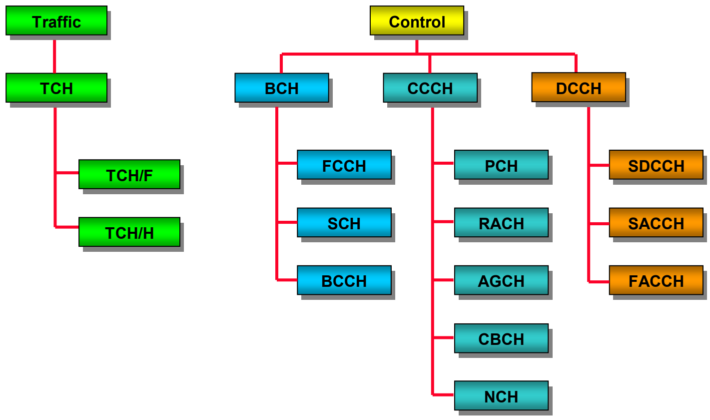
1.3.1 LOGICAL CHANNELS

In addition to physical channels (timeslots), GSM uses the concept of 'logical' channels.

The reason logical channels are used is because GSM has a number of control channels which do not require to operate at the full rate of a physical channel. Most of these control channels can therefore multiplexed onto a single physical channel known as the 'control channel'. In a single-carrier cell, this is always allocated to the physical channel 'Timeslot 0'.

GSM Logical Channels

- Two types of logical channel are defined; traffic and control channels
- Each is further sub-divided as shown:



1.3.2 MULTFRAMES

Multiframes are used to denote a pattern of timeslots that repeat on a cyclic basis. For example, a traffic channel multiframe sequence repeats every 26 timeslots whereas a control channel multiframe sequence repeats every 51 timeslots. As each of these timeslots represents a physical channel or single timeslot in a TDMA frame, it can also be said that these sequences repeat every 26 and 51 TDMA frames respectively.

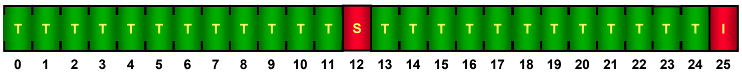
Multiframes allow one timeslot allocation (physical channel) in a TDMA frame to be used for a variety of purposes (logical channels). This is achieved by multiplexing several logical channels onto a single physical timeslot.

1.3.3 TRAFFIC CHANNEL MULTFRAMES

A Traffic Channel Multiframe repeats cyclically every 26 TDMA frames. Its structure is shown in the illustration below:

Traffic Channel Multiframe

- The TCH multiframe consists of 26 timeslots.
- This multiframe maps the following logical channels:
  - •TCH
  - •SACCH
  - •FACCH
- TCH Multiframe structure:



T = TCH S = SACCH I = Idle

FACCH is not allocated slots in the multiframe. It steals TCH slots when required - indicated by the stealing flags in the normal burst.

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1.3.4 CONTROL CHANNEL MULTIFRAMES

Control channels are used by the MS to establish communication with the network in the idle mode and also in initiating calls to enter the dedicated mode. Timeslot 0 is grouped into structures of 51 frames referred to as Control Channel Multiframes. The control channels are grouped as Broadcast Control Channels (BCCH) Common Control Channels (CCCH) and Dedicated Control Channel (DCCH).

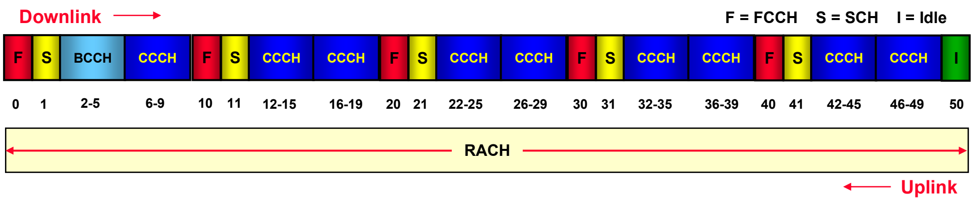
Section 1 – GSM Principles

Control Channel Multiframe

- The control channel multiframe is formed of 51 timeslots
- CCH multiframe maps the following logical channels:

Downlink:
- •FCCH
- •SCH
- •BCCH
- •CCCH (combination of PCH and AGCH)

Uplink:
- •RACH



- Other multiframe structures (for SDCCH and CCCH) are described in Section 2

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1.4 Review of the BCH Carrier

Each cell has one carrier designated as a BCH carrier. The BCH carrier has all 8 timeslots continuously on, either with traffic or dummy bursts. Timeslot 0 of the BCH carrier contains logical control channels.

Section 1 – GSM Principles

BCH Characteristics

- Each cell has a designated BCH carrier
- All BCH timeslots transmit continuously on full power
- TS 0 contains logical control channels
- TS1-7 optionally carry traffic
- BCCH block occurs once each 51-frame multiframe
- Each block comprises 4 frames carrying 1 message

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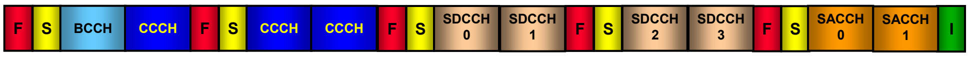
The BCCH occurs once in the 51-frame cycle, and contains information that is packed in a block of 4 frames. The information on the BCCH is known as System Information, and includes network identities, cell parameters, cell channels and option configurations. A GSM mobile reads the BCCH when it first camps on a cell and at intervals thereafter to detect any change in parameter settings.

On the BCH carrier there are 3 or 9 blocks of the Common Control Channel.

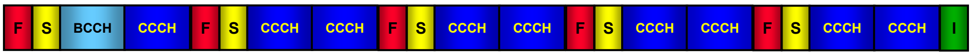
Each block comprises 4 TDMA frames and contains one signalling message. The Common Control Channel blocks are further subdivided into the Access Grant Channel (AGCH) and Paging Channel (PCH).

BCH Channel Configuration

- On the downlink, CCCH consists of paging (PCH) and access grant (AGCH) messages
- A combined multiframe has only 3 CCCH blocks to allow for SDCCH and SACCH:



- A non-combined multiframe has 9 CCCH blocks on timeslot 0:



- A complete paging or access grant message takes four bursts (timeslots), i.e. one CCCH block.

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To save battery power, a mobile does not monitor all the Paging Channels in a multiframe; it only monitors the Paging Channel belonging to its paging group. Each Paging Channel in a multiframe has a different group number. In the next multiframe, the same Paging Channel will have a different or identical paging group number, depending on the settings of the cell parameter BS_PA_MFRMS. This parameter informs the mobile of the number of multiframes (ranging from 1 to 9) after which the same paging group is repeated. The mobile will only turn on its receiver to decode the paging message in its paging group, which might repeat once in 1 to 9 multiframes.

1.5 Paging Procedures

Paging is the procedure used for identifying the current cell location of an MS in order to route an incoming (mobile terminated) call.

Three paging message types have been defined:

- Type 1: can address up to 2 mobiles using either IMSI or TMSI.
- Type 2: can address up to 3 mobiles, one by IMSI and the other 2 by TMSI.
- Type 3: can address up to 4 mobiles using the TMSI only.

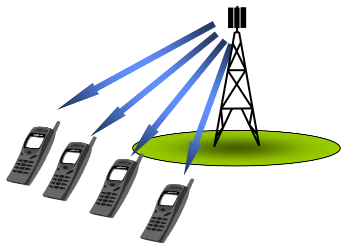
Paging messages for individual mobiles are sent to BSS which stores them temporarily until there are enough to make up a full type 1,2 or 3 message or until a configurable timer (set by the operator) expires. The message is then broadcast on the paging channel (PCH).

To save battery power, a mobile does not monitor all the Paging Channels in a multiframe; it only monitors the Paging Channel belonging to its paging group. Each Paging Channel in a multiframe has a different group number. In the next multiframe, the same Paging Channel will have a different or identical paging group number, depending on the settings of the cell parameter BS_PA_MFRMS. This parameter informs the mobile of the number of multiframes (ranging from 1 to 9) after which the same paging group is repeated. The mobile will only turn on its receiver to decode the paging message in its paging group, which might repeat once in 1 to 9 multiframes

Section 1 – GSM Principles

Paging Procedures

- Paging locates MS to cell Level for call routing
- Three paging message types:
    - Type 1 - 2 MSs using IMSI/TMSI
    - Type 2 - 3 MSs (1xIMSI, 2xTMSI)
    - Type 3 - 4 MSs using TMSI only
- Paging message requires 4 bursts (1 CCCH block)
- Paging messages may be stored at BSS
- Transmitted on PCH
- If DRX is implemented MS listens only to allocated paging group



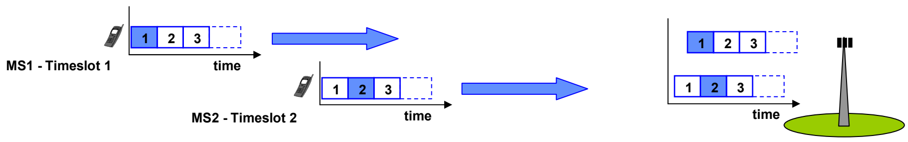
The technique works by dividing the MSs within a cell into groups. The group in which an MS resides is then known locally at both the MS and the BSS. All paging requests to each group are then scheduled and sent at a particular time which is derived from the TDMA frame number in conjunction with the IMSI of the MS and some BCCH transmitted data.

Thus both the BSS and the MS know when relevant page requests will be sent and the MS can power down for the period when it knows that page requests will not occur. The page request can contain the IMSI and may contain the TMSI in order to identify the MS concerned. The IMSI is however always used to identify the paging population.

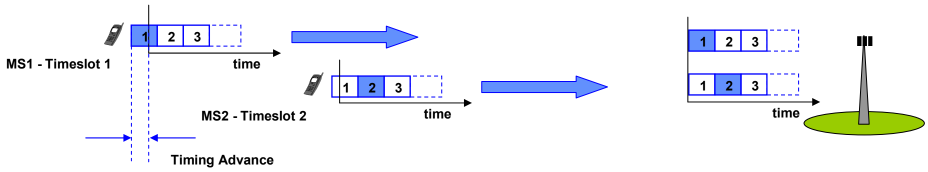
1.6 Timing Advance

Timing Advance

- Signal from MS1 takes longer to arrive at BTS than that from MS2
- Timeslots overlap - collision



- Timing Advance signal causes mobiles further from base station to transmit earlier - this compensates for extra propagation delay



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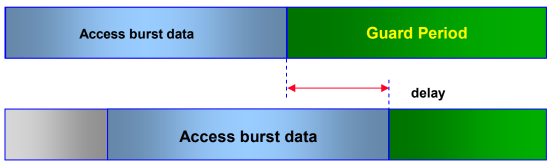
Timing Advance is needed to compensate for different time delays in the transmission of radio signals from different mobiles. The maximum value of Timing Advance sets a limit on the size of the cell. The TA value to use is found initially from the position of the received RACH burst in the guard period and is adjusted during the call in response to subsequent normal burst positions.

Timing Advance

- Timing Advance is calculated from delay of data bits in the access burst received by the base station - long guard period allows space for this delay



- TA signal is transmitted on SACCH as a number between 0 and 63 in units of bit periods
- TA value allows for ‘round trip’ from MS to BTS and back to MS
- Each step in TA value corresponds to a MS to BTS distance of 550 metres
- Maximum MS to BTS distance allowed by TA is 35 km

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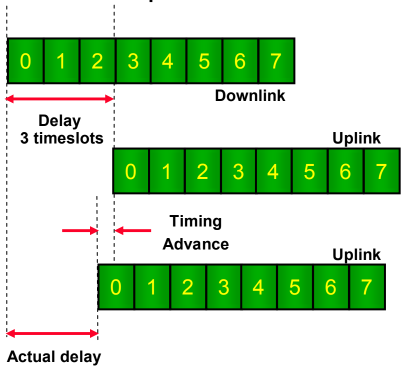
Timing Advance

- Timing Advance value reduces the 3 timeslot offset between downlink and uplink



- The Timing Advance technique is known as *adaptive frame alignment*

1.7 Cell Selection and Reselection

Cell Selection Procedure

- MS powers-up
- MS starts measuring received power level from all cells in range
- MS calculates average power level received from each cell:
  - Stored in RXLEV(n) parameter
- MS calculates C1 parameter for each cell based on RXLEV(n)
- Mobile compares cells which give a positive value of C1 and 'camps-on' to the cell with the highest C1 value

On switch-on, an MS periodically measures the received power level on each of the BCCH frequencies of all cells within range. From these periodic measurements the MS calculates the mean received level value from each cell, stored in the parameter RXLEV(n) where n=neighbouring cell number.

Cell Re-selection – GSM Phase 1 Mobiles

For GSM Phase 1 mobiles, cell reselection is achieved by comparing current cell C1 with neighbouring C1 cell measurements:

- Between cells within a Location Area:

C1 (new) > C1 (old)
(for more than 5 seconds)

- Between cells on a Location Area boundary:

C1 (new) > C1 (old) + OFFSET
(for more than 5 seconds)

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Based on these calculated values, the MS selects which cell to connect to. This connection process is referred top as 'Camping-on' to that cell.

Once camped-on, a MS in idle mode must periodically measure the received power level on each of the BCCH frequencies of neighbouring cells and stores this measurement in the parameter RXLEV(n) where n=neighbouring cell number. From these periodic measurements the MS calculates the mean received level value from each cell and stores the result of the calculation in the C1 parameter for the best 6 neighbouring cells. Any C1 values of 0 or below are discarded and the best 6 of the remainder are stored..

The hysteresis term prevents unnecessary re-selection on a location area boundary thatld require extra signalling to perform the location update.

Cell Re-selection – GSM Phase 2 Mobiles

- GSM Phase 2 introduced a separate cell re-selection parameter, C2
- Intended to:
  - Prevent multiple handovers for fast-moving mobiles
  - Ensure MS camps on to cell with greatest chance of successful communications
- The C2 calculated is:

C2 = C1 + OFFSET – (TEMPORARY_OFFSET x *H*(PENALTY_TIME –T)

In order to optimise cell reselection, additional cell reselection parameters can be optionally broadcast on the BCCH of each cell. The cell reselection process can optionally employ a parameter C2, the value of which is determined by these parameters.

The parameters used to calculate C2 are as follows:

<u>If PENALTY_TIME <> 11111</u>
C2 = C1 + CELL_RESELECT_OFFSET - TEMPORARY OFFSET * H(PENALTY_TIME - T)

<u>If PENALTY_TIME = 11111</u>
C2 = C1 - CELL_RESELECT_OFFSET

Where: H(PENALTY_TIME-T) = 0 if x < 0
H(PENALTY_TIME-T) = 1 if x >= 0

Cell Reselection Offset
This optional parameter is a positive or negative offset applied to each cell to encourage or discourage MSs to reselect that cell.

Penalty Time
When the MS places the cell on the list of the strongest carriers (Neighbour list), it starts a timer which expires after the PENALTY_TIME. This timer will be reset when the cell is taken off the list. For the duration of this timer, C2 is given a negative offset. This will tend to prevent fast moving MSs from selecting the cell.

Temporary Offset
This is the amount of the negative offset described in the 'Penalty Time' above. An infinite value can be applied, but a number of finite values are also possible.

1.8 Handovers

In a cellular network, the radio and fixed links required are not permanently allocated for the duration of a call. Handover, or handoff as it is called in North America, is the switching of an on-going call to a different channel or cell. The execution and measurements required for handover form one of basic functions of RR management.

There are four different types of handover in the GSM system, which involve transferring a call between:

- Channels (time slots) in the same cell
- Cells (Base Transceiver Stations) under the control of the same Base Station Controller (BSC),
- Cells under the control of different BSCs, but belonging to the same Mobile services Switching Centre (MSC), and
- Cells under the control of different MSCs.

1.8.1 HANDOVER CATEGORIES

Section 1 – GSM Principles

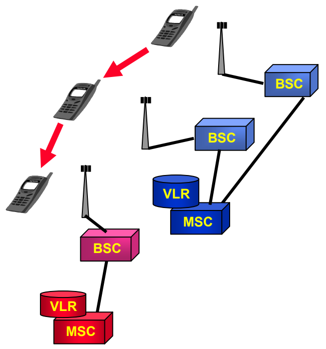
Handover Categories

There are four different types of handover in the GSM system, which involve transferring a call between:

Internal
- Channels (time slots) in the same cell
- Cells within the same BSS (same BSC)

External
- Cells in different BSSs (different BSCs) but under the control of the same MSC
- Cells under the control of different MSCs

GSM handovers are 'hard' – i.e. mobile only communicates with one cell at a time



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Handovers within a BSC are known as 'internal' handovers as they involve only one Base Station Controller (BSC). To save signalling bandwidth, they are managed by the BSC without involving the Mobile services Switching Centre (MSC), except to notify it at the completion of the handover.

Handovers between BSCs (either intra- or inter-MSC) are known as 'external' handovers and are handled by the MSCs involved. An important aspect of GSM is that the original (or *anchor*) MSC, remains responsible for most call-related functions, with the exception of subsequent inter-BSC handovers under the control of the new (or *relay*) MSC.

1.8.1 HANDOVER TYPES

Handovers can be initiated by either the MS or the MSC (e.g. as a means of traffic load balancing).

During its idle time slots of a multiframe, the MS scans the BCCH of neighbouring cells, and forms a list of the six best candidates for possible handover, based on the received signal strength. This information is passed to the BSC and MSC, at least once per second, and is used by the handover algorithm.

Section 1 – GSM Principles

Handover Types

- Handover can be initiated by either MS or MSC
- Handover decision is based on the following parameters (in priority order):
  - Received signal quality
  - Received signal strength
  - Distance of MS from BTS
  - Drops below power budget margin
  - Interference
- Can be up and down-link specific
- Each parameter has a operator-defined threshold and handover decisions can be based on one or a combination of the parameters

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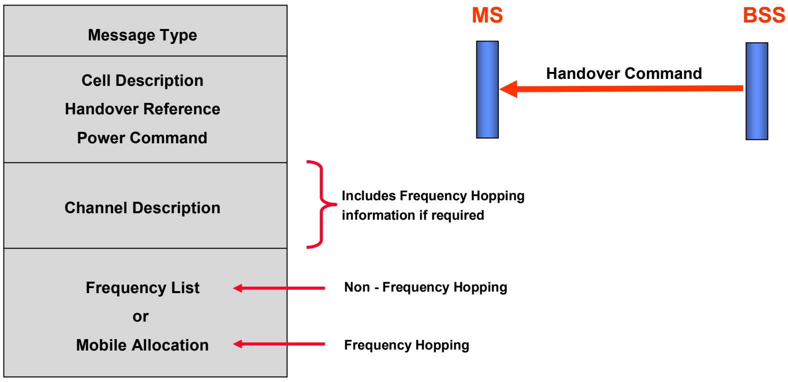
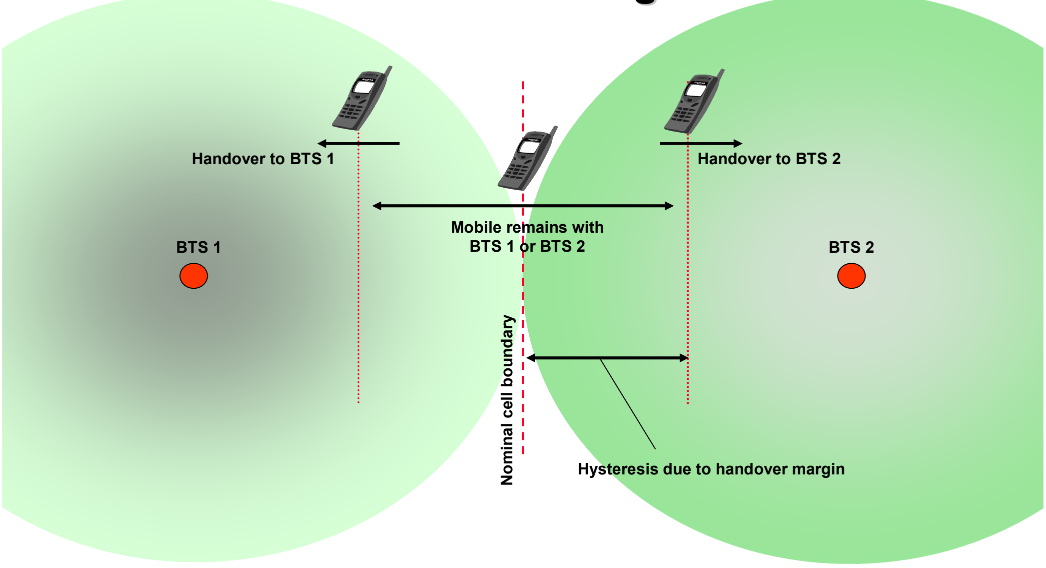
Handover Command Message

Structure of the message sent to MS by original BSS:



Section 1 – GSM Principles

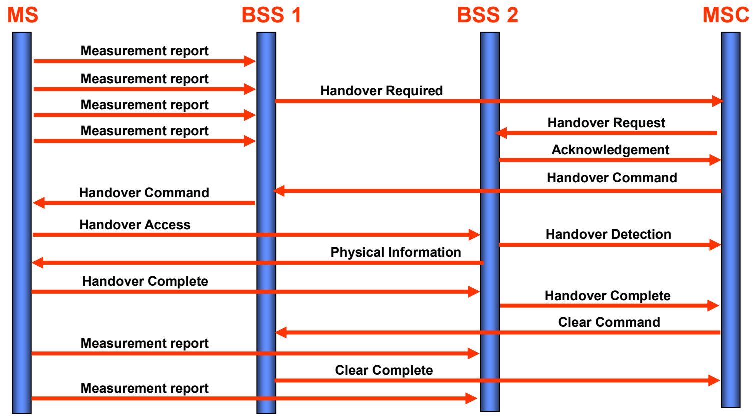
Handover Margin



The algorithm for when a handover decision should be taken is not specified in the GSM recommendations. There are two basic algorithms used, both closely tied in with power control. This is because the BSC usually does not know whether the poor signal quality is due to multipath fading or to the mobile having moved to another cell. This is especially true in small urban cells.

Example of Handover Signalling

Signalling for a basic Inter-BSC handover involving only one MSC (Intra - MSC):



1.9 Power Control

1.9.1 GSM POWER CONTROL FUNCTIONS

GSM Power Control Functions

- Prevent unnecessary power emissions to:
  - Increase life of battery-powered devices
  - Reduce network interference
- Equalise power levels received at BTSs
- Adjustments to cell coverage
- Methods Include:
  - Adaptive Power Control
  - Discontinuous Transmission (DTX)
  - Discontinuous Reception (DRX)

Power control within a GSM system has four main purposes:

- Reduce power outputs to the minimum required for effective communications in order to reduce interference
- Limit unnecessary power emissions in order to increase the longevity of battery-power equipments
- Prevent MSs closer to BTS de-sensitising those more distant
- Enable the network controller to adjust cell coverage by adjusting BTS output power.

GSM power control is achieved by a number of methods. These include:

- Adaptive Power Control. This automatically adjusts power outputs up or down to ensure to the minimum required to meet the prescribed service quality level.
- Discontinuous Transmission (DTX). This is a procedure whereby transmissions are only made when information is to be passed.
- Discontinuous Reception (DRX). This procedure enables battery-powered MSs to minimise power consumption by only listening out on specific control channels.

1.9.2 GSM POWER CLASSES

Section 1 – GSM Principles

Mobile Station Power Classes

MS Class	Full Rate	
	Power mW	dBm
GSM class 2	960	39 (8W)
GSM class 3	600	37 (5W)
GSM class 4	240	33 (2W)
GSM class 5	96	29 (0.8W)
DCS class 1	120	30 (1W)
DCS class 2	30	24 (.25W)
DCS class 3	480	36 (4W)

GSM class 1 – deleted under GSM Phase 2 Specification
Power (mW) = Nominal maximum mean power output (milliwatts)
Power (dBm) = Maximum power output in dBm (+watts)

Source: ETSI GSM 02.06 Version 4.5.2)

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BTS Power Classes

GSM 900		DCS 1800	
TRX Power Class	Maximum O/P Power (W)	TRX Power Class	Maximum O/P Power (W)
1	320	1	20
2	160	2	10
3	80	3	5
4	40		
5	20		
6	10		
7	5		
8	22.57		

Source: ETSI GSM 05.05 (Version 4.23.1)

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Note that most GSM-900 BTSs operate in the 5-7 Class.

The ETSI GSM recommendations specify power classes for both MSs and BSSs. These power levels, together with the defined GSM receiver sensitivity levels are shown in the tables above.

GSM 900 MSs fall into one of 5 (4 in GSM phase 2) classes, distinguished by their power output levels. DCS1800 MSs have 3 equivalent classes. Note than GSM 900 Class 1 MSs were dropped from the GSM Phase 2 recommendations

1.9.3 GSM REFERENCE SENSITIVITY LEVELS

The reference sensitivity performance in terms of frame erasure, bit error, or residual bit error rates (whichever appropriate) is specified below, according to the type of channel and the propagation condition. The actual sensitivity level is defined as the input level for which this performance is met. The actual sensitivity level should be less than a specified limit, called the reference sensitivity level. The reference sensitivity levels are:

Receiver Sensitivity Levels

System	Class	Sensitivity
GSM 900	Small MS	-102dBm
GSM 900	Other MS	-104dBm
GSM 900	Macro BTS	-104dBm
GSM 900	M1 Micro BTS	-97dBm
GSM 900	M2 Micro BTS	-92dBm
GSM 900	M3 Micro BTS	-87dBm
DCS 1800	MS Class 1 or 2	-100 dBm
DCS 1800	MS Class 3	-102 dBm
GSM 1800	M1 Micro BTS	-102dBm
GSM 1800	M2 Micro BTS	-97dBm
GSM 1800	M3 Micro BTS	-92dBm

Source: ETSI GSM 05.05 (Version 4.23.1)

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Note that these parameters are drawn from the ETIS GSM Recommendations. Vendor-specific equipment implementations may vary.

1.9.4 MS ADAPTIVE POWER CONTROL

Section 1 – GSM Principles

Adaptive Power Control Process

- Compulsory in MS, optional in BTS
- 32 power levels separated by 2dBm
- Power changes are commanded using:
  - Reduction - POW_RED_STEP_SIZE (2, 4 dB steps)
  - Increase - POW_INC_STEP_SIZE (2, 4, 6 dB steps)
- Commands issued on SACCH
- One 2dB step change every 60mS

Source: ETSI GSM 05.08 (Version 4.22.1)

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Adaptive power control is employed to minimise the transmit power required by MS or BSS whilst maintaining the quality of the radio links. By minimising the transmit power levels, interference to co-channel users is reduced. In addition, by controlling the emissions from mobile devices, the power consumption can be reduced and therefore extend battery life.

Adaptive power control is compulsory in all MSs in order to compensate for 'near-far' interference effects. BTS power control is optional. However, if implemented, the BCH channel must still remain on constant power in order to enable neighbouring cell power measurements

1.9.5 GSM/DCS MS POWER CONTROL PROCESS

GSM/DCS MS power output is controlled in levels, each level is separated by 2dBm as shown in the table below. However, individual adjustments can be made in 2,4 or 6dB steps. 6dB adjustments are only possible with power increases. The levels are shown in the table below:

When first accessing a cell on the RACH and before receiving the first power command an MS adopts the power level defined by the M_TXPWR_MAX_CCH parameter broadcast on the BCCH of the cell.

The MS then periodically measures the received power level (RXLEV) and reports this back to the BTS in the form of a measurement report which is forwarded to the BSC. It also monitors the RxLev on adjacent cells but only the BCH of these cells. The BTS commands the power level changes at the MS using the SACCH

GSM 900		DCS 1800	
Power Control Level	Nominal O/P Power (dBm)	Power Control Level	Nominal O/P Power (dBm)
0-2	39	29	36
3	37	30	34
4	35	31	32
5	33	0	30
6	31	1	28
7	29	2	26
8	27	3	24
9	25	4	22
10	23	5	20
11	21	6	18
12	19	7	16
13	17	8	14
14	15	9	12
15	13	10	10
16	11	11	8
17	9	12	6
18	7	13	4
19-31	5	14	2
		15-28	0

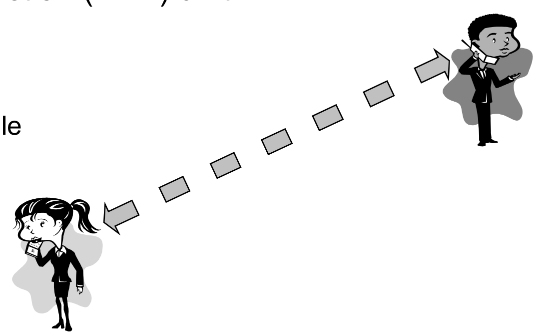
1.9.6 DISCONTINUOUS TRANSMISSION (DTX)

When a call is established, the MS remains in transmit mode for the duration of the call. However, in speech mode, it has been shown that information (encoded speech) is actually being transmitted for less than half the time. DTX is a technique that reduces emissions from the MS by only transmitting when information is to be sent.

DTX is achieved by the use of a voice activation device (VAD) incorporated into the MS handset. The VAD detects speech and initiates transmission at normal speech-encoded data rates (13kbps). When no speech is detected, the data rate is reduced to approximately 500bps which is sufficient to provide comfort noise to the distant end but also significantly reduces the power output requirements.

Discontinuous Transmission (DTX)

- In a conversation, a person generally only speaks for about 30% to 40% of the time
- DTX makes use of this by reducing transmission when no voice signal is detected
- Uses a Voice Activity Detection (VAD) unit
- Advantages:
  - Reduces interference
  - Prolongs battery life of mobile



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1.9.7 DISCONTINUOUS RECEPTION (DRX)

DRX is a technique that allows the MS to power down significant amounts of its internal circuitry for a high percentage of the time when it is in the idle mode. It also ensures that the MS is aware of exactly when page requests for it may be transmitted and it can then therefore schedule other tasks such that it avoids the problem of not decoding valid page requests transmitted by the network in the idle mode periods.

Discontinuous Reception (DRX)

- Allows MS to power down parts of its circuitry in idle mode
- MSs within a cell divided into paging groups
- MS only listens paging requests within its own group
- Increases battery life of MS

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1.10 Frequency Hopping

1.10.1 FREQUENCY HOPPING CONCEPT

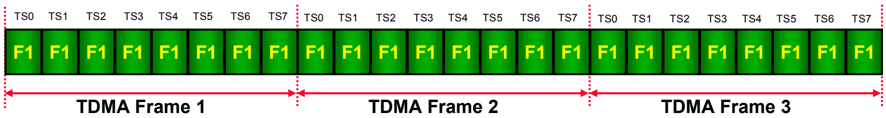
Mobile radio carriers suffer from frequency-selective interferences, for example, fading due to the multipath propagation phenomena. As the carrier signal attenuates with distance, frequency-selective interference can have an increasingly significant affect on the signal quality.

Frequency hopping (FH) employs a constantly changing transmission frequency on the radio carrier. Therefore the effects of frequency selective interference will be reduced by producing an averaging effect over the interference caused on each frequency employed within the FH sequence. This results in an overall improvement in S/N ratio.

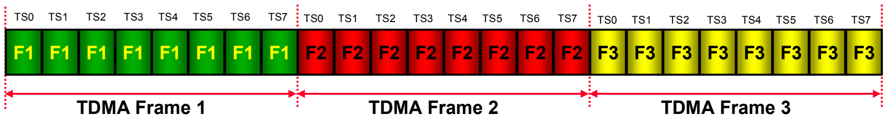
The GSM specification defines optional FH implementation where the frequency on a carrier changes with each new TDMA frame transmission.

Frequency Hopping Concept

- **Non-Frequency Hopping Carrier:**



- **Frequency Hopping Carrier:**



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1.10.2 FREQUENCY HOPPING SEQUENCE

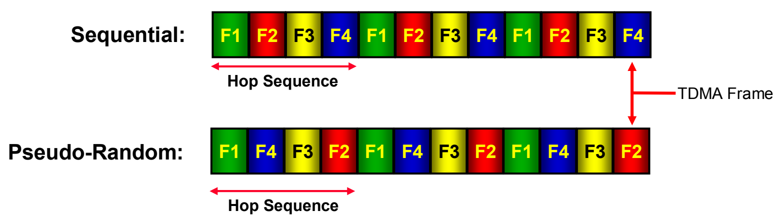
A TDMA frame has a duration of 4.617ms (8 timeslots of 0.577ms each). If the frequency changes with each TDMA frame, then it must change every 4.617ms or approximately 217 times per second. This is referred to as slow FH as the rate of frequency change is slower than the symbol rate of the data transmitted on the carrier.

Section 1 – GSM Principles

Frequency Hopping Sequence

- One TDMA frame is 4.6 ms long
- Rate of hopping = 1/ (4.6 x 10^{-3}) = 217 hops / second

- The frequency changes follow either a sequential or pseudo-random pattern
- GSM defines 1 sequential pattern and 63 pseudo-random patterns
- Each pattern is defined by a Hop Sequence Number (HSN)



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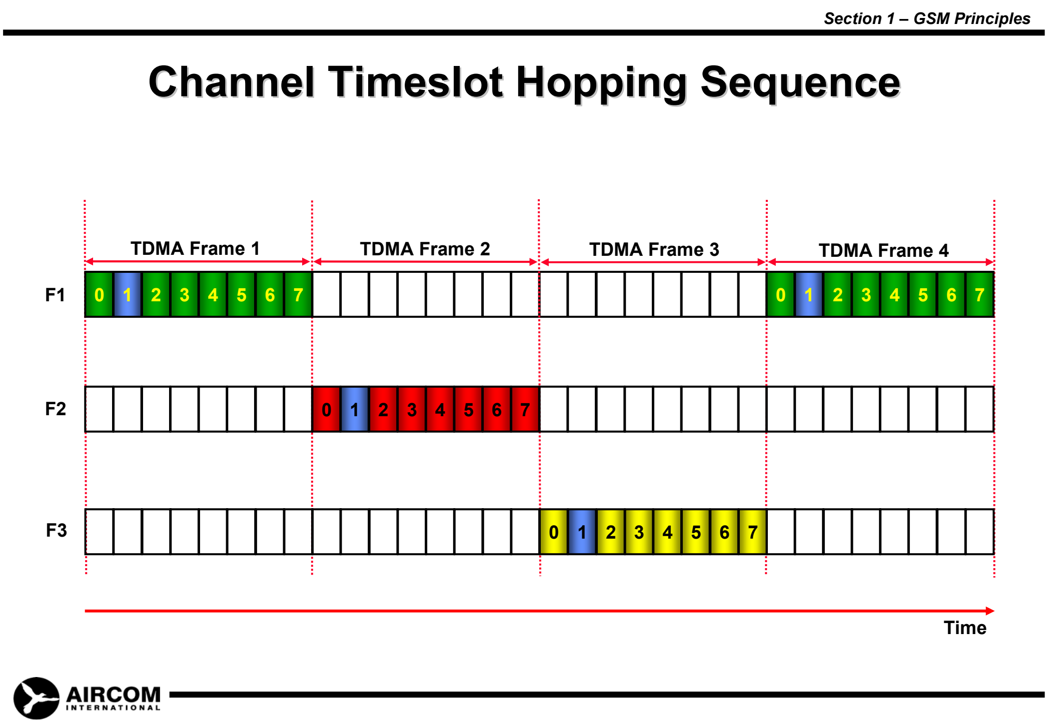
The pattern of hopping used within GSM can be sequential or pseudo-random. The GSM network can assign either one sequential cyclic hopping pattern or any one of 63 pseudo-random cyclic hopping patterns. Each sequence is defined by a unique Hop Sequence Number (HSN) in the range 0 – 63.

The effect of changing frequencies with every TDMA frame is that each consecutive timeslot of each channel is transmitted on a different frequency.



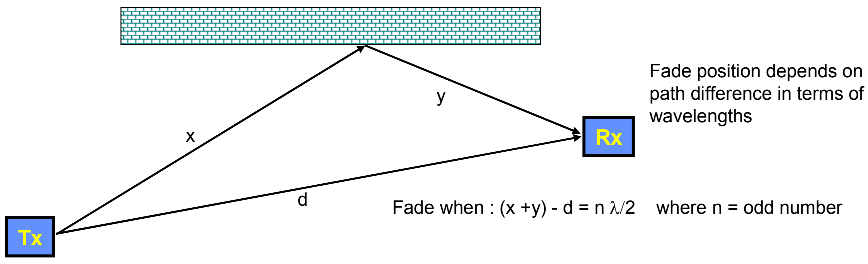
1.10.3 REASONS FOR IMPLEMENTING SFH

Implementing SFH in GSM can have a number of benefits:

Reduces Multipath Fading Interference. For a static MS, if its operating frequency suffers from multipath fading, the degree of fading interference will be constant. However, as the degree of multipath fading changes with frequency, by continually changing the operating frequency of the MS, the degree of fading can be reduced over the whole period of the frequency hopping cycle.

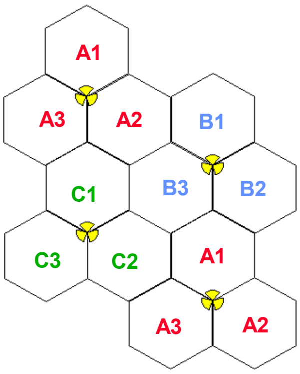
Reasons for Frequency Hopping (1)

- GSM radio signals are affected by multi-path interference, causing fading
- Changing frequency (wavelength) moves the position of the fade
- Frequency hopping cycles through many fade positions
- This reduces the effect of the fades when the mobile is moving slowly



Reasons for Frequency Hopping (2)

- Cells are subject to interference from other cells using the same carriers at the re-use distance
- If the cells hop through a set of frequencies in different sequences, the effect of this interference is reduced
- C/I ratio is increased



Increases C/I Value Through Frequency Diversity. For a non-hopping GSM link, the minimum requires C/I ratio is 11-12dB. Implementing FH can reduce this margin to approximately 9dB.

1.10.4 IMPLEMENTING FREQUENCY HOPPING AT THE BTS

When implementing FH at the Base Station the following must be considered:

Section 1 – GSM Principles

Frequency Hopping at the BTS

- BCCH carrier will not hop - mobiles must be able to access this for neighbour cell power level measurements
- Only TRXs used for traffic channels will hop through set sequences
- The set of carrier frequencies assigned to the sequence (Mobile allocation – MA) will normally be from current cell allocation
- Hopping sequence for each TRX must be different or have a different Mobile Allocation Index Offset (MAIO)

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The Carrier containing the BCCH must not frequency hop. This is to ensure that:

- Neighbouring cells (which may not be using frequency hopping) can continue to monitor the cell's BCCH for signal strength measurements prior to handover.
- When entering a cell implementing FH, the BCCH of that cell can pass frequency hopping information to the MS to initiate the sequence.

Only those carrier fully dedicated to traffic channels (TCHs) can implement frequency hopping.

To avoid significantly changing the network frequency plan, the allocation of hopping frequencies is taken from the existing cell allocation. Therefore, if a cell currently has 4 TRXs, three of the four frequencies can be used to implement the hopping sequence (BCCH carrier does not hop). However, when implementing this configuration, it must be ensured that no two transmitters hop to the same frequency at the same time.

This can be avoided by starting the hopping sequence for each transmitter at a different time. For example, using a sequential hopping implementation:

Example of 4-Frequency Hopping

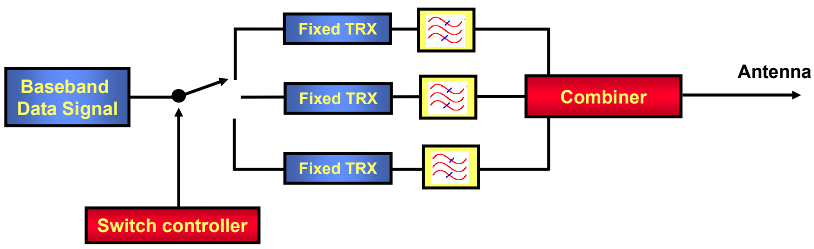
Transmitter	Hop 1	Hop 2	Hop3	Hop 4
TRX 1	F1	F1	F1	F1
TRX 2	F2	F3	F4	F2
TRX 3	F3	F4	F2	F3
TRX 4	F4	F2	F3	F4

- BCCH carrier remains on single frequency
- TCH carriers must start at different points in sequence (MAIO) to avoid co-channel (C/I) interference
- Above example uses same HSN for each TRX but different MAIOs

1.10.5 HARDWARE IMPLEMENTATION AT THE BTS

Two different BS hardware implementations of FH exist; Baseband Hopping and Synthesiser Hopping.

Baseband Frequency Hopping

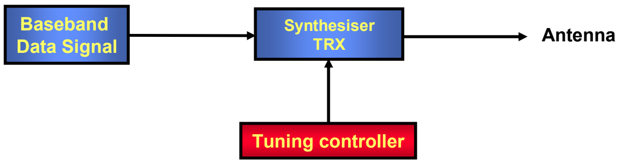


- The baseband signal is fed to one of several TRXs in turn by a switch
- The TRX outputs must be combined to be fed to the antenna
- The combiner must be able to handle a wide bandwidth of signals
- This can be achieved using either:
  - hybrid combiners - several stages causing large loss
  - cavity filters - one associated with each TRX - maximum loss ~ 5 dB

Baseband Hopping. Base band hopping implies switching the transmit frequency at the baseband frequency level. This can be implemented where the Base Station is equipped with a number of discreet transceivers, each operating at a fixed frequency. The data stream is switched to each transceiver in accordance with the assigned hopping sequence.

Section 1 – GSM Principles

Synthesiser Frequency Hopping



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Synthesiser Hopping. Implementing Synthesiser hopping requires the use of a transceiver employing frequency synthesis procedures foe frequency changes. In this case, a single synthesises transceiver is used and the transmit frequency is switched using a tuning controller set to the assigned hopping sequence.

1.10.6 IMPLEMENTING FREQUENCY HOPPING AT THE MS

While Frequency Hopping (FH) is not mandatory for Base Stations (BSs), all Mobile Stations (MSs) must have this capability. This is to ensure that an MS continues to maintain contact if it is handed over to a BS currently implementing FH.

When an MS implements FH it must still be capable of taking signal strength measurements from adjacent cells. This is the primary reason why Slow Frequency Hopping (SFH) has been implemented in GSM.

Frequency Hopping at the MS

- All mobiles must be capable of SFH in case it enters a cell in which it is implemented
- SFH is implemented to allow time to continue to take measurements from adjacent cells
- The mobile needs to know:
  - Frequencies used for hopping (Mobile Allocation)
  - Hop Sequence Number (HSN)
  - Start frequency (Mobile Allocation Index Offset - MAIO)
- The MS uplink HSN is the same as the TRX downlink HSN but offset by 45MHz

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1.10.7 FREQUENCY HOPPING AND HANDOVER

Before entering a cell using FH, the MS musty be provided with the following information:

- The Group of frequencies being used for hopping, known as the Mobile Allocation (MA)
- The Hope Sequence Number (HSN), in the range 0-63.
- The Frequency on which it must start hopping in the sequence, known as the Mobile Allocation Index Offset (MAIO).

This information is passed to the MS with the handover messaging.

The uplink HSN from the MS is the same as the downlink HSN to the MS but maintains the same 45Mhz offset used for normal GSM uplink/downlink carrier pairs.

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2. Introduction to Performance Management

2.1 Introduction

Performance management is the process and procedures involved in ensuring that a network operates at maximum efficiency and to the defined Quality of Service (QoS) levels throughout its lifetime.

In order to carryout this function a number of tools have been designed to assist both network managers and network engineers

Section 2 – Introduction to Performance Management

What is Performance Management?

'Performance Management is a process by which the network is continuously monitored to ensure optimum performance and to identify & rectify problems areas.'

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2.2 The Purpose of Performance Management

Section 2 – Introduction to Performance Management

Purpose of Performance Management

- Performance Management:
  - Ongoing process to monitor network performance
  - Sustains network quality throughout its lifecycle by proactive maintenance
  - Reduces risk of network degradation
  - Improve network performance through optimisation techniques
  - Supports business interests of the network operator
- Poor maintenance procedures lead to network performance degradation resulting in:
  - Reactive fault rectification
  - More complaints from customers
  - Customer churn
  - Reduced profit margins
  - Weakening of operator's business position

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A drop in quality as perceived by the subscribers will result in more customer complaints and a lack of subscriber loyalty. This will result in customer 'churn' and a weakening of the operator's business performance.

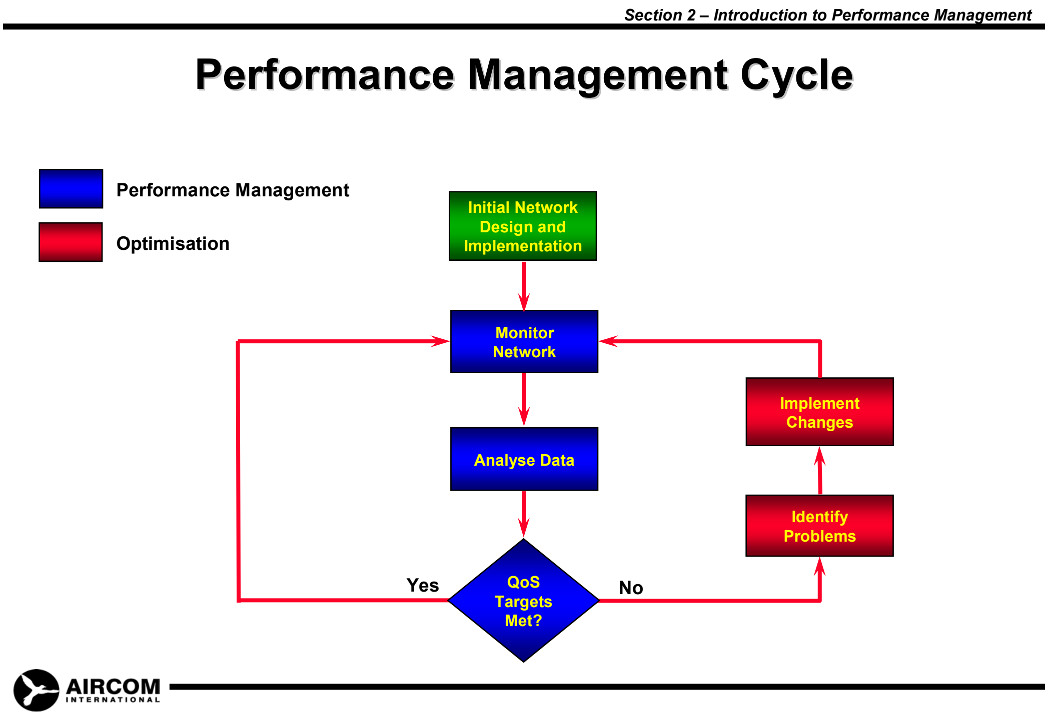
A growth in traffic, while indicating customer satisfaction with the network, requires careful planning in order to increase capacity while maintaining the desired quality of service level.

Subscriber distribution will change continuously as new accommodation for residential and commercial purposes is built and patterns of road and rail traffic vary. This will require constant monitoring to maintain performance.

Introduction of a new service should be based on market research to assess potential demand. The present network should be optimised to maximise performance and free up resources for the new service.
Build-out of the network may be part of a planned development of the system or a response to traffic growth or subscriber movement. Again it is important to maintain the performance of the existing network while the extension is implemented.

Maintenance and expansion of the network should be planned following the principles outlined above. Typical situations include the removal of 'high sites' and their replacement by a number (often quite large) of smaller sites. A poor performance as perceived by the user may be due to problems at the BTS / BSC or in the NSS. Different measurement statistics and diagnostic tools are available to identify the various causes and distinguish between them.

2.3 The Performance Management Cycle



2.4 Initial Network Design and Implementation

Initial Network Design and Implementation

- Part of network design and implementation process involves:
  - Defining quality of service (QoS) levels.
  - Defining KPIs for each reporting level
  - Defining custom network performance reports
- Network performance KPIs will be measured against the QoS targets.
- QoS targets may require adjustment in light of updated demographic/geographical planning data and/or introduction of new services.

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2.5 Network Monitoring Phase

Network Monitoring Phase

- Monitoring current network performance at various levels:
  - Network, Regional MSC, BSS, NSS transmission levels
- Performance data sources include:
  - Drive Tests
  - Statistical Measurements:
    - MSC, Databases (HLR/VLR), BSS Data (BTS/BSC)
  - Customer Complaints
  - Field Engineer Reports
- Some sources generate information in the form of performance metrics

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Monitoring the network involves gathering information about current network performance. This information can be derived at a number of levels and from a number of sources:

LEVELS

Network Level. At this level it is the overall performance of the network as a whole that is monitored. Its main purpose is long-term monitoring to identify trends and gather information for network expansion plans, rather that identifying faults requiring immediate attention.

Regional (MSC) Level. Monitoring at this level is more localised and concentrates on the performance of the MSC and its associated network elements (BSC, BTS, VLR etc). Reports should be generated on a more frequent basis (e.g. every 2 weeks) than those at network level.

BSS Level. BSS monitoring is primarily concerned with identifying specific faults or significant degradation in network performance. This is achieved either through periodic routine testing or as a result of customer complaints. In addition to periodic BSS monitoring, this process is also carried out to assist with other processes including:

- Determine site configuration.
- Capacity planning for a specific area
- To enable planning and engineering groups to define strategies for network optimisation

Reading should be taken over a reasonable period (e.g. 48 hours) to prevent overreaction to spurious events.

Network Switching Level. GSM does not define specific technologies for implementation over the fixed transmission network. Therefore, defining specific performance parameters is not possible. Each case must be examined and parameters defined that reflect the implemented technology. However, there are a number generic parameters common to all NSS network performance monitoring:

- Monitoring Period
- Number of connecting links
- Capacity of links
- Number of links unavailable for specific reasons
- % efficiency of trunk usage
- % congestion per trunk/route

PERFORMANCE DATA SOURCES

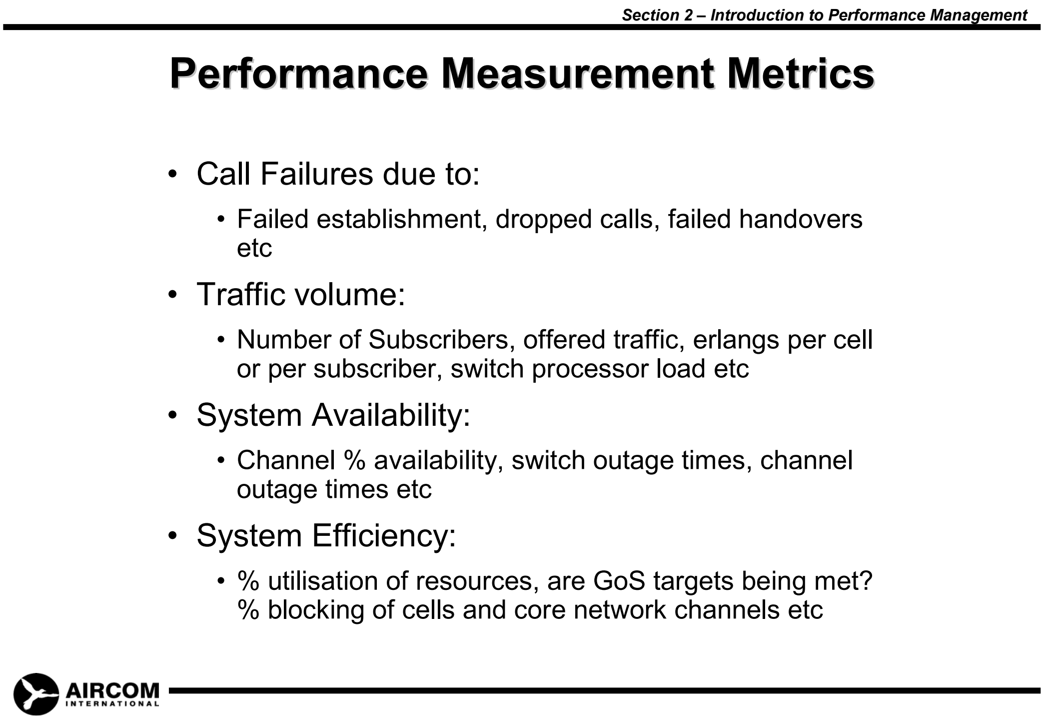
Performance Data can be obtained from a number of sources including:

- Drive Tests
- Statistical Measurements:
  - MSC data
  - Databases (HLR/VLR)
  - BSS data (BTS/BSC)
- Customer Complaints
- Field Engineer Reports

2.6 Measuring Network Performance

2.6.1 PERFORMANCE MEASUREMENT METRICS

Being able to measure the performance of a network is critical to the process of ensuring that Quality of Service (QoS) targets are being met and that network resources are being utilised most efficiently.



Any identified problems indicate that the network is not operating at peak performance and therefore a degree of optimisation may be necessary. The optimisation process should identify the source of there problem and hence what rectification action must be taken.

There are a number of parameters (or metrics) available within network software that can be used to measure network performance. These include:

- How well the system functioning technically:
  - Can the subscriber access the system? (% Established Calls)
  - Can subscribers stay on the system? (% Dropped Calls)
  - Can subscribers move through the system? (% Handoff Failures)
  - Failures Per Erlang

- Volume of use on (size of) the system:
  - Cell Erlangs
  - Subscribers
  - Erlangs per Subscriber
  - Switch Processor Load

- Availability of the system:
  - Channel availability (Average Out Of Service (OOS))
  - Channel availability due to site outages (% Channel Availability)
  - Switch Outage Time

- Dimensioning of the system:
  - How well are network resources used? (% Utilization)
  - Is the system providing the desired Grade of Service? (e.g. 2%?)
  - % Blocking of cell routes [Erlang B GoS])
  - Are trunk routes effectively dimensioned? (% Blocking)

These performance metrics will be covered in more detail later in the course

2.6.2 PERFORMANCE MEASUREMENT METHODS

In general, it is only possible to obtain a full picture of QoS (and therefore overall performance) of a GSM network by a combination of measurement results drawn from the following sources:

- Drive Test Data
- OMC Statistical Data
- Protocol Analyser Data

Performance Measurement Methods

Generally, three methods:

- Drive Testing
- OMC Statistical Testing
- Protocol Analyser Testing

2.6.3 DRIVE TEST DATA

Drive-testing is the first step in the performance measurement process, with the goal of collecting measurement data as a function of location. Once the data has been collected over the desired RF coverage area, it is output to post-processing software. Engineers can use this data together with post-processing software to identify any problems in the network.

Section 2 – Introduction to Performance Management

Drive Testing Data

- When Used:
  - Fault Identification from performance data analysis or customer complaints
  - First phase of network audit prior to optimisation
  - Validate work carried out by engineers
- Used to identify:
  - Coverage Gaps
  - Abnormal interference levels
  - Missing Neighbour relationships
  - Messaging protocol performance

Detailed drive testing of the network will be needed to identify and resolve radio related problems. These problems will be caused by factors that will include:

- Coverage gaps.
- Interference (co-channel and adjacent channel)
- Missing neighbour relationships

This phase of field trial measurements is essential, as the software planning system will not be able to identify all such problems

After the network becomes operational, it will remain important to drive test the network and measure the performance of the system as seen by the subscriber. Typical requirements from these ongoing measurements will be to:

- Further optimise the performance of the radio network.
- Pinpoint and resolve problems reported by customers.
- Validate engineering work such as frequency re-tuning.

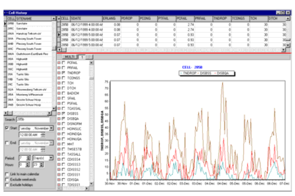
2.6.4 OMC STATISTICAL DATA

Embedded within the software that controls the network are a multitude of parameters used to record events that take place throughout the network. Many of these parameters have been designed specifically to record error conditions and network quality. Generally, these parameters are 'activated', monitored and logged at the Operations and Maintenance Centre (OMC).

Section 2 – Introduction to Performance Management

OMC Statistical Data

- OMC uses counters embedded with the network software
- Uses counters to record events
- Counters are 'activated' and results logged
- Events relate to errors or quality
- Analyses collected data to identify faults



2.6.5 PROTOCOL ANALYSER DATA

A protocol analyser is a high-impedance measuring device that can be intrusively or non-intrusively connected to a live transmission link in order to monitor the activity on that link without disrupting the information flow. Its primary purpose is to monitor control traffic rather than user data i.e. the bidirectional passage protocol information.

A protocol analyser can be connected to BTSs, BSCs and MSC over a period of time. During this time the transmission paths are constantly measured and these measurements are logged in the form of **trace files** for subsequent analysis.

Protocol Analyser Characteristics

- Used for measuring signalling traffic
- Intrusive or non-intrusive network connection
- Should have hardware capable of:
  - Connecting to the required transmission medium
  - Displaying measurements for immediate analysis
  - Storing data for subsequent analysis
  - Exporting data to other *{storage}* devices
- Should have software capable of:
  - Searching for protocol-specific data and parameters
  - Applying filters
  - Translating raw data into a readable display format
  - Providing remote access to the measuring device

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A typical Protocol analyser generally has the following characteristics:

- Hardware capable of attaching to the transmission medium
- Software capable of capturing and decoding the raw protocol data passing along it
- Software capable of filtering and/or searching for protocol-specific data and parameters
- A screen to display measurement results
- Facilities for remote access
- A storage device to record measurements for subsequent processing

Protocol Analysers

Tektronix K-1103

Tektronix K-1205-1279

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The use of Protocol Analysers is reducing as more sophisticated OMC statistical measurements are available where network-wide measurements can be taken rather that the restricted view offered by expensive analysers.

2.6.6 COMPARISON OF MEASURING METHODS

Section 2 – Introduction to Performance Management

Comparison of Measurement Methods

- OMC
  - Central position in network – network-wide overview
  - Capability exists within standard network software
  - Continuous Monitoring capability
  - Speedier response to network problems
- Drive Testing:
  - Can only provide data for limited geographical region
  - Can only provide a ‘snap-shot’ of network characteristics
  - More accurate local picture
  - Can identify specific faults
  - Manpower and equipment resource intensive
  - Expensive
- Protocol Analyser Testing
  - Can test uplink and down link more effectively than test Mobile.
  - Can test transmission links
  - Expensive – hence cost-limited in number

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OMC
OMC statistical performance data capture is generally the most common method of managing network performance on a continuous basis. The OMC has a number of advantages and disadvantages when compared the the other two forms of measuring:

- Through its central positioning, that it is able to gather data from across the whole network rather than a single BTS/BSC or individual transmission link.
- Monitoring of OMC statistics allows for a speedier response to indicated fault conditions.
- OMC functionality is generally an integral part of the GSM system procurement and therefore requires no additional investment.
- When the analysis of the OMC data indicates a specific problem, network engineers often need to resort to localised drive test or protocol analyser measurement to identify specific causes and determine suitable rectification procedures.

DRIVE TESTING
- Drive testing can be expensive in terms of cost, manpower and equipment resources.
- It can only cover a certain geographical region for the above reasons.
- It can only provide data on the network for the period the tests are in progress .i.e. a 'snot-shot' of network performance with a limited timeframe.

PROTOCOL ANALYSERS
- Relatively expensive pieces of equipment.
- Generally not feasible to deploy them is sufficient numbers to monitor the whole network on a continuous basis.
- Non-intrusive testing.

2.7 Data Analysis Phase

Statistical data is usually generated in the form of reports. These reports indicate the measurements of specific pre-defined KPIs. Analysis should take two forms:

- **Current Parameter Values**. Identifying unusual parameter values, for example, an unusually high number of dropped calls over the reporting period.
- **Comparison with Previous Reports**. Comparison of current parameter values with those acquired over a longer period may identify patterns of problems or trends in potential degradation which could be addressed before significantly affecting network performance.

Analysis of Data

Data can be analysed under several headings:

- Call success
  - evaluating the outcome of call attempt in terms of set-up time, clear down success, assignment success etc
- Statistical distributions
  - RxLev, RxQual
- Handover analysis
  - showing success rate of attempted handovers
- Neighbours
  - comparing neighbour cells found by signal level measurements with the neighbour list in the site database
- Coverage Analysis
  - Analysing the coverage threshold levels using serving cell/neighbour cell comparison to identify problem areas
- Quality
  - gives a comparison of signal quality from serving and neighbouring cells

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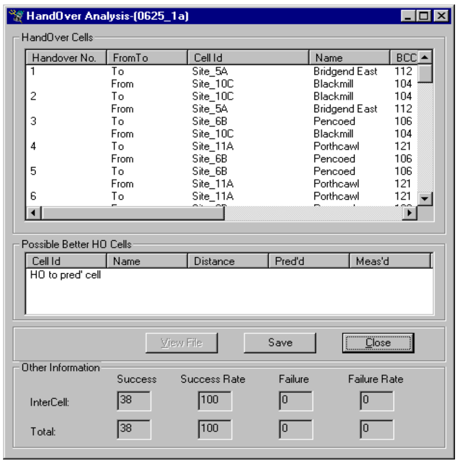
Results should also be compared with existing specific data sets such as demographic data, marketing data, trends and traffic growth predictions.

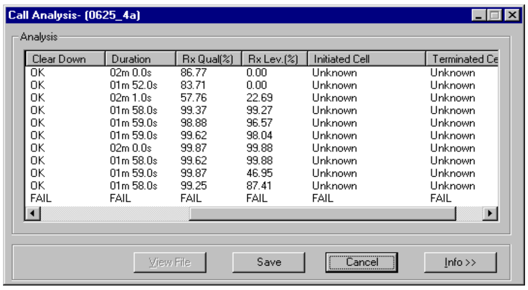
Drive Test Data Analysis Screens

- Examples of analysis screens in Neptune:

Handover



Call Success



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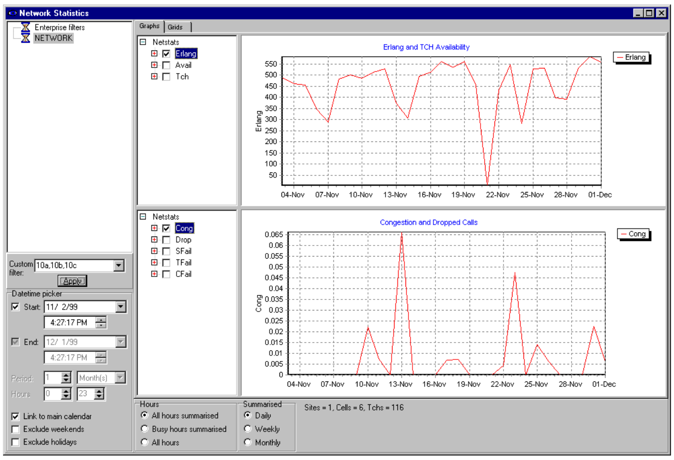
OMC Data Analysis Screens

- **Example of analysis screen in OPTIMA**:



3. Network Characteristics and Problem Types

3.1 Introduction

When designing a network, there are three, often conflicting requirements:

- To ensure adequate coverage is provided for the geographical region
- To ensure there is sufficient capacity for the predicted number of subscribers and usage patterns
- To ensure that Quality of Service (QoS) levels offered to customers are established and maintained.
- To ensure that efficiency of equipment is optimised to ensure maximum Return of Investment (ROI).

All the above requirements must be considered when designing a balanced and cost-efficient network. Problems identified in any of these areas indicate that the target criteria are not being met and therefore some remedial action may be necessary to rectify the condition.

This section of the course looks at these network characteristics and identifies some of the significant problems that may occur within each area.

Requirements of a Mobile Network

The general requirements when designing a mobile network are to maximise:

- Coverage
- Capacity
- Quality of Service (QoS)
- Cost-effectiveness (ROI)

When designing a mobile network, the first stage is generally to provide sufficient coverage for the area concerned. This may also be a stipulation of the frequency license agreement. For example, in some countries, when a mobile frequency licence is awarded by the Government, one of the stipulations in the past has been that a certain percentage of the geographical area or population must be covered within a specified number of years from initial implementation.

Having acquired sufficient sites to provide the required coverage, the next stage is generally to determine the spread of potential customers (subscribers) and estimate the amount of traffic likely to be generated by each. The network plan is then modified to ensure that, in addition to providing the required coverage, sufficient capacity exists within that coverage area to service the estimated traffic levels.

Thirdly, having determined the coverage and capacity requirements, Quality of Service (QoS) parameters must be determined, against which the performance of the network is monitored. There parameters, known as Key Performance Indicators (KPIs) are critical to the efficient performance management process and are also key benchmarks against which the success of any optimisation is gauged.

BSS and Non-BSS Issues

- Network problem types can be divided into two distinct areas:
  - Those arising at the BSS (BTS - BSC)
  - Those arising in the transmission and the NSS
- Despite often resulting in the same effect, problems in each area require a different approach:
  - BSS issues typically relate to frequencies, radio resource dimensioning and/or maintenance of BSS database parameters
  - Non-BSS issues may relate to transmission links availability, call set-ups, location updates and paging attempts

Network problems are not confined to the BSS (air interface and mobile users) but may also arise in the transmission and core network area. In terms of user perception,

The end effect of these problems may be similar (handover problems, dropped calls etc) but resolving the problems requires a different approach for each:

BSS issues typically involve interference and frequency planning issues, radio resource dimensioning or the maintenance of parameters in the BSS database for handover, power control etc.

Non-BSS issues may relate to the availability of transmission links, call set-ups, location updates and paging attempts

3.2 BSS Coverage Issues

Problems with BSS coverage primarily manifest themselves in the form of gaps or 'dead areas' within the network region. This is often caused by inadequate initial coverage planning or a change in operating parameters. The result is that cell coverage does not overlap sufficiently and therefore a moving MS may drop a call when it loses coverage whilst moving between cells.

3.2.1 CAUSES OF COVERAGE DEGRADATION

Shortfalls in any of the following areas issues may cause coverage gaps to be created:

- Poor Cell Balancing
- Antenna Configuration
- Degradation in Equipment Performance

Causes of BSS Coverage Degradation

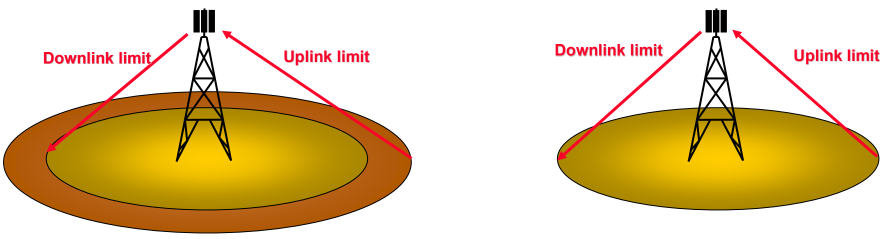
- Cell Balancing
- Antenna Configuration
- Equipment Performance

3.2.2 CELL BALANCING

Section 3 – Network Characteristics & Problems

Cell Balancing

- Power budget calculations show the maximum distance of the mobile from the base station at which uplink and downlink can be maintained
- In a balanced system, the boundary for uplink and downlink must be the same



Unbalanced system

Balanced system

- An unbalanced cell could drop many calls in the fringe region

There is little use in being able to communicate in one direction only on a mobile telephone system. The coverage area, and hence the maximum path loss tolerated, should be the same for the uplink and the downlink. If this is the case the system is said to be "balanced".

Conditions for Cell Balance

- The conditions for cell balance depend on the asymmetries between the uplink and downlink power budgets
- These asymmetries include:
  - MS and BTS $P_{out\ (max)}$ not the same
  - MS receiver less sensitive than BTS
  - Diversity reception at BTS but not at MS
  - Downlink-only combiner loss

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Section 3 – Network Characteristics & Problems

System Balance Equation

- Power budget equations:

Downlink: $P_{inMS} = P_{oBS} - L_c - L_d - L_{fb} + G_{ab} - L_p + G_{am} - L_{fm}$

Uplink: $P_{inBS} = P_{oMS} - L_{fm} + G_{am} - L_p + G_{dBS} + G_{ab} - L_{fb} - L_d$

- When the mobile is at the extreme boundary of the cell:

$$P_{inMS} = P_{refMS}$$
$$P_{inBS} = P_{refBS}$$

These are the reference sensitivities of the MS and BTS

The output levels P_{oBS} and P_{oMS} are the maximum allowed values

- If the boundaries for uplink and downlink are the same, the path loss L_p will be the same in each direction
- Subtracting the uplink equation from the downlink gives the system balance equation:

$$P_{oBS} = P_{oMS} + L_c + G_{dBS} + (P_{refMS} - P_{refBS})$$

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By considering the asymmetries between the uplink and the downlink it is possible to derive an equation that will allow the required base station transmit power to be calculated in terms of the mobile transmit power, the combiner loss, the diversity gain and the threshold levels of the base station and mobile receivers

Field Implications of System Balance

- When changing cell size to alter coverage, consider whether the change will affect the system balance, for example:
  - Increasing BTS Tx power ($\mathbf{P}_{oBS}$) to increase coverage would upset the balance
- Ways of altering coverage without affecting balance include:
  - Decreasing BTS Tx power - the BSS can force the MS to use dynamic output power control (adjusting $\mathbf{P}_{oMS}$ to maintain balance)
  - Altering the gain of the base station antenna - $\mathbf{G}_{ab}$ is a symmetrical term in the power budgets
  - Antenna down tilting changes coverage area without affecting balance

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When making modifications to a network design, it is important to consider the impact on the system balance of any changes. For example, if it is required to increase coverage, simply increasing the BTS tranmit power will not help as it will upset the system balance. However, utilising a higher gain antenna will provide increased coverage whilst maintaining balance . Similarly, adjusting the tilt of the antenna will affect coverage without upsetting the system balance.

3.2.3 ANTENNA CONFIGURATION

Antenna Configuration

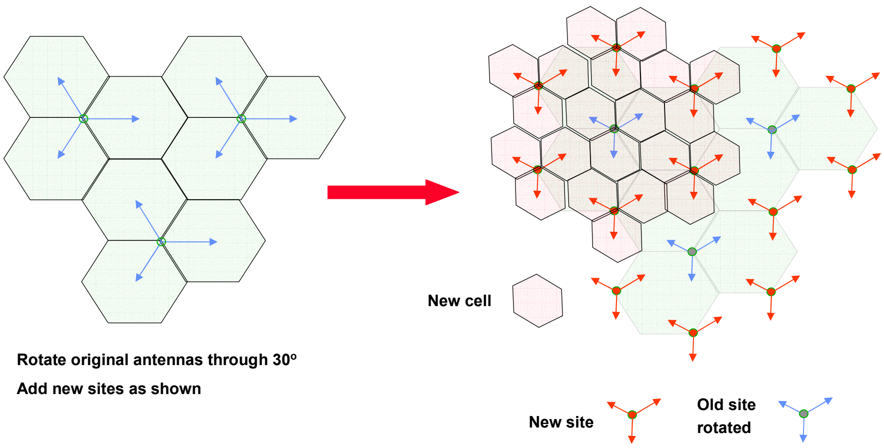
- The following antenna configuration issues can affect coverage performance:
  - Antenna Alignment
  - Tilting Configuration
  - Use of Antenna Diversity

A
ntenna Alignment

The azimuth (horizontal) direction of the antenna can have a significant effect on interference with other cells. This interference can result in shrinkage of cell size and quality of service degradation.

Antenna Alignment

Capacity can be increased by cell splitting where antenna re-alignment is necessary

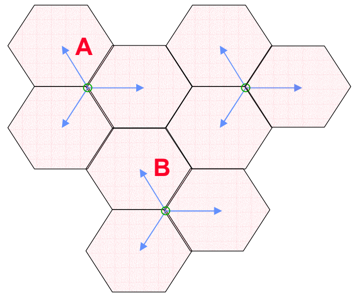


The above illustration indicates that when changing the cell configuration, realignment of antennas may be a pre-requisite to avoid interference.

Section 3 – Network Characteristics & Problems

Effect of Antenna Alignment on Interference

- Directional pattern of sectored antennas reduces response to interference
- Increases C/I significantly
- Allows greater frequency re-use, i.e. smaller cells
- If cells A and B use the same carrier:
  - B will cause co-channel interference in A
  - A will cause very little co-channel interference in B
- Interference is no longer mutual



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The above diagram illustrates how directionality of antenna configurations can be used to reduce the effects of interference.

Antenna Tilt

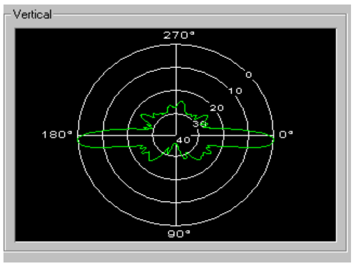
The first generation of antenna featured mechanical and/or electrical tilting. Mechanically tilting the antenna a few degrees from the vertical provides a coarse means of modifying cell coverage. Yet traditional mechanical tilt brought with it a number of problems. Effective only in the forward direction, it can distort the azimuth beam and launch rear lobes upward. It also has no effect on side radiation, a source of multi-path and co-channel interference.

Second-generation cellular antennas addressed the shortcomings of mechanical tilt by the introduction of electrical tilt, where the beam is 'tilted' by altering the signal phasing. This solution offers an undistorted azimuth beam plus the distinct advantage of tilting all lobes (main, rear and side) to the same measure, thus controlling interference in all directions.

Good control of beam tilt is an increasingly crucial factor for system operators, who need to trim cell coverage to suit an ever-changing cell terrain, shape and density. The early mechanical and electrical tilt technologies provided system planners and operators with antenna tilt that was somewhat limited, being available only in discrete steps.

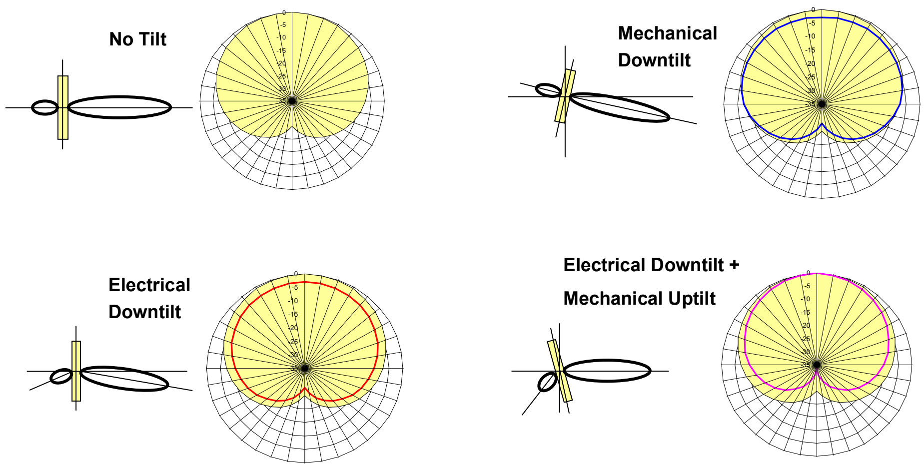
Antenna Tilt

- Down tilt of antennas often used to:
  - reduce interference
  - adjust cell size
  - direct coverage e.g. into a building
- Mechanical tilt:
  - set by operator
  - distorts azimuth (H plane) radiation pattern
- Electrical tilt:
  - set by manufacturer
  - reduces radiation H plane pattern equally in all directions, without distortion



Omni-directional antenna with electrical down tilt

Examples of Antenna Tilt



Use of Antenna Diversity

Antenna diversity is a technique that can be used to improve the reception characteristics of a BTS. It normally comprises two antenna elements separated by a pre-determined distance, each receiving the same signal. The two signals can then be adjusted in phase to ensure they combine to enhance the overall received signal strength. The decision whether or not to provide uplink diversity is connected with the issue of link balancing.

Section 3 – Network Characteristics & Problems

Diversity Reception

- Diversity reception is a way to improve the quality and strength of the signal arriving at the base station, by receiving it in several independent ways
- Two forms of diversity reception often employed are:
  - Space diversity
  - Polarisation diversity
- Frequency hopping is sometimes referred to as frequency diversity

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Diversity reception gives extra gain on the uplink by reducing fading at the base station antenna. It introduces a gain into the uplink power budget typically of about 5dB.

A base station may use either space or polarisation diversity, but would not generally use both.

Space Diversity

- Two receiving antennas are used at the base station
- If they are far apart, the received signals will be independent of each other
  - If one has suffered fading, the other may not
- A suitable distance is generally about 10 wavelengths
- GSM 900, 10λ = 3 metres
- Better isolation between the two signals can also be obtained by mounting the antennas at different heights on the tower

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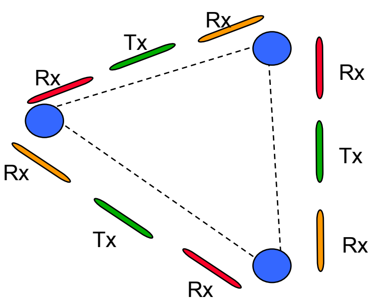
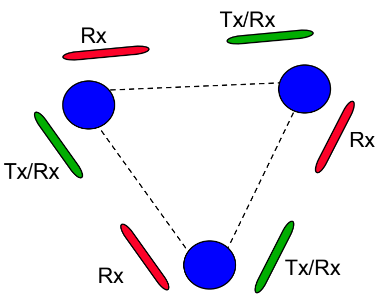
Space Diversity Antenna Systems

- Plan views of two possible tri-sectored site antenna systems

Transmit antenna is separate from the receivers

One antenna is used for transmit and receive, using a duplexer in the BTS to direct the signal





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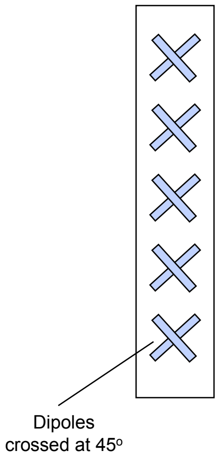
This diagram illustrates the reduction in space required on the tower by using a duplexer. This allows one receive antenna to be combined with the transmit antenna in each sector. A duplexer uses filters to direct the uplink and downlink signals to and from the antenna. This introduces a loss of 1 or 2 dB into the power budget.

Polarisation Diversity

- As the radio signal undergoes multiple reflections and scattering, the plane of polarisation is rotated randomly
- This can be used to provide diversity reception by designing antennas with dipoles crossed to receive different components of the polarisation
- The preferred method is to cross the dipoles at 45°
- This gives good coverage of vertical polarisation and strong components of rotated signals



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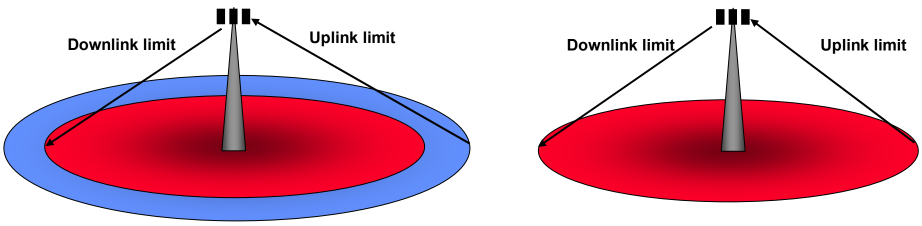
Deciding whether to use Diversity



Unbalanced system

Balanced system

- Diversity is used when necessary to balance the system.
- It helps the uplink but not the downlink.
- Diversity allows the BTS to operate at higher power whilst maintaining link balance.
- Hence it allows greater coverage to be achieved.

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Handover algorithms used by the BSS take uplink and downlink power and quality levels into account. If the system were unbalanced, the information would be inconsistent and handovers would not be correctly implemented.

Using diversity allows link balance to be maintained whilst increasing the base station transmit power. If coverage can be provided on the downlink using a low transmit power, diversity is not required.

3.2.4 DEGRADATION OF EQUIPMENT PERFORMANCE

Section 3 – Network Characteristics & Problems

Equipment Performance

- Effects of changes in equipment parameters can result in:
  - Frequency drift - resulting in increased interference problems
  - Output power variance – leading to coverage and interference problems
- Can be addressed through an effective, proactive equipment maintenance program

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The electrical characteristics of communications equipment tend to vary with time. This variance can manifest itself in the form of frequency drift of a transmitter of receive filter, or degradation of performance parameters such as power output.

Inadequate proactive maintenance of network equipment can lead to degradation in performance resulting in possible power output reductions or frequency drift. In both cases, .this can manifest itself in the form of reduced cell coverage, thereby creating 'dead spots' in the network coverage. This may not become apparent until the situation has deteriorated to the point where calls are being dropped through intermittent coverage.

Causes of Equipment Performance Degradation

- Electronic component degradation
- Environmental conditions:
  - Wind, rain, temperature
- Water ingress into connectors
- Deterioration of feeders

In addition, degradation of feeders and connectors through lack of maintenance can also significantly effect the performance of a communications system.

It is therefore important that equipment characteristics are monitored regularly in order that proactive maintenance can be carried out to maintain equipment within tolerable operating parameters. This prevents degradation to the point where impact on network performance becomes significant.

Losses in Feeders and Connectors

- Long feeder cables from antenna to base station equipment can cause considerable power loss
- Typical loss in co-axial cable: 3 -10 dB per 100m
- Loss increases with frequency:
  - 1800 MHz can have 4 - 10 dB greater loss than 900 MHz
- Loss depends on quality of cable:
  - Cheap cable may give 20 dB per 100m
  - Very expensive cable can have:
    - 1 dB / 100m for 900 MHz
    - 3 dB / 100m for 1800 MHz

- Connectors between duplexers, combiners, couplers and so on should produce no more than 0.2 dB loss

3.3 BSS Capacity Issues

Capacity reflects a network's ability to service the requirements of its subscribers within a prescribed level of service quality. There are a number of issues that may affect the capacity requirements of an existing network:

- Changes in subscriber density.
- Changes in subscriber usage patterns.
- Introduction of new services.

Section 3 – Network Characteristics & Problems

Issues Affecting Capacity

Issues that may affect network capacity include:

- Change in subscriber densities
  - Initial dimensioning based on inaccurate initial demographic data
  - Creation of new high-density subscriber areas
- Change in subscriber usage patterns
  - Average number of calls
  - Average call duration
  - Predicted usage of existing services
- Introduction of new services
  - Predicted take-up of new services
  - Usage patterns for new service
  - Capacity requirements for new service (e.g. HSCSD vs GPRS)

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3.3.1 CHANGES IN SUBSCRIBER DENSITIES

Demographic changes can lead to changes in offered traffic different parts of the network. Cells which were under-used may become overloaded (and visa-versa) due to such changes For example, a new airport or shopping mall has been built creating unforeseen congestion in a particular part of the network

A significant change in the distribution of subscribers within a specific network area may result in unforeseen congestion that generally manifests itself in the form of reduced customer service through an inability gain network access ('network busy' message).

Such changes in subscriber distribution could result from:

- Initial dimensioning based on inaccurate demographic data.
- Creation of new high-density areas such as new shopping malls or airports/train stations etc where an unanticipated concentration of mobile subscribers are created.

3.3.2 CHANGES IN SUBSCRIBER USAGE PATTERNS

Initial network capacity planning is generally based on demographic data and predicted subscriber usage patterns. Usage patterns refer to how the average subscriber uses his mobile device i.e:

- average number of calls.
- average call duration.
- predicted usage of services such as SMS, WAP, GPRS etc.

It may be that the original predictions for usage patterns were incorrect and performance indications identify a requirement to adjust the capacity requirements in certain parts of the network. Alternatively, it may be that social trends force a change in the way subscribers use network services. An example of this is the use of SMS in the UK. The use of 'texting' has become a social pastime amongst the younger generation in the UK. This has placed an unexpected burden on network capacity which now has to be adjusted for.

A significant change in these usage patterns can create additional congestion in the network resulting in the conditions described above.

3.3.3 INTRODUCTION OF NEW SERVICES

The Operator may wish to add new services to the network (such as HSCSD/GPRS/SMS) in order to attract more customers and/or increase revenue generation. This may result in an increased requirement for network capacity either in terms of additional customers and/or an average increase in traffic per existing customer. Network optimisation may enable these services to be introduced with minimal additional infrastructure investment to meet the increased capacity demand.

The introduction of new services needs to be carefully managed in order to avoid congestion which will result in a service quality degradation.

To avoid this happening, the following should be considered:

- What is the predicted take-up of the new service?
- What are the predicted subscriber usage patterns for the new service?
- What network resources will need to be allocated to maintain the desired quality of service?

3.4 BSS Quality of Service (QoS) Issues

Quality of Service refers to the perceived ability of a subscriber to use the services offered by the network.

Indications of reduced network quality generally come from two sources:

- Monitoring of network performance parameters
- Customer complaints
-

Part of the initial network implementation process should be defining performance indicators. It is these indicators that are monitored on a regular basis to identify performance trends or areas where problems exist. Rectification of such problems would be carried out using optimisation techniques.

Customer complaints are generally a very good indication of poor air-interface performance in certain network areas and should not be ignored. Poor quality of service immediately impacts on the customer in a number of obvious and frustrating ways:

- Inability to set up a call (‘network busy’)
- Long call set-up times (compared to PSTN calls)
- Call dropping during a conversation
- Inability to understand distant end due to low level speech or interference.

3.4.1 IDENTIFYING QoS DEGRADATION

When a network is initially designed, one of the key design criteria is the level of service to be offered to the customer as this will determine the network capacity requirements and therefore hardware utilisation. For example, how many BTSs are required to serve a particular cell in order to provide the required subscriber capacity.

It is because of this close link between defined quality of service levels and subscriber perception that it is not uncommon for network problems to first be identified through subscriber complaints. However, good performance management should identify these problems through performance indicators before they become significantly perceivable by the customers.

Issues Affecting BSS QoS

- QoS issues are generally identified through:
  - Indications from key network performance parameters
  - Customer complaints
- Issues affecting network QoS include:
  - Frequency Plan
  - Call set-up failures
  - Long call set-up times
  - Calls being dropped
  - Poor speech quality

3.4.2 FREQUENCY PLAN

Section 3 – Network Characteristics & Problems

Frequency Plan

- A good frequency plan requires a good RF design strategy
- The quality of a frequency plan relates to:
  - Frequency re-use efficiency - tighter frequency re-use allows greater traffic capacity across the network
  - Interference levels - there will always be a compromise between tighter frequency re-use and a decrease in C/I values

Adverse Influences on Frequency Plan

- Site Design:
  - Physical parameters such as inconsistent antenna heights will adversely affect the frequency re-use efficiency
- Terrain and Topography:
  - Hilly terrain can produce unexpected coverage effects such as 'splashes' into other cells which can upset handovers as well as producing interference
  - Good site design and antenna positioning is critical to minimise such effects
- External Interference:
  - May be caused by unauthorised use of spectrum, such as 900MHz cordless telephones used outside the USA
  - Another source of interference is from operators in neighbouring countries

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Section 3 – Network Characteristics & Problems

C/I for Typical Cluster Sizes

- Estimates of C/I in dB, using the equation:

$$C/I = 10\log\left(\frac{(\sqrt{3N})^x}{6}\right)$$

Cluster Size N	Propagation Coefficient x: 2	3	3.5	4
3	1.76	6.53	8.92	11.3
4	3.01	8.41	11.1	13.8
7	5.44	12.05	15.36	18.66
9	6.53	13.68	17.27	20.85
12	7.78	15.56	19.45	23.34
21	10.21	19.21	23.71	28.21

- Analog systems require a minimum C/I of about 20 dB
- Digital systems can cope with C/I as low as 9 dB

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3.4.3 CALL SETUP FAILURES

The most obvious indication to a subscriber of poor QoS is the inability to access the network to make a call (the 'network busy' message). There are a number of problems that could lead to this condition:

Faulty Mobile or Network Equipment.
A hardware problem could have developed on the MS which is preventing call establishment. Similarly there could be a configuration error in the MS. Such errors could include:

- Reduced power output and therefore reduced uplink range
- Invalid MS IMEI, causing the AuC to bar access.
- Invalid SIM parameters, barring access to the required network

It is also possible that a BSS hardware element has developed a hardware or software fault which is affecting the ability of that network element to process calls.

Congestion.
A poor air interface channel configuration could cause congestion and result in call setup failures due to:

- Inadequate SDCCH/AGCH channel capacity preventing TCH assignment.
- Inadequate TCH resources resulting in channel assignment failure.
- Inadequate PCH capacity for locating MS to set-up mobile-terminated calls.

In terms of channel congestion, this is most likely to occur on the SDCCH and/or TCH as the AGCH and PCH are generally well provisioned in mobile networks

It is possible that a part of the network becomes either temporarily of permanently overloaded. Temporary congestion can result from a sudden increase in subscriber density in a specific geographical region for a short-duration public event for example. Longer term congestion could result from the creation of new population centres or commercial sites such as a new shopping mall or airport.

Inadequate Network Coverage.
Expansion of population areas could result in the requirement for coverage expanding beyond that originally anticipated. Similarly, changes in network performance could result in changes in anticipated coverage (see 'Coverage' above) resulting in subscribers losing coverage in areas where it may have been available previously. This may result in failed call setups or dropped calls.

Frequency Related Problems
If an MS happens to be in a temporary high fading environment such as a subway or tunnel when attempting to initiate a call, this additional attenuation due to fading may prevent call establishment. Similarly if the subscriber is in a high interference area, the signal quality threshold may be too low to establish a communications link to the BTS or the reverse.

Incorrect Parameter Configuration.
The network parameters that are set to meet specific performance criteria, particularly in the BSS, are complex and inter-related. Any changes made to these parameters can have a cascade effect on performance in other areas. It is possible that a parameter change to improve performance in one area may result in unanticipated changes to network performance in other areas. For example, changing the handover threshold in one area to reduce handover failures may unbalance the capacity distribution i.e. how much traffic is captured by each cell.

3.4.4 LONG CALL SETUP TIMES

From a subscriber perspective, call setup time refers to the time delay between pressing the call button on the handset to ringing tone being returned from the distant end. This time delay can vary considerably and long delays are an indication of poor network performance.

Long Call Setup Times

- Inadequate SDCCH / TCH capacity available
- Locating recipient of Call
- Roaming
- Inadequate paging capacity at called MT end

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Such delays can originate from a number of sources, the primary one being lack of signalling channel resources. If resources are not immediately available, the MS will continue to repeat requests until the requested resources have been allocated. Similarly, it databases are not being updated correctly, significant delays may be experienced while the recipient of the call is located.

3.4.5 DROPPED CALL FAILURES

Dropped Call Failures

- Faulty mobile or network equipment
- Handover failure
- Inadequate network coverage
- Frequency-related problems (fading/interference) etc
- Incorrect cell parameter configuration
- Emergency call pre-emption (Phase 2+ option)

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Dropped call failures refer to the disconnection of calls, once established, without being instigated by the calling or called parties. Causes of dropped calls can include:

Faulty Mobile or Network Equipment.
It is possible that an equipment failure can occur, either within the MS (e.g battery fail) or the network, whilst a call is in progress. Such occurrences are rare and generally beyond the control of the network operator (particularly MS failures). However, generally such network failures are immediately indicated to the NMS and rectification action can be instigated rapidly.

Handover Failure.
If an MS is moving around the network area during a call, it may be necessary to 'handover' the existing call to a new cell. This is a well-established network procedure and is transparent to the subscriber.

However, a number of conditions can result in the call being dropped whilst trying to handover to a new cell:

- <u>Lack of Coverage</u>. The user moves out of the coverage of one cell but there is inadequate coverage from the cell it is being handed over to.
- <u>Lack of Capacity</u>. The user moves out of the coverage of one cell but there is inadequate capacity in the cell it is being handed over to.

Handing-over to a cell is normally related to the BA or neighbour list which identifies the six best neighbouring cells. If this list is incorrect i.e. has not been kept up to date, handovers to non-existent or non-optimised cells may occur.

<u>Inadequate Network Coverage</u>.
Degradation in network performance can lead to coverage gaps developing. If passing though such a coverage gap whilst on the move it is possible that such coverage gaps, if sufficiently large, can cause a call to be lost or 'dropped' due to an inability to maintain communications with a base station.

<u>Frequency-Related Problems</u>.
In a radio network, interference is a common problem. However, it needs to be managed in order to prevent a perceivable degradation to the network. This interference could be caused by other network elements operating on similar frequencies or sources of interference external to the network, for example other high power transmitters operating within the coverage area of the network. Another interference phenomenon, more unique to mobile radio, is fading. Fading is a change in radio path propagation due to intervening obstacles that change frequently as the position of the MS changes.

This is generally a more temporary effect than conventional interference, but in both cases the strength and duration of the interference can result in breaking the MS communication link with the BSS and thereby dropping an ongoing call.

<u>Incorrect Cell or MS Configuration</u>.
The performance and characteristics of the BSS air interface are primarily governed by the database configuration parameters.

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4. Performance Measurement Metrics

4.1 Introduction

The availability of an accurate statistical measurement and reporting method is vital for through-life network performance monitoring, the assessment of network performance during the optimisation processes and also subsequent network growth.

This section of the course describes a general set of Key Performance Indicators (KPI's) to be monitored and recorded on a regular basis. KPI definitions are presented, along with a common method for calculating each of these KPI's from raw counters.

4.2 Key Performance Indicators (KPIs)

Key Performance Indicators

- KPIs are established by the operator as a benchmark against which to judge the performance of a network
- Which KPIs the operator decides to use will depend on:
  - the nature of the network
  - operator assessment of priorities for their business
  - Counters implemented by vendors
- KPIs are generally based on two sets of data:
  - Network statistics from the OMC
  - Drive test statistics using test mobile equipment

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General Key Performance Indicators

KPI'S vary from operator to operator but the following are generally common to all KPI statistics:

- TCH Usage
- SDCCH Usage
- Handover Statistics
- Connection Establishment

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KPIs – TCH/SDCCH Usage

The KPI'S commonly monitored for TCH and SDCCH usage include:

- Traffic Flow
- Mean holding time
- Congestion
- Busy time
- RF Losses

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KPIs – Handover Statistics

The KPI'S commonly monitored for Handover performance monitoring include:

- Success rate
- Failure rate
- Handovers due to poor quality
- Handovers due to poor level
- Power budget handovers
- Handover due to interference
- Inter-cell handovers
- Inter-BSS handovers
- Intra-BSS handovers

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KPIs – Connection Establishment

The KPI'S commonly monitored for connection establishment include:

- Successful immediate assignment procedure
- Attempted immediate assignment procedure
- Cell TCH assignments

Speech Quality Measurements

- Speech QoS represented by:
  - Received Signal Level – RxLev
  - Received Signal Quality – RxQual
- Factors affecting these values include:
  - BTS power output
  - MS power output
  - Current BTS loading

4.3 BSS KPI Definitions

This section provides a list of commonly used Base Station Subsystem (BSS) KPIs, together with their generic definition.

CALL SETUP SUCCESS RATE (CSSR)

CSSR measures the proportion of call setup attempts resulting in a successful TCH assignment, excluding those setup attempts for reasons that do not require a TCH (eg. Location Update, IMSI Detach etc.)

$$Call\_Setup\_Success\_Rate = \frac{Successfully\_Completed\_Call\_Setups}{Valid\_Call\_Setup\_Attempts}$$

DROP CALL RATE (DCR)

DCR measures the proportion of successfully established calls that are terminated abnormally

$$DCR = \frac{TCH\_RF\_Losses + HO\_Fail\_Drop}{Successfully\_Completed\_Call\_Setups + successful\_\mathrm{incoming}\_handovers}$$

CALL SUCCESS RATE (CSR)

CSR measures the proportion of call setup attempts that are successfully established and terminated normally (ie. not dropped)

$$CSR = CSSR(1 - DCR)$$

HANDOVER SUCCESS RATE (HOSR)

HOSR measures the proportion of total handover attempts resulting in a successfully completed handover, including inter-cell, Intra-BSS and Inter-BSS Handovers.

$$HOSR = \frac{Total\_Successful\_handovers}{Total\_Handover\_Attempots}$$

HANDOVER FAILURE RATE (HOFR)

HOFR measures the proportion of handover attempts that result in handover failure with dropped call (ie. excluding handover attempts that fail and recover to the source cell)

$$HOFR = \frac{Total\_HO\_Fail\_Drop}{Total\_Handover\_Attempts}$$

TRAFFIC CHANNEL BLOCKING (TCH_Cong)

TCH_Cong measures the proportion of attempts to allocate a TCH that are blocked due to lack of TCH resources. This should exclude blocked TCH assignment attempts that subsequently succeed due to queuing procedures.

$$TCH\_Cong = \frac{Blocked\_TCH\_Assignments}{Total\_TCH\_Assignment\_Attempts}$$

SDCCH CHANNEL BLOCKING (SD_Cong)

SD_Cong measures the proportion of SDCCH assignment attempts that are blocked due to lack of SDCCH resources.

$$SD\_Cong = \frac{Blocked\_SDCCH\_Assignments}{Total\_SDCCH\_Assignment\_Attempts}$$

CALL DROPPED – RF FAILURE (TCH_RF_Loss)

TCH_RF_Loss measures the proportion of successfully established calls that drop due to TCH RF loss (as distinct from HO_Fail_Drop)

$$TCH\_RF\_Loss = \frac{Total\_TCH\_RF\_Losses}{Successfully\_Completed\_Call\_Setups}$$

TRAFFIC CHANNEL ASSIGNMENT FAILURE RATE (TCH_Ass_Flr)

TCH_Ass_Flr measures the proportion of TCH assignment attempts that fail after TCH allocation and before completion of the call setup procedure.

$$TCH\_Ass\_Flr = \frac{TCH\_Assignment\_Failures}{Total\_TCH\_Assignment\_Attempts}$$

SDCCH ACCESS SUCCESS RATE (SD_Acc_Suc)

SD_Acc_Suc measures the proportion of Immediate Assignment Attempts that result in successful assignment to SDCCH, for all call setup reasons including location update, IMSI detach etc.

$$SD\_Acc\_Suc = \frac{Successful\_\mathrm{Im}mediate\_Assignments}{Total\_\mathrm{Im}mediate\_Assignment\_Attempts}$$

NON-BSS CALL SETUP FAILURE RATE (Non-BSS_CSFR)

Non-BSS_CSFR measures the proportion of Call Setup Attempts that fail due to Non-BSS reasons (eg. MSC rejections, subscriber error, etc.)

$$Non - BSS\_CSFR = \frac{Total\_Call\_Setup\_Failures - BSS\_Call\_Setup\_Failures}{Valid\_Call\_Setup\_Attempts}$$

UTILISATION FACTOR

The Utilisation Factor is the ratio of actual traffic carried to the theoretical traffic that can be carried for a 2% Grade of Service, based on the number of available TCH's and Erlang-B formula.

$$Utilization = \frac{Erlangs\_Carried}{Theoretical\_Erlangs\_2\%GOS}$$

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5. Measuring Network Performance - Drive Testing

5.1 Introduction

Drive testing consists of test teams driving on pre-defined routes in a network region and periodically initiating calls and measuring signal strength. The types of test data collected include unsuccessful handovers, low-quality audio and dropped calls etc.

These results are transferred from the MS to a dedicated PC where the various data groups are processed in order to produce graphical and tabular data in a format that can be readily interpreted by the test engineer.

5.2 Benefits and Limitations of Drive Testing

Drive Test Benefits and Limitations

- Benefits:
  - Replicates subscriber conditions (QoS perspective)
  - Able to provide comparative performance between different operators
  - Focus on specific parameter set or geographical region
- Limitations:
  - Difficult to replicate subscriber usage patterns
  - Area access restriction may limit realistic testing
  - Difficult to achieve network-wide snapshot (limited time and/or geographical area)
  - Primarily down-link analysis only
  - Resource intensive and expensive

Ascom QVoice
Test Mobile Box

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ADVANTAGES

Replicate Subscriber Conditions
Drive testing field tests are carried out using a Test Mobile MS as interface to the network. The test mobile is the same as a standard MS from RF performance point of view. However, it contains a number of hardware modifications to enable network performance data to be measured and exported to a recording device (e.g. a laptop with appropriate software) Therefore, the measurements taken should be identical to those experienced by a standard MS

Comparative Operator Performance
In the increasingly competitive cellular market, visibility of competitors strengths and weaknesses can be key to gaining and/or maintaining market share. Drive test measurements enable operators compare the performance of their own network with those of its competitors in order identify and improve areas of comparative weakness.

Focusing on Particular Parameter Set and/or Geographical Regions
Drive testing can be a resource and time-intensive activity. By selecting a suitable route and/or parameter set, the drive test team can focus on specific problem areas rather than having to carry out network-wide testing.

LIMITATIONS

Replicating Subscriber Usage Profiles
Whist the test mobile can simulate a standard MS from a functional viewpoint, it is less simple to accurately replicate subscribers usage profiles in terms of frequency of received calls and types of services used.

Restricted Area Access
Restrictions on accessing certain areas may preclude accurate drive test measurements in a specific geographical area. In such cases, alternative methods can be used such as call tracing

Limited Network-Wide Performance Measurements
Due to limited resources, it may not be possible to obtain a global impression of network performance within an acceptable time period due to having to continuously redeploy test teams (e.g. attempting to gain a day-long or busy-hour performance indication). In order to overcome this limitation, the centralised monitoring based on BSC/MSC statistics can be used in tandem with field tests.
The field investigations can be done only if field test engineers can physically access the area. But not all areas are easy to get access in it. If some of those are not important from operating point of view (ex: private garden), others are very important (ex: residential houses and offices). Alternative investigation methods shall be used here – i.e. call tracing.

Based mostly on down-link analysis
Measurements are generally taken by the test MS, on the downlink. Other than Layer 3 messages send by mobile, no information is gathered during drive tests regarding up-link behavior. Some correlation with system measurement reports can enhance the depth of analysis.

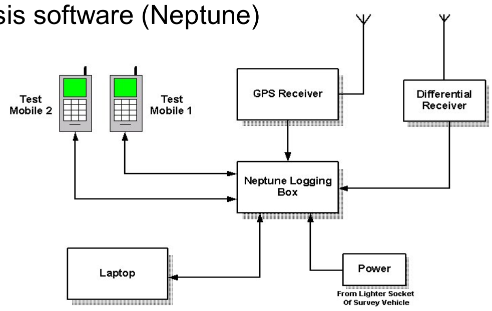
5.3 Drive Test Equipment

A conventional drive-test equipment suite can take many forms. Common to most suites are:

Test Mobile(s). The test mobile monitors the GSM channels for the appropriate messages and can simulate subscriber actions. Using two test mobiles simultaneously, each logged onto a different operator's network, enables direct comparison between the performance of the two networks.

Drive Testing Equipment

- System consists of:
  - Test mobiles - either one or two for benchmarking against another network
  - GPS and differential receivers to provide location information
  - Logging box to interface the measurement equipment to a laptop computer
  - Computer running logging and analysis software (Neptune)



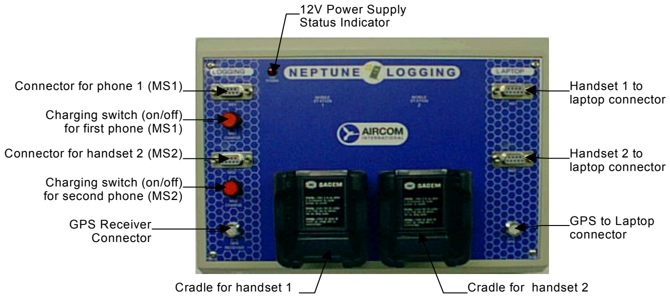
Logging Device. The logging device integrates the information received by the test mobile with that provided by the GPS receiver and the differential receiver (if used)

GPS Receiver. This provides positioning information to be used in conjunction with the collated network data

Differential Receiver. The actual receiving device can be a phone-based, receiver-based or combined phone and receiver-based, the latter providing the most efficient results. A test mobile gives a customer's view of the network, but can only indicate the type of problem that exists. It cannot show the cause of the problem. These limitations are overcome if a GSM receiver is integrated with the phone. A differential receiver provides several additional capabilities, including independent network analysis, faster scanning, spectrum analysis, interference management, CW and channel power measurements, and delta measurements.

The Logging Box

- A logging box can be used to interface the test mobile outputs and GPS signals to the laptop computer system.
- The Aircom logging box is designed for use with Neptune:



- Then use of logging boxes is diminishing as PC software and hardware becomes more sophisticated and adaptable

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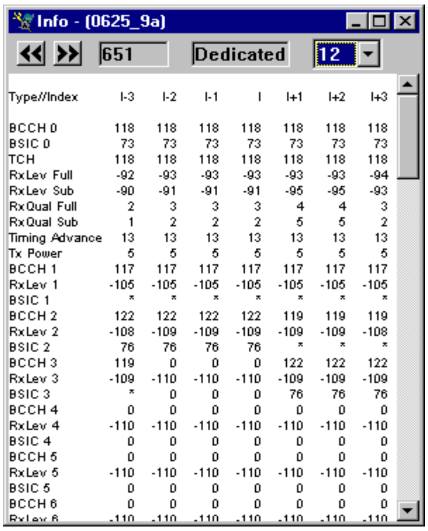
5.4 Test Mobile Data

Section 5 – Drive Testing

Test Mobile Data

- Typical data collected is shown here on the All Data screen in Neptune:
  - Serving cell information - BCCH, BSIC, TCH, RxLev and RxQual, Timing Advance, Tx Power
  - Neighbour cell information - BCCH and RxLev for six best neighbour cells



Type//Index	I-3	I-2	I-1	I	I+1	I+2	I+3
BCCH 0	118	118	118	118	118	118	118
BSIC 0	73	73	73	73	73	73	73
TCH	118	118	118	118	118	118	118
RxLev Full	-92	-93	-93	-93	-93	-93	-94
RxLev Sub	-90	-91	-91	-91	-95	-95	-93
RxQual Full	2	3	3	3	4	4	3
RxQual Sub	1	2	2	2	5	5	2
Timing Advance	13	13	13	13	13	13	13
Tx Power	5	5	5	5	5	5	5
BCCH 1	117	117	117	117	117	117	117
RxLev 1	-105	-105	-105	-105	-105	-105	-105
BSIC 1	*	*	*	*	*	*	*
BCCH 2	122	122	122	122	119	119	119
RxLev 2	-108	-109	-109	-109	-109	-109	-108
BSIC 2	76	76	76	76	*	*	*
BCCH 3	119	0	0	0	122	122	122
RxLev 3	-109	-110	-110	-110	-109	-109	-109
BSIC 3	*	0	0	0	76	76	76
BCCH 4	0	0	0	0	0	0	0
RxLev 4	-110	-110	-110	-110	-110	-110	-110
BSIC 4	0	0	0	0	0	0	0
BCCH 5	0	0	0	0	0	0	0
RxLev 5	-110	-110	-110	-110	-110	-110	-110
BSIC 5	0	0	0	0	0	0	0
BCCH 6	0	0	0	0	0	0	0
RxLev 6	-110	-110	-110	-110	-110	-110	-110

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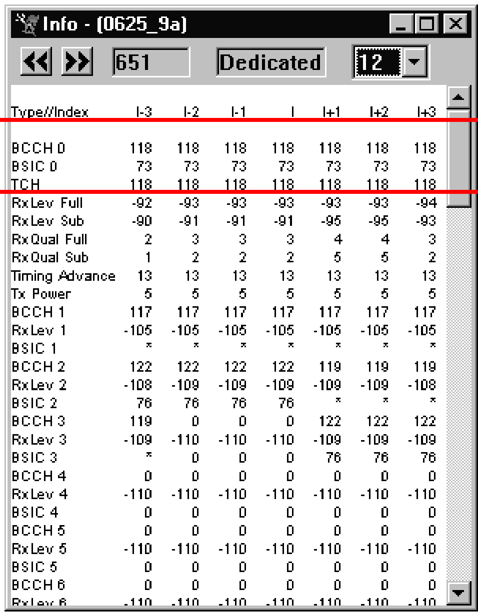
5.4.1 BCCH/BSIC/TCH INFORMATION

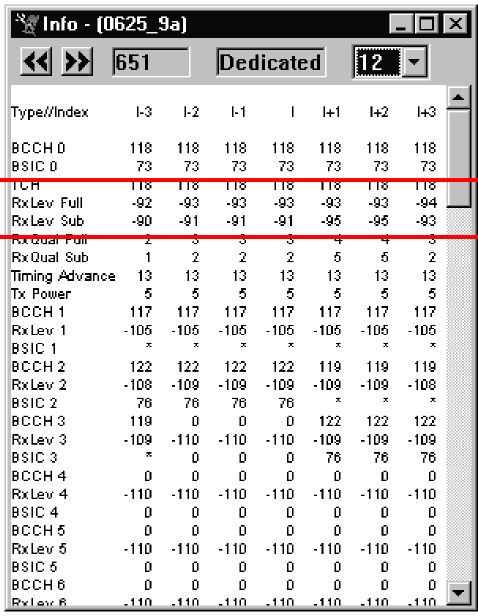
For each measurement taken, the test mobile records the identity of the Broadcast Control Channel (BCCH) and Base Station Identity Code (BSIC) and the traffic channel (TCH) being monitored.



Type//Index	I-3	I-2	I-1	I	I+1	I+2	I+3
BCCH 0	118	118	118	118	118	118	118
BSIC 0	73	73	73	73	73	73	73
TCH	118	118	118	118	118	118	118
RxLev Full	-92	-93	-93	-93	-93	-93	-94
RxLev Sub	-90	-91	-91	-91	-95	-95	-93
RxQual Full	2	3	3	3	4	4	3
RxQual Sub	1	2	2	2	5	5	2
Timing Advance	13	13	13	13	13	13	13
Tx Power	5	5	5	5	5	5	5
BCCH 1	117	117	117	117	117	117	117
RxLev 1	-105	-105	-105	-105	-105	-105	-105
BSIC 1	*	*	*	*	*	*	*
BCCH 2	122	122	122	122	119	119	119
RxLev 2	-108	-109	-109	-109	-109	-109	-108
BSIC 2	76	76	76	76	*	*	*
BCCH 3	119	0	0	0	122	122	122
RxLev 3	-109	-110	-110	-110	-109	-109	-109
BSIC 3	*	0	0	0	76	76	76
BCCH 4	0	0	0	0	0	0	0
RxLev 4	-110	-110	-110	-110	-110	-110	-110
BSIC 4	0	0	0	0	0	0	0
BCCH 5	0	0	0	0	0	0	0
RxLev 5	-110	-110	-110	-110	-110	-110	-110
BSIC 5	0	0	0	0	0	0	0
BCCH 6	0	0	0	0	0	0	0
RxLev 6	-110	-110	-110	-110	-110	-110	-110

5.4.2 RECEIVED SIGNAL LEVEL (RXLEV)

For each measurement taken, the test mobile records the received signal strength by extracting the value of the RXLev parameter:

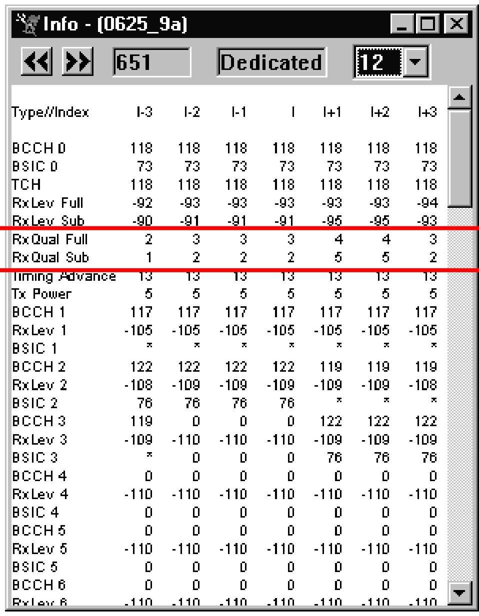


Type//Index	I-3	I-2	I-1	I	I+1	I+2	I+3
BCCH 0	118	118	118	118	118	118	118
BSIC 0	73	73	73	73	73	73	73
TCH	118	118	118	118	118	118	118
RxLev Full	-92	-93	-93	-93	-93	-93	-94
RxLev Sub	-90	-91	-91	-91	-95	-95	-93
RxQual Full	2	3	3	3	4	4	3
RxQual Sub	1	2	2	2	5	5	2
Timing Advance	13	13	13	13	13	13	13
Tx Power	5	5	5	5	5	5	5
BCCH 1	117	117	117	117	117	117	117
RxLev 1	-105	-105	-105	-105	-105	-105	-105
BSIC 1	*	*	*	*	*	*	*
BCCH 2	122	122	122	122	119	119	119
RxLev 2	-108	-109	-109	-109	-109	-109	-108
BSIC 2	76	76	76	76	*	*	*
BCCH 3	119	0	0	0	122	122	122
RxLev 3	-109	-110	-110	-110	-109	-109	-109
BSIC 3	*	0	0	0	76	76	76
BCCH 4	0	0	0	0	0	0	0
RxLev 4	-110	-110	-110	-110	-110	-110	-110
BSIC 4	0	0	0	0	0	0	0
BCCH 5	0	0	0	0	0	0	0
RxLev 5	-110	-110	-110	-110	-110	-110	-110
BSIC 5	0	0	0	0	0	0	0
BCCH 6	0	0	0	0	0	0	0
RxLev 6	-110	-110	-110	-110	-110	-110	-110

'RxLev_Full' refers to the monitored the receive signal level of a full-rate traffic channel. RxLev_Sub refers to monitoring a traffic channel when DTX has been implemented. In this case, not all TDMA frames are measured so the average power level may differ from the full-rate channel.

5.4.3 RECEIVE QUALITY LEVEL (RXQUAL)

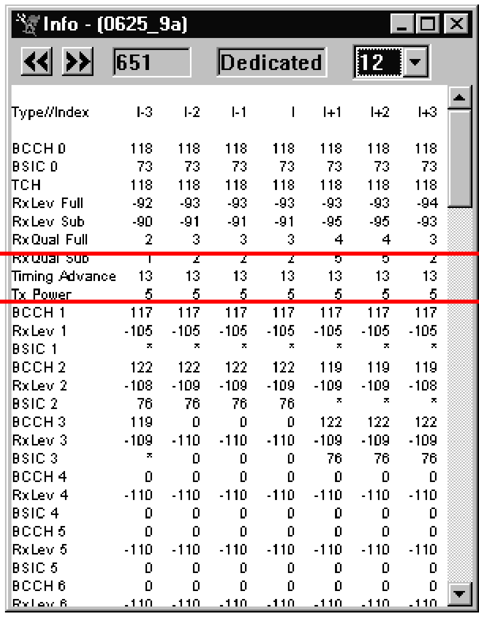
For each measurement taken, the test mobile records the received signal quality by extracting the value of the RXQual parameter:



Type/Index	I-3	I-2	I-1	I	I+1	I+2	I+3
BCCH 0	118	118	118	118	118	118	118
BSIC 0	73	73	73	73	73	73	73
TCH	118	118	118	118	118	118	118
RxLev Full	-92	-93	-93	-93	-93	-93	-94
RxLev Sub	-90	-91	-91	-91	-95	-95	-93
RxQual Full	2	3	3	3	4	4	3
RxQual Sub	1	2	2	2	5	5	2
Timing Advance	13	13	13	13	13	13	13
Tx Power	5	5	5	5	5	5	5
BCCH 1	117	117	117	117	117	117	117
RxLev 1	-105	-105	-105	-105	-105	-105	-105
BSIC 1	*	*	*	*	*	*	*
BCCH 2	122	122	122	122	119	119	119
RxLev 2	-108	-109	-109	-109	-109	-109	-108
BSIC 2	76	76	76	76	*	*	*
BCCH 3	119	0	0	0	122	122	122
RxLev 3	-109	-110	-110	-110	-109	-109	-109
BSIC 3	*	0	0	0	76	76	76
BCCH 4	0	0	0	0	0	0	0
RxLev 4	-110	-110	-110	-110	-110	-110	-110
BSIC 4	0	0	0	0	0	0	0
BCCH 5	0	0	0	0	0	0	0
RxLev 5	-110	-110	-110	-110	-110	-110	-110
BSIC 5	0	0	0	0	0	0	0
BCCH 6	0	0	0	0	0	0	0
RxLev 6	-110	-110	-110	-110	-110	-110	-110

'RxQual_Full' refers to the monitored the channel quality for a full-rate traffic channel. RxQual_Sub refers to monitoring a traffic channel when DTX has been implemented. In this case, not all TDMA frames are measured so average power level may differ from the full-rate channel.

5.4.4 TIMING ADVANCE (TA)

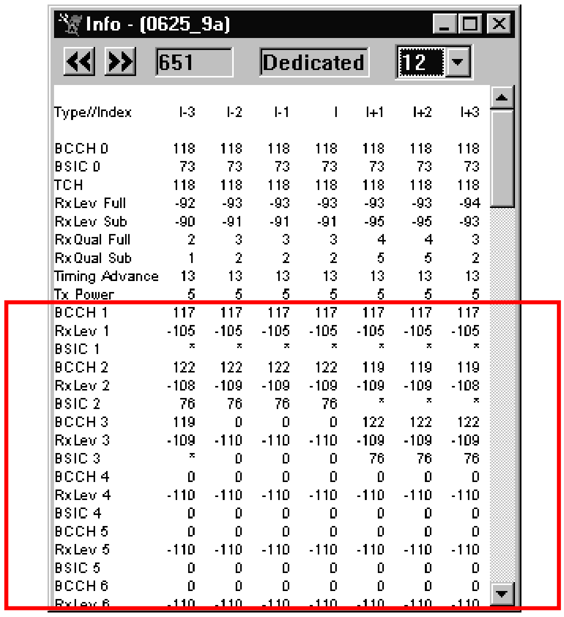


Type/Index	I-3	I-2	I-1	I	I+1	I+2	I+3
BCCH 0	118	118	118	118	118	118	118
BSIC 0	73	73	73	73	73	73	73
TCH	118	118	118	118	118	118	118
RxLev Full	-92	-93	-93	-93	-93	-93	-94
RxLev Sub	-90	-91	-91	-91	-95	-95	-93
RxQual Full	2	3	3	3	4	4	3
RxQual Sub	1	2	2	2	5	5	2
Timing Advance	13	13	13	13	13	13	13
Tx Power	5	5	5	5	5	5	5
BCCH 1	117	117	117	117	117	117	117
RxLev 1	-105	-105	-105	-105	-105	-105	-105
BSIC 1	*	*	*	*	*	*	*
BCCH 2	122	122	122	122	119	119	119
RxLev 2	-108	-109	-109	-109	-109	-109	-108
BSIC 2	76	76	76	76	*	*	*
BCCH 3	119	0	0	0	122	122	122
RxLev 3	-109	-110	-110	-110	-109	-109	-109
BSIC 3	*	0	0	0	76	76	76
BCCH 4	0	0	0	0	0	0	0
RxLev 4	-110	-110	-110	-110	-110	-110	-110
BSIC 4	0	0	0	0	0	0	0
BCCH 5	0	0	0	0	0	0	0
RxLev 5	-110	-110	-110	-110	-110	-110	-110
BSIC 5	0	0	0	0	0	0	0
BCCH 6	0	0	0	0	0	0	0
RxLev 6	-110	-110	-110	-110	-110	-110	-110

Timing advance is used to compensate for propagation delays resulting from variations in distances between the BTS and its associated MSs.   The TA signal is transmitted on SACCH as a number between 0 and 63 in units of bit periods and allows for 'round trip' from MS to BTS and back to MS.

Each step in TA value corresponds to a MS to BTS distance of 550 metres
Maximum MS to BTS distance allowed by TA is 35 km

5.4.5 ADJACENT CELL RECEIVE LEVELS (RXLEVn)



Info - (0625_9a)

651 Dedicated 12

Type//Index	I-3	I-2	I-1	I	I+1	I+2	I+3
BCCH 0	118	118	118	118	118	118	118
BSIC 0	73	73	73	73	73	73	73
TCH	118	118	118	118	118	118	118
RxLev Full	-92	-93	-93	-93	-93	-93	-94
RxLev Sub	-90	-91	-91	-91	-95	-95	-93
RxQual Full	2	3	3	3	4	4	3
RxQual Sub	1	2	2	2	5	5	2
Timing Advance	13	13	13	13	13	13	13
Tx Power	5	5	5	5	5	5	5
BCCH 1	117	117	117	117	117	117	117
RxLev 1	-105	-105	-105	-105	-105	-105	-105
BSIC 1	*	*	*	*	*	*	*
BCCH 2	122	122	122	122	119	119	119
RxLev 2	-108	-109	-109	-109	-109	-109	-108
BSIC 2	76	76	76	76	*	*	*
BCCH 3	119	0	0	0	122	122	122
RxLev 3	-109	-110	-110	-110	-109	-109	-109
BSIC 3	*	0	0	0	76	76	76
BCCH 4	0	0	0	0	0	0	0
RxLev 4	-110	-110	-110	-110	-110	-110	-110
BSIC 4	0	0	0	0	0	0	0
BCCH 5	0	0	0	0	0	0	0
RxLev 5	-110	-110	-110	-110	-110	-110	-110
BSIC 5	0	0	0	0	0	0	0
BCCH 6	0	0	0	0	0	0	0
RxLev 6	-110	-110	-110	-110	-110	-110	-110

The test mobile also measures and records data for the six best neighbouring cells. This data includes the BCCH ARFCN (1-124), cell identity (BSIC), RxLev (in dBm) and RxQual (as a level in the range 0-7). The above screen display does not show the RxQual reading.

5.4.6 NEIGHBOUR LISTS

Section 5 – Drive Testing

Neighbour Lists

- Many handover problems, dropped calls and so on are due to incorrect neighbour lists.
- Each time a change is made to a network, the neighbour relationships should be rigorously updated.
- Failure to maintain neighbour lists leads to problems such as:
  - Unwanted legacy neighbours
  - Neighbour lists reaching the maximum allowable (typically 32)
  - Neighbours defined on co-channel frequencies
  - Missing neighbours
  - Unintended one-way neighbour definitions
- Depending on the vendor, the OMC may support automated neighbour detection via A-bis interface traces.

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Section 5 – Drive Testing

Neighbour Data

- RxLev data can be displayed for the six best neighbour cells and compared with the serving cell's RxLev
- This can be used to identify neighbouring cells that do not currently exist in the BA list of the serving cell

Svr. List - (0625_1a)

Cell	BCCH	BSIC	RxLev	RxQual
Site_2B Port Talbot	112	74	-88	1
Site_2A Port Talbot	118	74	-100	
Site_7B Swansea	102	73	-106	
Unknown Unknown	117	*	-107	
Unknown Unknown	119	*	-108	
Unknown Unknown	121	*	-109	
Unknown Unknown	0	0	-110	

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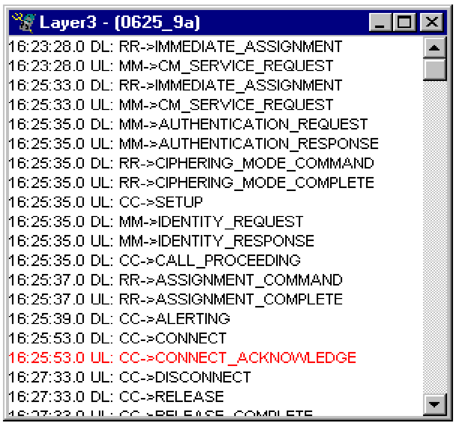
5.4.7 LAYER 3 MESSAGES

Layer 3 Messages

- Neptune displays all layer 3 messages recorded by the test mobile using the following fields:
  - Time of message
  - Direction
    - UL = Uplink
    - DL = Downlink
  - Message Category
    - RR = Radio Resource
    - MM = Mobility Management
    - CC = Call Control
  - Message Type
    - More detailed description



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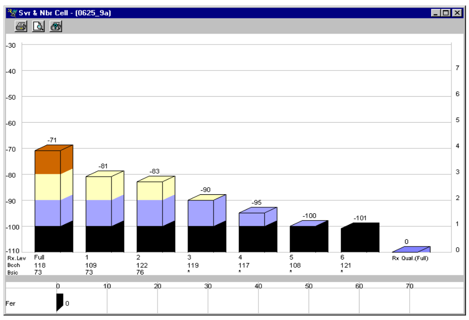
Section 5 – Drive Testing

Graphical Display

- Data can be displayed in a variety of graphical forms
- The display here shows:
  - RxLev for the serving cell
  - RXLev for six best neighbours
  - RxQual for the serving cell
  - Frame Erasure Rate (FER) of the current measurement



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5.4.8 COMPARING BSS DATA AND TEST MOBILE DATA

Test Mobile Data vs BSC Statistics

- A test mobile logging tool such as Aircom's ***Neptune*** allows data to be collected by drive testing a live network

- Advantages of test mobile data over BSC statistics:
  - BSCs provide counters with the number of dropped calls but do not indicate why or where
  - BSCs do not collate information on poor downlink quality
  - BSCs cannot give information on areas without network access from either poor signal or quality
  - BSCs do not store detailed information on calls
  - Test mobiles are the only solution for diagnosing localised network performance issues

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6. Measuring Network Performance - The OMC

6.1 Introduction

The Operations and Maintenance Centre (OMC) is the focal point for day-to-day operations and management of the cellular network. It also supports performance management and optimisation processes. This section of the course explains the role and functions of the OMC and describes some of the Key Performance Indicators (KPIs) used in these processes.

6.2 Role and Functions of the OMC

Role of the OMC

- Perform operations and maintenance (O&M) activities on GSM PLMN Elements
- Provide central network overview
- Often regionally-based under NMC hierarchy
- Manually ordering or remotely configuring disconnections or restoration of network elements
- Manage the traffic loads at various points in the network

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The OMC is a management system that oversees the GSM functional blocks. The OMC assists the network operator in maintaining satisfactory operation of the GSM network. Hardware redundancy and intelligent error detection mechanisms help prevent network down-time. The OMC is responsible for controlling and maintaining the MSC, BSC and BTS. It can be in charge of an entire public land mobile network (PLMN) or just specific parts of the PLMN.

Section 6 – OMC Statistical Data

OMC Functions

- Fault and Alarm Management
- Configuration and Operations Management
- Performance Management

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6.2.1 FAULT AND ALARM MANAGEMENT

Section 6 – OMC Statistical Data

OMC Fault and Alarm Management

- Monitoring System Alarms
- Specific fault identification
- Executing Diagnostic testing
- Prioritise fault rectification
- Implement corrective procedures based on test results
- Record faults to identify patterns/trends
- Selective testing for pre-emptive maintenance purposes

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The OMC provides alarm handling functions to report and log alarms generated by network entities. OMC maintenance personnel can define the criticality of alarms and prioritise their processing according to importance.

In the case of a fault alarm, the OMC operator can implement diagnostic tests from the OMC and, where the cause of the fault is identified, implement corrective action. An example of such action is implementing traffic control to relive temporary congestion by forcing handovers.

Logged alarms can analysed to identify trends or patterns in faults so that pre-emptive procedures can be implemented to reduce the risk of re-occurrence. OMC can also carry out periodic selective testing in order to check current network status and the status of individual network elements. This enables pre-emptive countermeasures to be implemented to reduce the risk of fault occurrence or reoccurrence.

6.2.2 CONFIGURATION AND OPERATIONS MANAGEMENT

OMC Configuration and Operations Management

- Permits physical and logical overview of network elements
- Remote reconfiguration of network elements
- Controlling software upgrades
- Introduction of new network features
- Controlling network expansion
- Network Auditing

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Configuration management enables an overview of the logical and physical structure of network elements. For example, a typical OMC implementation allows the internal configurations of a BSS, MSC and other deployed assemblies to be displayed at any time.

The OMC provides a system of change control for software revisions database configurations in the network entities (e.g. HLR/VLR). Software builds can be downloaded from the OMC to network entities or uploaded to the OMC. The OMC also keeps track of different software versions operating in different subsystems of the network.

The OMC also supports configuration changes involving network expansion e.g adding new BTSs / BSCs etc.

In addition, the OMC supports periodic network auditing to assess network integrity.

6.2.3 OMC ROLE IN PERFORMANCE MANAGEMENT

Section 6 – OMC Statistical Data

OMC Performance Management

- Collection of traffic statistics and other performance-related data
- Scheduling of data collection periods
- Determining composition of performance reports
- Analysis of collected data to:
  - Identify performance trends
  - Identify fault trends
  - Identify pre-emptive maintenance tasks through selective reporting

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OMC Performance management functions include collecting traffic statistics for GSM network entities and archiving them in files or displaying them for analysis. Because the potential exists to collect an overwhelming amount of data, maintenance personnel can select which of the detailed statistics to be collected and displayed based on network procedures, experience or personal interests.

Maintenance functions cover both technical and administrative actions to maintain and correct system operation, or to restore normal operations after a breakdown, in the shortest possible time.

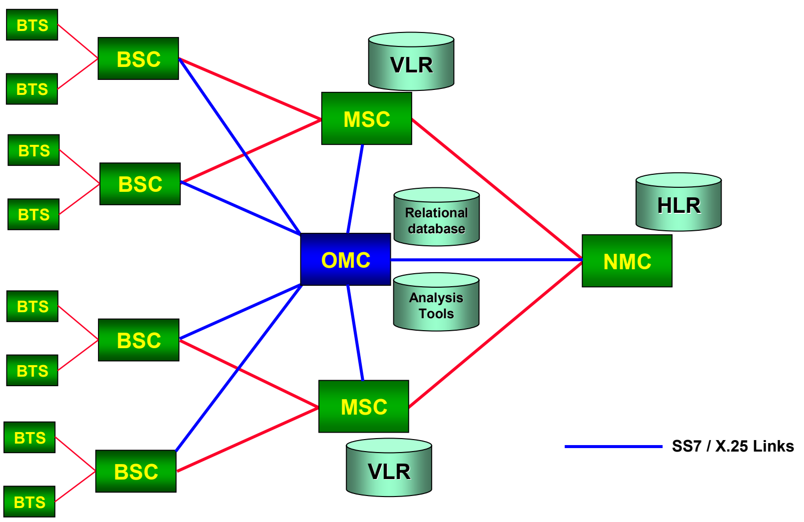
6.3 OMC Communications

OMC Communications

- OMC must communicate with other network elements
- Uses a separate TMN to communicate with network components – frequently utilising PSTN lines
- OMC data passed using:
  - SS7 protocols for short/medium length control messages within GSM network
  - X.25 protocols for large external data transfers such as downloads or subscriber database transfers between subscription centres

Section 6 – OMC Statistical Data

OMC Communications



7. Introduction to Optimisation

7.1 Introduction

7.1.1 DEFINITIONS OF OPTIMISATION

Section 7 – Optimisation Overview

Dictionary Definition of Optimisation

‘Determining the best compromise between potentially conflicting requirements in order to plan and implement an activity with maximum efficiency.’

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A Mobile Network Definition of Optimisation

'The identification and rectification of performance affecting problems within the constraints of an existing network infrastructure.'

7.1.2 REASON FOR OPTIMISATION

The goal of optimisation is to ensure the network is operating at optimum efficiency and within the defined quality of service constraints.

This is achieved by implementing corrective action and procedures to rectify network problems identified though analysis of performance management monitoring parameters.

Reason for Optimisation

- Goal:
  - Ensure optimum network performance within QoS constraints
- Process:
  - Identify network problems through analysis of KPIs
  - Implement corrective actions and/or procedures to rectify problems
  - Monitor results of modifications
- Purpose:
  - Maintain/improve QoS
  - Reduce churn rate
  - Attract new customers
  - Maximise revenue-generating service
  - Maximize efficiency of network functional elements

The reason this optimisation process is carried out is to:

- Maintain or improve quality of service
- Reduce churn rate by retaining existing customers
- Attract new customers
- Maximise revenue generating services by maximising efficiency of functional network elements.

7.2 Requirements for Optimisation

Requirements for Optimisation

- Network issues that may generate a requirement for optimisation include:
  - Perceived reduction in network quality
    - Indications from network performance monitoring
    - Subscriber's experience of using the network
  - Maximising the use of existing infrastructure
    - operator wants to ensure best return on investment
  - Introduction of new services
    - maximise existing resources to accommodate new services such as GPRS
  - Change in original design parameters
    - Flawed original design information
    - Original design information has changed
- Regardless of the initiating event, the optimisation procedures remain generally the same

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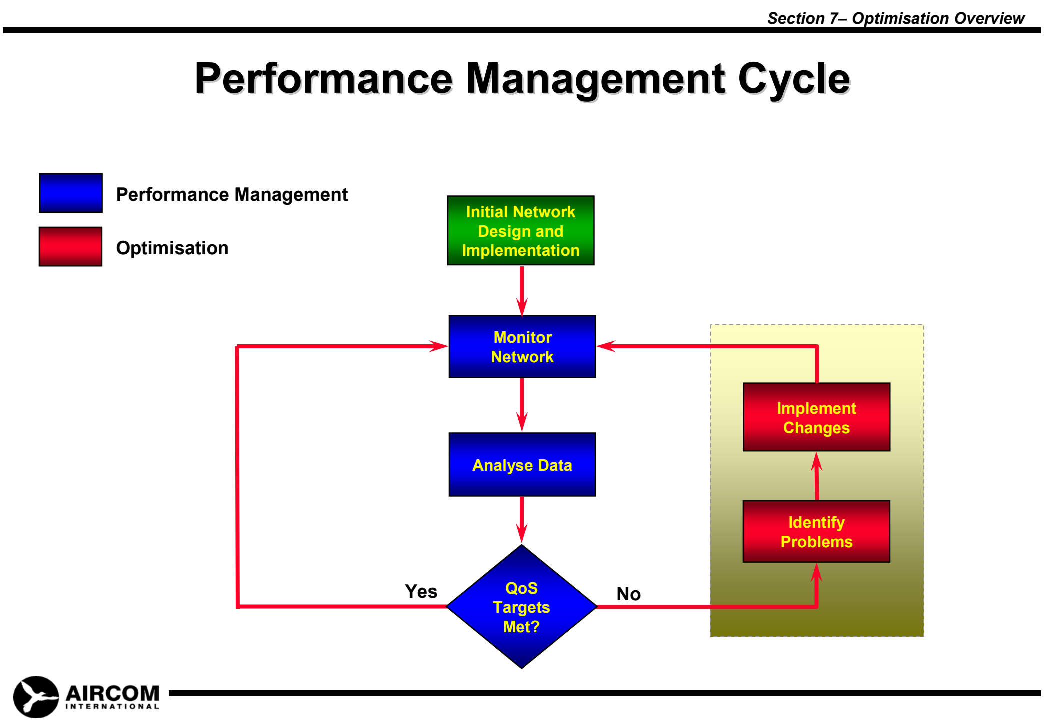
Vendors are continually seeking ways of maximising revenue generation with minimum additional investment. One way of achieving this is to identify areas where the network is not operating at peek efficiency and making adjustments for improvement. For example, over capacity may exist in certain areas allowing for a possible removal of TRXs. Alternatively, congestion may exist in certain areas and by prudent optimisation, additional capacity can be generated with no additional infrastructure investment.

The Vendor may wish to add new services to the network (such as HSCSD/GPRS) in order to attract more customers and/or increase revenue generation. This may generate an increased requirement for network capacity either in terms of additional customers or an average increase in traffic per existing customer. Network optimisation may enable these services to be introduced with minimal additional infrastructure investment to meet the increased capacity demand.

It may be that the original network design was based on flawed information and as a result the network is not performing as originally envisaged. Alternatively, information on which the network design was based has subsequently changed, requiring a change to the network configuration. For example, a new airport or shopping mall has been built creating unforeseen congestion in a particular part of the network.

7.3 Outline Optimisation Process

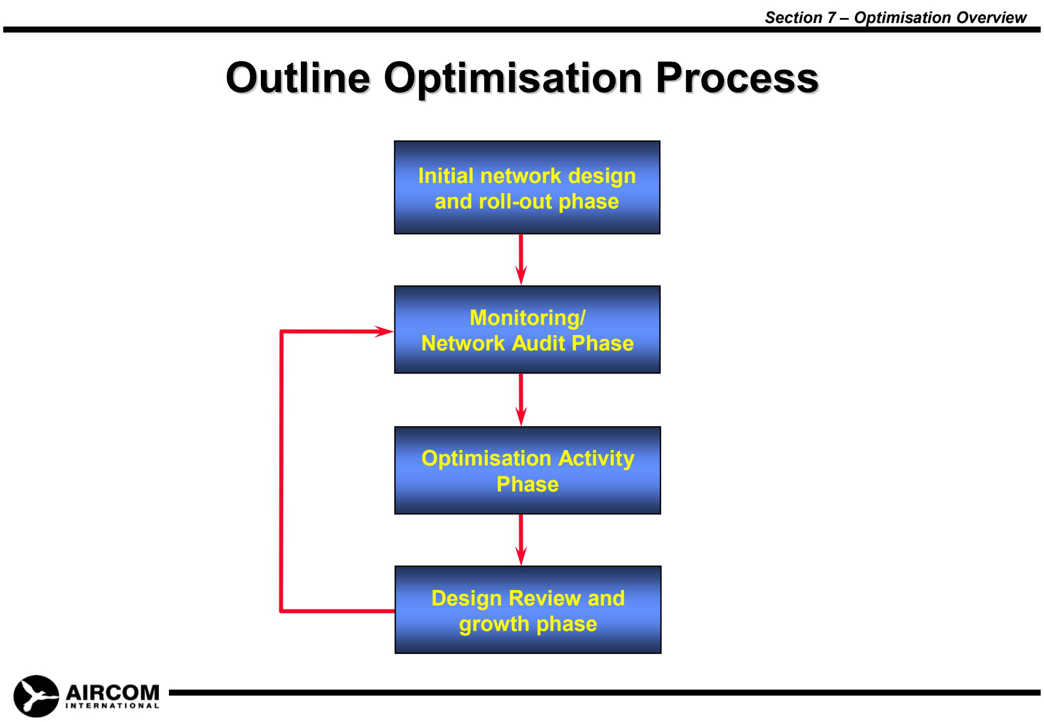
7.3.1 PERFORMANCE MANAGEMENT AND OPTIMISATION



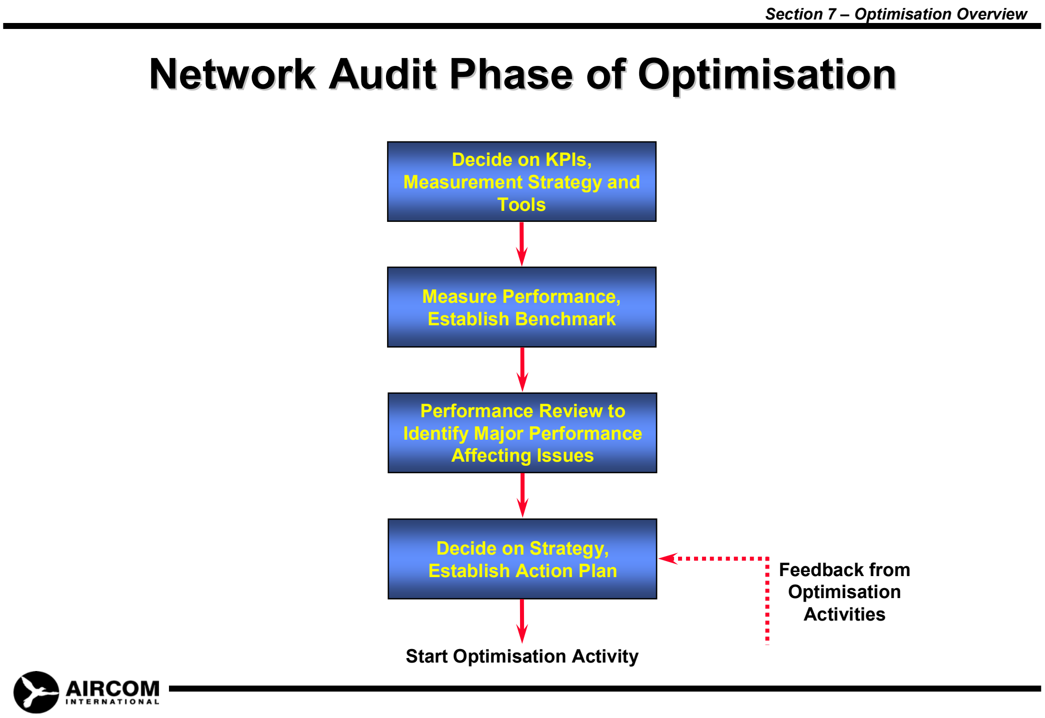
Optimisation forms part of the performance management process. The objective of the radio network optimisation is to extract the optimum performance from the cellular network, at any given phase of its lifecycle. All cellular systems will be associated with continuous change, with new radio sites being introduced, old sites being enhanced and assigned additional frequencies, omni-directional sites being sectorised, new frequency plans being implemented in different regions, etc.

The initial step in performance management is to define a set of QoS (Quality of Service) parameters such as dropped call rates and call success rates. Key metrics are derived from data collected from sources such as drive tests, statistical data, customer complaints and field engineer reports and are used to measure the performance of the network. These metrics are analysed and compared to the QoS targets in order to identify any performance degradation in the network. If problematic areas are identified from analysis of the network performance parameters, corrective processes and/or procedures are implemented to rectify the situation using one or a combination of techniques. This process of corrective actions is known as optimisation.

7.3.2 OUTLINE OPTIMISATION PROCESS



7.4 Network Audit Phase of Optimisation



The network audit phase serves two primary purposes:

- A review of existing network hardware and software (inc database) configurations to determine the both validity and consistency across the network.
- Analysis of data gathered from performance-related network monitoring in order to identify weaknesses or sub-optimal operating performance levels.

7.4.1 DECIDING ON KPIs, MEASUREMENT STRATEGY AND TOOLS

This step in the process is normally only implemented when these elements do not exist within the network. A mature network should already have its KPIs and measurement strategy in place, together with tools to support this process. However, in such cases, part of the network audit process would be to validate these measurement counters and procedures.

7.4.2 MEASURING PERFORMANCE AND ESTABLISHING BENCHMARKS

In mature networks, benchmarks would have already been established. Measuring performance is an ongoing process. However, if a network audit is to carried out as an independent process, a review of existing performance parameters and benchmarks will be required to ensure their validity and applicability to the audit taking place.

7.4.3 PERFORMANCE REVIEW

Having established benchmarks and validated performance parameters, a review of performance is carried out. A possible structure of such a review is as shown in the slide below.

The performance Review is not intended to provide all the answers to all the problems, but to highlight the major issues and provide all the necessary background for further analysis, investigation and in-depth troubleshooting of the major performance-impacting problems in the network. It is important that any network performance audit should follow a methodical process and should be systematic in its approach to data collection.

Section 7 – Optimisation Overview

Network Audit Process

- Performance Review Processes:
  - Network performance statistics (OMC)
  - A-Interface performance statistical analysis
  - Call Trace Analysis
  - Alarms and events
  - GSM performance drive test
  - GPRS Performance drive test
  - Competitive drive test benchmarking

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Network Audit Process

- For each category the following structure can be applied:
  - Objective. What are we trying to measure?
  - Description. Why measure it and its relevance to performance?
  - Report Form. How should the results be presented?
  - Interpretation. What conclusions can be drawn from results?
  - Recommendations. How can the problem be resolved?

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For each of the performance category headings in the outline structure, the following logical process is applied:

- **Objective:** What parameter are we trying to measure?
- **Description:** Why are we measuring it and what is the relevance of the measurement to network performance?
- **Report Format:** How should the measurement be presented, in what kind of graph and what format?
- **Interpretation:** What are the possible conclusions we can draw from the results?
- **Recommendations:** Based on our observations and conclusions, what recommendations can we make for solving the problem or for further investigation?

OMC STATISTICS REVIEW

Network Audit Process

- OMC Statistics Review:
  - Call Success Rate
  - Call Setup Rate
  - TCH Blocking
  - TCH Assignment Failure (RF)
  - SDCCH RF Loss
  - SDCCH Access performance
  - Dropped Calls
  - Handovers

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A INTERFACE ANALYSIS

Network Audit Process

- A Interface Analysis:
  - Call Setup Failures
  - Location Update Success Rate
  - Handover Causes

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CALL TRACE ANALYSIS

Network Audit Process

- Call Trace Analysis:
  - DL receive level and BTS power
  - UL receive level and MS transmit power
  - UL and DL RxQual distributions

EVENTS AND ALARMS ANALYSIS

Network Audit Process

- Events and Alarms:
  - Types of alarms generated
  - Relevance of alarms
  - Procedures for actioning alarms

DRIVE TEST METRICS

Network Audit Process

- Drive Test Metrics - Route **:**
  - Coverage route plot
  - Quality route plot
  - Frame erasure (FER) route plot
  - MS transmit power route plot
  - Speech Quality Index (SQI) route plot

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Section 7 – Optimisation Overview

Network Audit Process

- Drive Test Metrics - Events **:**
  - Dropped call events
  - Call setup failure events
  - Handover failure events
  - Successful handover events

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Network Audit Process

- GPRS-Specific Drive Test Metrics:
  - RLC throughput
  - LLC throughput
  - RLC BlkER
  - RLC retransmission rate
  - Coding scheme usage (CS1-4)
  - Allocated timeslots
  - Packet loss rate
  - Latency/Jitter
  - PDP Context activation failure
  - PDP context loss (GPRS call drop)

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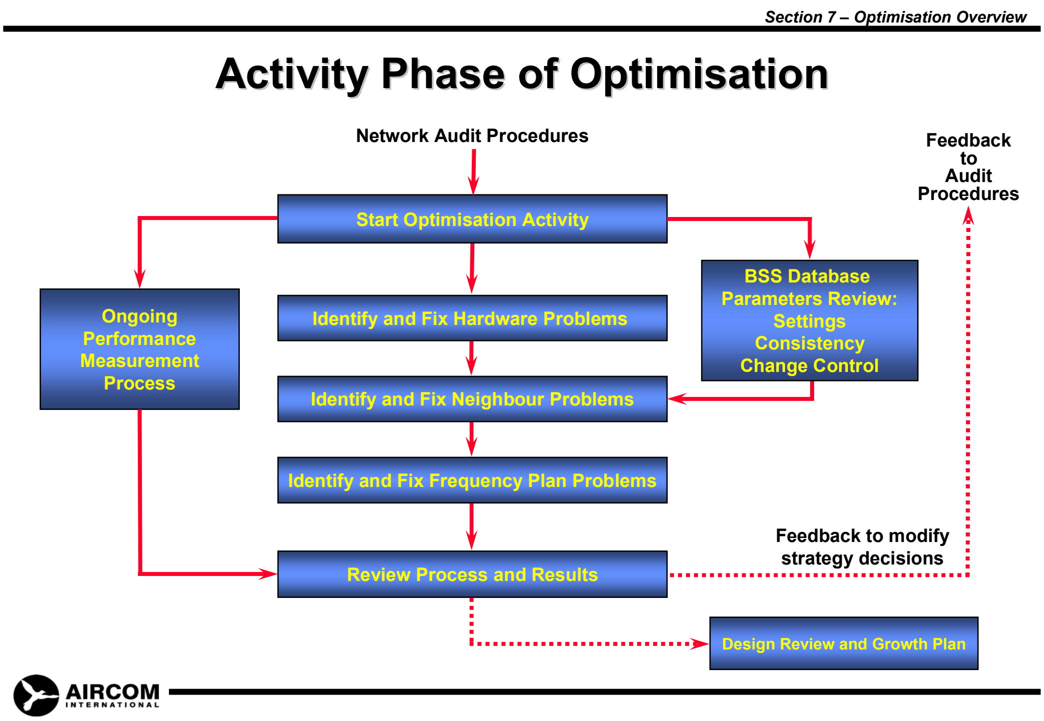
7.5 Network Performance Review Summary

The summary of the Network Performance Review should aim to highlight the specific performance problems identified in the network, on Network level, BSC level and Cell level. The following headings should be included here:

Network Name	Call Success Rate	Call Setup Success Rate	Drop Call Rate	TCH Congestion	SDCCH Assignment Success Rat	Call Volume / traffic	Handover Success Rate
XYZ-net	91.70%	93.40%	1.85%	0.73%	92.10%	1244300	95.60%

7.6 Activity Phase of Optimisation



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8. Evaluating Performance Data

8.1 Introduction

The network is capable of generating a huge amount of statistical data. There is therefore a danger that information overload could obscure some fundamental problems. Hence, it is important to categorise the data in terms of importance and relevance. To achieve this, performance counters are divided into groups by network element and frequency of sampling.

In this section of the course, these categories are described. In addition, various symptoms and causes of those network problems identified by performance statistics are evaluated.

8.2 Main QoS Parameters

There are three main parameters that quantify network quality as perceived by the subscriber, these are:

- **Dropped call rate:** indicates the number of premature call terminations
- **Blocking (GoS):**, indicates number of failed call establishments due network problems (primarily congestion)
- **Erlangs**: indicates the amount of traffic carried by the network

Section 8 – Evaluating Performance Data

Main QoS Parameters

- Dropped Call Rate (< 2%):

$$DroppedCallRate = \frac{NumberOfDroppedCalls}{NumberOfActiveCalls} \times 100$$

- Blocking (GoS) (2%-5%):

$$GOS = \frac{NumberOfCallAttempts - NumberOfCallSuccesses}{NumberOfCallAttempts} \times 100$$

- Traffic Throughput:

$$\text{Traffic for one subscriber} = \frac{\text{no of calls per hour per subscriber} * MHT}{3600}$$

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8.2.1 DROPPED CALL RATE

Dropped Call Rate is a measure of the number of calls prematurely terminated or ‘dropped’ in a certain time frame as a percentage of the number of successful calls set-ups in the same time frame:

$$DroppedCallRate = \frac{NumberOfDroppedCalls}{NumberOfActiveCalls} \times 100$$

As an overall network parameter the dropped call rate should be below 2%. The variance of the dropped call rate on a cell level is higher (since it is dependent on a smaller sample set). Typical values differ between 0% and 5%, where any cells with a dropped call rate higher than the network’s average, should receive attention.

8.2.2 BLOCKING (GoS)

Blocking is the percentage of calls that fail to connect due to network problems. This is normally expressed as a ratio of call attempts to call successes. The definition of Grade of Service GoS (as perceived by the subscriber) is given by:

$$GOS = \frac{NumberOfCallAttempts - NumberOfCallSuccesses}{NumberOfCallAttempts} \times 100$$

The performance criterion of a network is specified as the GoS in the busy hour, which is typically between 2% and 5%. Collecting data on regular intervals is required to identify the busy hour of any particular site and for the network as a whole.

8.2.3 TRAFFIC THROUGHPUT

Erlangs is the unit of measure for describing the amount of traffic throughput across the network. It can be expressed as the sum of the duration of all the calls divided by the measurement time.

$$\textit{Traffic for one subscriber} = \frac{\textit{no of calls per hour per subscriber * MHT}}{3600}$$

MHT = Mean Holding Time (generally 90s = 2.5mE/subscriber)

8.3 Periodic Counters

As mentioned above, the periodicity of capturing measurement statistics depends on the function of the element being tested and the level at which it is situated in the network.

8.3.1 DAILY CELL MEASUREMENTS

Cell measurements should be captured daily. They are intended to identify faults in the cell as soon as possible so that corrective action can be taken with minimum delay. Examples of such measurements include:

- Call setup success rate
- TCH Drop Call Rate
- Handover Success Rate
- TCH Congestion
- SDCCH Congestion

Periodic Counters

- Daily:
  - Cell Level
  - Rapid Fault Identification
  - Includes Call setup rate, TCH/SDCCH conjestion, TCH drop call rate
- Weekly:
  - Cell Level
  - Performance Trends
  - Includes traffic trends, cell retention, cell accessibility
- Monthly:
  - BSC Level
  - Performance Trends
  - Includes processor loading, BSS call setup, handover success rates

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8.3.2 WEEKLY BSS MEASUREMENTS

There are a number of parameters at the BSS that are less critical for day-to-day fault identification, but are more useful for identifying performance trends. These statistics should be captured weekly. Examples of such measurements include:

- Traffic Trends
- Cell Retaining
- Cell Accessibility

8.3.3 MONTHLY BSC MEASUREMENTS

On a monthly basis reports should be generated containing data about BSC performance. As with weekly reports the primary purpose is to identify trends rather than specific faults, but at the BSC level rather than the Cell level. Examples of such measurements include:

- BSC processor load
- BSC call setup rate
- BSC handover success rate

8.4 Daily Cell Counters

Daily Cell Measurements

- Call Setup Success Rate
- Dropped Call Rate
- Handover Failure Rate
- SDCCH Blocking
- TCH Blocking

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8.4.1 CALL SETUP SUCCESS RATE

Section 8 – Evaluating Performance Data

Call Setup Success Rate

- No access to SDCCH
  - Congestion prevents SDCCH allocation
- CM service reject
  - Incompatible algorithms/cipher keys
  - Requested service not available
- TCH assignment failure
  - Congestion prevents SDCCH allocation
  - Excessive Interference on TCHs
- Hardware Problems

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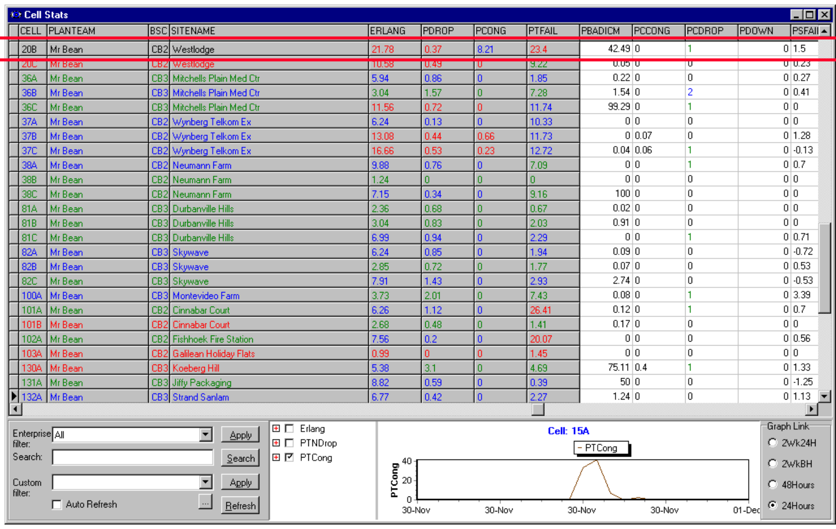
Call Setup Success Rate



Cell Stats

CELL	PLANTEAM	BSC	SITENAME	ERLANG	PDROP	PCONG	PTFAIL	PBADICM	PCCONG	PCDROP	PDOWN	PSFAIL
20B	Mr Bean	CB2	Westlodge	21.78	0.37	8.21	23.4	42.49	0	1	0	1.5
20C	Mr Bean	CB2	Westlodge	10.58	0.49	0	9.22	0.05	0	0	0	0.23
36A	Mr Bean	CB3	Mitchells Plain Med Ctr	5.94	0.86	0	1.85	0.22	0	0	0	0.27
36B	Mr Bean	CB3	Mitchells Plain Med Ctr	3.04	1.57	0	7.28	1.54	0	2	0	0.41
36C	Mr Bean	CB3	Mitchells Plain Med Ctr	11.56	0.72	0	11.74	99.29	0	1	0	0
37A	Mr Bean	CB2	Wynberg Telkom Ex	6.24	0.13	0	10.33	0	0	0	0	0
37B	Mr Bean	CB2	Wynberg Telkom Ex	13.08	0.44	0.66	11.73	0	0.07	0	0	1.28
37C	Mr Bean	CB2	Wynberg Telkom Ex	16.66	0.53	0.23	12.72	0.04	0.06	1	0	-0.13
38A	Mr Bean	CB2	Neumann Farm	9.88	0.76	0	7.09	0	0	1	0	0.7
38B	Mr Bean	CB2	Neumann Farm	1.24	0	0	0	0	0	0	0	0
38C	Mr Bean	CB2	Neumann Farm	7.15	0.34	0	9.16	100	0	0	0	0
81A	Mr Bean	CB3	Durbanville Hills	2.36	0.68	0	0.67	0.02	0	0	0	0
81B	Mr Bean	CB3	Durbanville Hills	3.04	0.83	0	2.03	0.91	0	0	0	0
81C	Mr Bean	CB3	Durbanville Hills	6.99	0.94	0	2.29	0	0	1	0	0.71
82A	Mr Bean	CB3	Skywave	6.24	0.85	0	1.94	0.09	0	0	0	-0.72
82B	Mr Bean	CB3	Skywave	2.85	0.72	0	1.77	0.07	0	0	0	0.53
82C	Mr Bean	CB3	Skywave	7.91	1.43	0	2.93	2.74	0	0	0	-0.53
100A	Mr Bean	CB3	Montevideo Farm	3.73	2.01	0	7.43	0.08	0	1	0	3.39
101A	Mr Bean	CB2	Cinnabar Court	6.26	1.12	0	26.41	0.12	0	1	0	0.7
101B	Mr Bean	CB2	Cinnabar Court	2.68	0.48	0	1.41	0.17	0	0	0	0
102A	Mr Bean	CB2	Fishhoek Fire Station	7.56	0.2	0	20.07	0	0	0	0	0.56
103A	Mr Bean	CB2	Galilean Holiday Flats	0.99	0	0	1.45	0	0	0	0	0
130A	Mr Bean	CB3	Koeberg Hill	5.38	3.1	0	4.69	75.11	0.4	1	0	1.33
131A	Mr Bean	CB3	Jiffy Packaging	8.82	0.59	0	0.39	50	0	0	0	-1.25
132A	Mr Bean	CB3	Strand Sanlam	6.77	0.42	0	2.27	1.24	0	0	0	1.13

site 20B has a high PTFAIL level (23.4% TCH setup failure)

The call setup rate should be above 90 % for a healthy network. Within Aircom's OPTIMA tool, the PTFAIL displays the percentage of call set up failures. There could be many reasons for a poor CSSR. Some are described as follows.

- No Access to SDCCH
- CM service reject
- TCH Assignment Failure
- Hardware Problems

NO ACCESS TO SDCCH:

Function. BSS detects *Channel Request* (in the form of RACH) from a source, requesting resources for network transactions. After validation of the resource request, the BSS attempts to allocate an SDCCH. Once the availability of SDCCH channel is confirmed, the BSS will send *Immediate Assignment* to the MS indicating the dedicated SDCCH sub-channel using the AGCH, whereby subsequent message exchange will be performed over the dedicated SDCCH.

Failure Indication. If congestion prevents assignment of an SDCCH, the BSS will response to MS with *Immediate Assignment Reject*, terminating the transactions.

Failure Cause. Insufficient capacity on SDCCH channel allocation.

CM (Connection Management) SERVICE REJECT

Function. When the MS initiates a service request message, the MS informs the network of the types of services it requires (i.e. Mobile Origination Call, Emergency Call, Short Message Transfer or Supplementary Services Activity). The MSC will response with either *Connection Confirmed*, confirming the success in link establishment between MS-BSS-MSC, or *Connection Refused*, indicating the termination of the specific network request.

Failure Indication. Failure to complete signalling procedures such as authentication, identity request or cipher commands.

Failure Cause. Possible hardware fault in MS or MSC. Requested services not available. Incompatible algorithms or Cipher keys.

TCH ASSIGNMENT FAILURE

Function. On completion of the link establishment, MSC issues *Assignment Request* to BSS, requesting TCH assignment to the MS. The BSS attempts to allocate a free TCH. Once *Assignment Command* is received by MS, stating the availability of TCH for the MS, it will move to the dedicated TCH and responds with *Assignment Complete*. In turn, the BSS will submit *Assignment Complete* to MSC to complete the signalling activity.

Failure Indication. The BSS fails to allocate a TCH to the requesting MS by issuing an *Assignment Failure* message, thereby terminating the connection.

Failure Cause. Insufficient capacity on TCHs. Excessive interference on TCH channels.

HARDWARE PROBLEMS

Hardware failures can play the major role for poor CSSR. Improper functionality of any BTS hardware can affect the overall performance of site.

8.4.2 HIGH DROPPED CALL RATE

High Dropped Call Rate

- Drop on Handover
  - Interference on target cell
  - Incorrect serving cell
- Low Signal Level/Quality
  - RxLev/RxQual thresholds exceeded
  - MS enter high attenuation area (building/tunnel etc)
  - Requested service not available
- High Co-, Adjacent- and/or Extraneous Interference
  - Excessive interference on TCHs
  - Excessive interference on CCHs
- Link Imbalance
  - Hardware degradation

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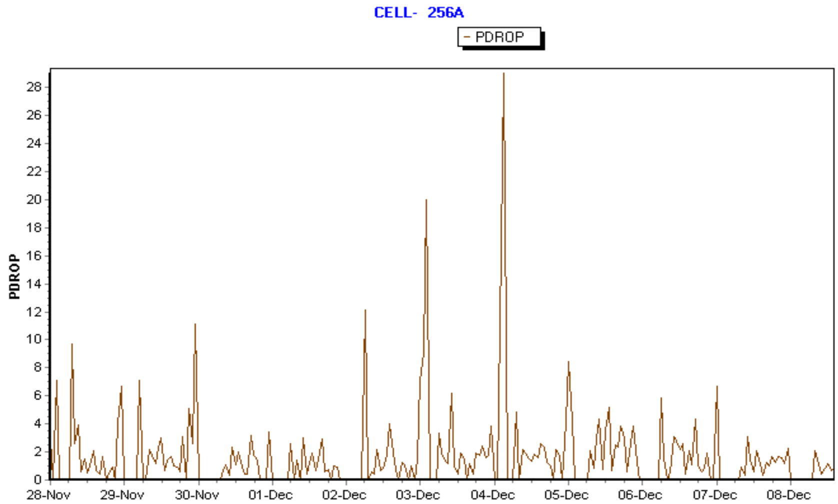
For a healthy network the drop call rate should be less than 1 %. There are again number of reasons, which could contribute towards higher dropped call rate:

- Drop on Handover
- Low signal level / quality
- Adjacent channel / Co-channel interference
- Extraneous interference
- Link imbalance

High Dropped Call Rate



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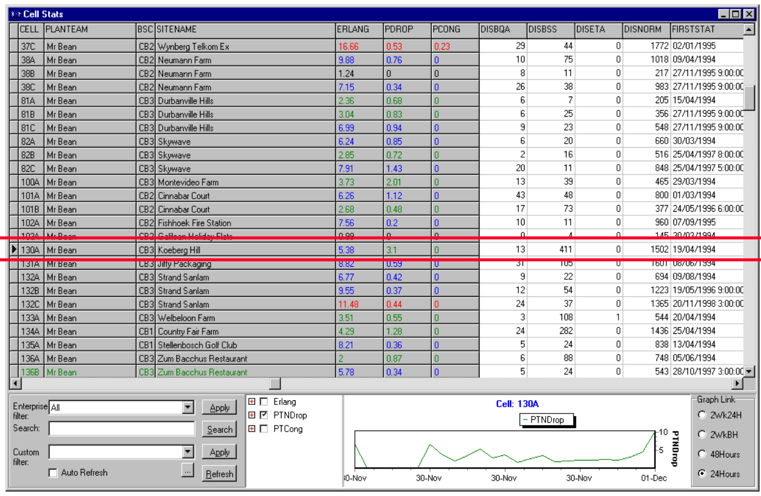
Section 8 – Evaluating Performance Data

High Dropped Call Rate



CELL	PLANTEAM	BSC	SITENAME	ERLANG	PDROP	PCONG	DISBQA	DISBSS	DISETA	DISNORM	FIRSTSTAT
37C	Mr Bean	CB2	Wynberg Telkom Ex	16.66	0.53	0.23	29	44	0	1772	02/01/1995
38A	Mr Bean	CB2	Neumann Farm	9.88	0.76	0	10	75	0	1018	09/04/1994
38B	Mr Bean	CB2	Neumann Farm	1.24	0	0	8	11	0	217	27/11/1995 9:00:0C
38C	Mr Bean	CB2	Neumann Farm	7.15	0.34	0	26	38	0	983	27/11/1995 9:00:0C
81A	Mr Bean	CB3	Durbanville Hills	2.36	0.68	0	6	7	0	205	15/04/1994
81B	Mr Bean	CB3	Durbanville Hills	3.04	0.83	0	6	25	0	356	27/11/1995 9:00:0C
81C	Mr Bean	CB3	Durbanville Hills	6.99	0.94	0	9	23	0	548	27/11/1995 9:00:0C
82A	Mr Bean	CB3	Skywave	6.24	0.85	0	6	20	0	660	30/03/1994
82B	Mr Bean	CB3	Skywave	2.85	0.72	0	2	16	0	516	25/04/1997 8:00:0C
82C	Mr Bean	CB3	Skywave	7.91	1.43	0	20	11	0	848	25/04/1997 5:00:0C
100A	Mr Bean	CB3	Montevideo Farm	3.73	2.01	0	13	39	0	465	29/03/1994
101A	Mr Bean	CB2	Cinnabar Court	6.26	1.12	0	43	48	0	800	01/03/1994
101B	Mr Bean	CB2	Cinnabar Court	2.68	0.48	0	17	73	0	377	24/05/1996 6:00:0C
102A	Mr Bean	CB2	Fishhoek Fire Station	7.56	0.2	0	10	11	0	960	07/09/1995
103A	Mr Bean	CB2	Galilean Holiday Flats	0.99	0	0	0	4	0	145	30/03/1994
130A	Mr Bean	CB3	Koeberg Hill	5.38	3.1	0	13	411	0	1502	19/04/1994
131A	Mr Bean	CB3	Jiffy Packaging	8.82	0.59	0	31	105	0	1601	08/06/1994
132A	Mr Bean	CB3	Strand Sanlam	6.77	0.42	0	9	22	0	694	09/08/1994
132B	Mr Bean	CB3	Strand Sanlam	9.55	0.37	0	12	54	0	1223	19/05/1996 9:00:0C
132C	Mr Bean	CB3	Strand Sanlam	11.48	0.44	0	24	37	0	1365	20/11/1998 3:00:0C
133A	Mr Bean	CB3	Welbeloon Farm	3.51	0.55	0	3	108	1	544	20/04/1994
134A	Mr Bean	CB1	Country Fair Farm	4.29	1.28	0	24	282	0	1436	25/04/1994
135A	Mr Bean	CB1	Stellenbosch Golf Club	8.21	0.36	0	5	24	0	838	13/04/1994
136A	Mr Bean	CB3	Zum Bacchus Restaurant	2	0.87	0	6	88	0	748	05/06/1994
136B	Mr Bean	CB3	Zum Bacchus Restaurant	5.78	0.34	0	5	24	0	543	28/10/1997 3:00:0C

site 130 A has large disconnection failure rate (411) due to bad signal level (DISBSS)

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DROP ON HANDOVER

Failure Indication . The call drops whilst attempting to handover to a new cell.

Fault Cause.
Primarily high interference on the target cell. Possibly the mobile is on the wrong serving cell (not planned for that area but serves due to the antenna overshoot).

LOW SIGNAL LEVEL/QUALITY

Failure Indication. MS unable to handover due to low signal reception from neighbouring cells.

Fault Cause
Neighbouring cell signal level drops below defined threshold, commonly -95dBm. If the mobile is unable to handoff to a better cell on level basis, the call will possibly be dropped.
Topology or Morphology issues may also be a cause if the MS enters into a tunnel or a building where higher RF losses will be incurred.

ADJACENT- AND CO-CHANNEL INTERFERENCE

Fault Indication. Call drops due to excessive interference.

Fault Cause. Excessive interference on TCH frequency. This could be due to poor frequency plan where higher than normal levels of C/I and C/A interference exist. Abnormally high levels of interference are generally due to some external frequency source.

EXTRANEOUS INTERFERENCE

Fault Indication. Call drops due to excessive interference.

Fault Cause. Extraneous interference can source from:

- Other mobile networks
- Military communication
- Cordless telephones
- Illegal radio Communication equipment

LINK IMBALANCE

Fault Indication. Call drops due to loss of communications link.

Fault Cause. An imbalance between up and down power budgets can result in one-way communications where, for example, the MS can receive the BTS transmission but us out of range to transmit back to the BTS. This can be caused by:

- Transmit and Receive antenna facing different direction
- Transmit and Receive antennas with different tilts
- Antenna feeder damage, corrosion or water ingress
- Physical obstruction of antennas

8.4.3 HIGH HANDOVER FAILURE RATE

High Handover Failure Rate

- High Neighbour Interference/congestion
  - Interference on neighbouring cells
  - Lack of capacity in neighbouring cells
- No Dominant Server
  - Difficult cell selection decision
- Database Parameters
  - Incorrect threshold parameter settings

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High handover failures rate will generally be due to one or more of the following reason.

- High neighbour interference/congestion
- No dominant server
- Database parameters
- Link imbalance

HIGH NEIGHBOUR INTERFERENCE / CONGESTION

Fault Indication. Call fails to handover due to neighbouring cell interference and/or congestion.

Fault Cause.
- Insufficient capacity in neighbouring cells to accept call.
- Best neighbouring cell is below minimum interference threshold.

NO DOMINANT SERVER

Fault Indication. Handover fails due to no dominant server being available.

Fault Cause. Poorly designed cell plan may result in neighbouring cells being received at similar levels. This may cause confusion and therefore make cell selection more difficult, possibly resulting in handover failures.

DATABASE PARAMETERS

Fault Indication. Handover fails due to not meeting threshold parameter requirements.

Fault Cause.
Receive level, receive quality and power budget algorithms are set in the system parameters to define the criteria for handover. Improper values for these criteria may result in poor handovers

8.4.4 HIGH SDCCH BLOCKING

Blocking is the term used to describe the situation where resources are not available to subscribers for establishing the calls. Some reasons for blocking of SDCCH and/or TCH channels include:

- No access to SDCCH
- Failure before assignment of TCH
- High signalling load

The first two reasons have been discussed in the previous categories above. The remaining two reasons are described below.

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High SDCCH Blocking

- No Access on SDCCH
  - Interference on neighbouring cells
  - Lack of capacity in neighbouring cells
- Failure before Assignment of TCH
  - Difficult cell selection decision
- High Signalling Load
  - Incorrect threshold parameter settings

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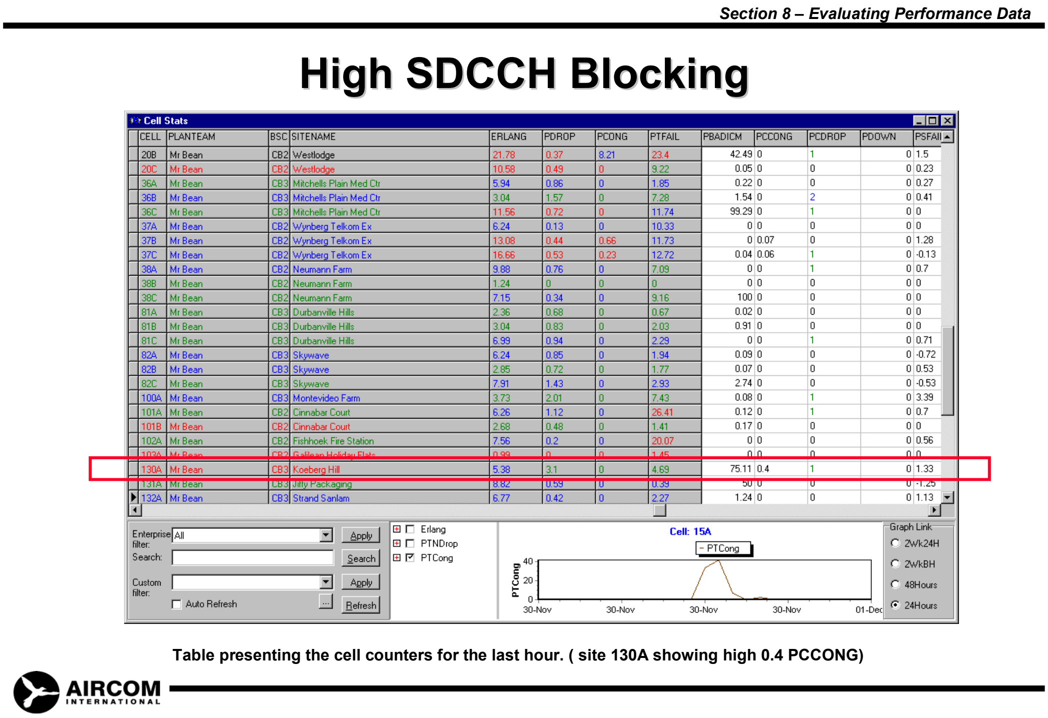
HIGH SIGNALLING LOAD

Fault Indication. Inability to allocate SDCCH due to high SDCCH signalling load.



CELL	PLANTEAM	BSC	SITENAME	ERLANG	PDROP	PCONG	PTFAIL	PBADICM	PCCONG	PCDROP	PDOWN	PSFAIL
20B	Mr Bean	CB2	Westlodge	21.78	0.37	8.21	23.4	42.49	0	1	0	1.5
20C	Mr Bean	CB2	Westlodge	10.58	0.49	0	9.22	0.05	0	0	0	0.23
36A	Mr Bean	CB3	Mitchells Plain Med Ctr	5.94	0.86	0	1.85	0.22	0	0	0	0.27
36B	Mr Bean	CB3	Mitchells Plain Med Ctr	3.04	1.57	0	7.28	1.54	0	2	0	0.41
36C	Mr Bean	CB3	Mitchells Plain Med Ctr	11.56	0.72	0	11.74	99.29	0	1	0	0
37A	Mr Bean	CB2	Wynberg Telkom Ex	6.24	0.13	0	10.33	0	0	0	0	0
37B	Mr Bean	CB2	Wynberg Telkom Ex	13.08	0.44	0.66	11.73	0	0.07	0	0	1.28
37C	Mr Bean	CB2	Wynberg Telkom Ex	16.66	0.53	0.23	12.72	0.04	0.06	1	0	-0.13
38A	Mr Bean	CB2	Neumann Farm	9.88	0.76	0	7.09	0	0	1	0	0.7
38B	Mr Bean	CB2	Neumann Farm	1.24	0	0	0	0	0	0	0	0
38C	Mr Bean	CB2	Neumann Farm	7.15	0.34	0	9.16	100	0	0	0	0
81A	Mr Bean	CB3	Durbanville Hills	2.36	0.68	0	0.67	0.02	0	0	0	0
81B	Mr Bean	CB3	Durbanville Hills	3.04	0.83	0	2.03	0.91	0	0	0	0
81C	Mr Bean	CB3	Durbanville Hills	6.99	0.94	0	2.29	0	0	1	0	0.71
82A	Mr Bean	CB3	Skywave	6.24	0.85	0	1.94	0.09	0	0	0	-0.72
82B	Mr Bean	CB3	Skywave	2.85	0.72	0	1.77	0.07	0	0	0	0.53
82C	Mr Bean	CB3	Skywave	7.91	1.43	0	2.93	2.74	0	0	0	-0.53
100A	Mr Bean	CB3	Montevideo Farm	3.73	2.01	0	7.43	0.08	0	1	0	3.39
101A	Mr Bean	CB2	Cinnabar Court	6.26	1.12	0	26.41	0.12	0	1	0	0.7
101B	Mr Bean	CB2	Cinnabar Court	2.68	0.48	0	1.41	0.17	0	0	0	0
102A	Mr Bean	CB2	Fishhoek Fire Station	7.56	0.2	0	20.07	0	0	0	0	0.56
103A	Mr Bean	CB2	Galilean Holiday Flats	0.99	0	0	1.45	0	0	0	0	0
130A	Mr Bean	CB3	Koeberg Hill	5.38	3.1	0	4.69	75.11	0.4	1	0	1.33
131A	Mr Bean	CB3	Jiffy Packaging	8.82	0.59	0	0.39	50	0	0	0	-1.25
132A	Mr Bean	CB3	Strand Sanlam	6.77	0.42	0	2.27	1.24	0	0	0	1.13

Table presenting the cell counters for the last hour. (site 130A showing high 0.4 PCCONG)

Fault Cause. High SDCCH signalling load can be caused by:

- High location update load, common on LA boundaries and in microcell environments.
- High SMS messaging load
- High paging load

8.4.5 HIGH TCH BLOCKING

TCH blocking may be due to the following reasons

- Handover and power budget margins
- Cells too large (capturing too much traffic)
- Capacity limitations (congestion)
- Incorrect or inappropriate timer settings

High TCH Blocking

- **Handover Margin**
  - Low margin values may reduce handovers causing congestion
- **Cells Too Large**
  - Antenna too high
  - Excessive power
  - Excessive traffic capture
- **Capacity Limitations**
  - Poor capacity dimensioning
  - Unanticipated traffic capture

HANDOVER MARGIN

Fault Indication. Failure to handover to due incorrect handover margins.

Fault Cause. Strict handover margins can result in fewer handovers and potentially cell congestion. A 6 db handover margin is considered to be appropriate for handover. Setting a lower value of handover margin will initiate ping-pong handovers, which generate excessive signalling loads.

CELLS TOO LARGE

Fault Indication. Excessive traffic being captured by cell.

Fault Cause. If cells are too large meaning antenna too high or antenna too shallow, it will pull in out of area traffic again causing congestion in the cell

CAPACITY LIMITATIONS (CONGESTION)

Fault Symptom. Failure to allocate TCH channel due to congestion.

Fault Cause. Insufficient capacity within cell to service offered traffic requirements. This may be a result of poor capacity planning or unanticipated traffic capture.

8.5 Weekly Counters

Weekly statistics are defined to determine the trend of the network. Some useful weekly statistics could be as follows. The trends can be seen on per cell basis within optima.

- Traffic Trends
- Cell Retaining
- Cell Accessibility

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Weekly Counters

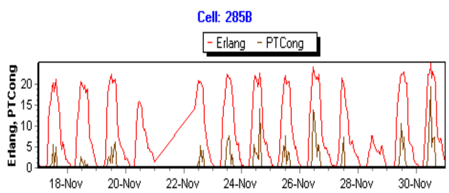
- **Traffic Trends**
- **Cell Retaining**
- **Cell Accessibility**

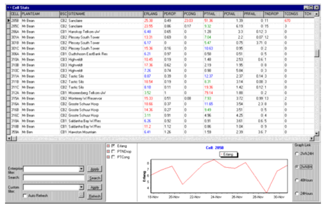
8.5.1 TRAFFIC TRENDS

Traffic trends (TCH and SDCCH Traffic) are mostly derived from daily peak hour statistics and are showed in graphical representation in optima. Within the network most of the future capacity planning is based on the traffic trend analysis. A high increase in trend shows traffic overload on a cell.

Weekly Counters – Traffic Trends

- TCH Traffic
- SDCCH Traffic
- Derived mainly from peak-hour statistics





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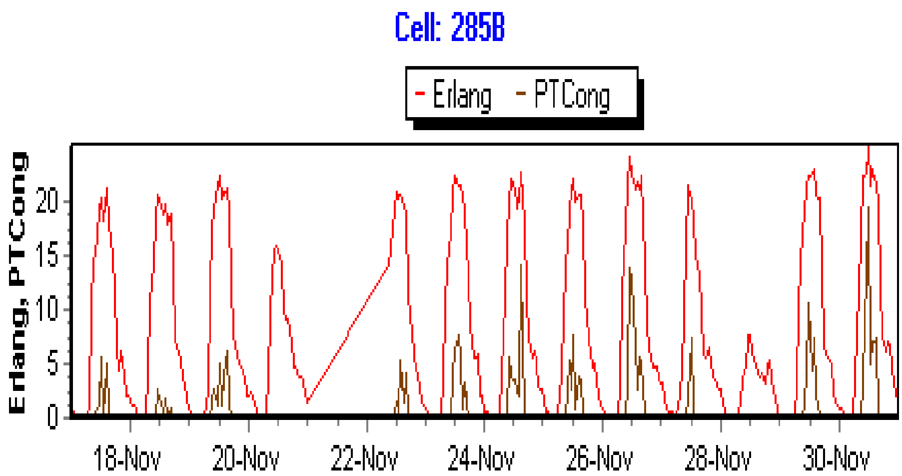
Weekly Counters – Traffic Trends



Traffic trend for cell site 285B

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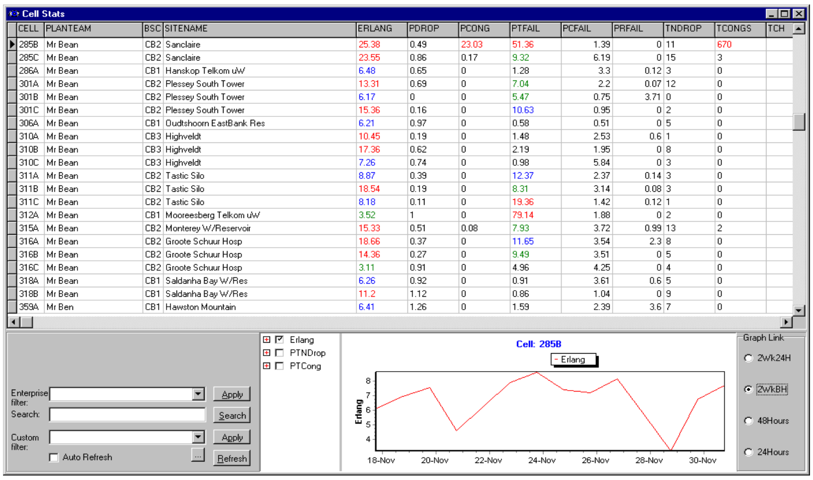
The above figure shows traffic trend of cell site 285B for a 2-week period. Analysis shows a high degree of TCH setup failures (PTCong) due to congestion. Therefore, more radios are required to cater for more traffic being experienced in the cell.

Weekly Counters – Traffic Trends



CELL	PLANTEAM	BSC	SITENAME	ERLANG	PDROP	PCONG	PTFAIL	PCFAIL	PRFAIL	TNDROP	TCONGS	TCH
285B	Mr Bean	CB2	Sanclaire	25.38	0.49	23.03	51.36	1.39	0	11	670	
285C	Mr Bean	CB2	Sanclaire	23.55	0.86	0.17	9.32	6.19	0	15	3	
286A	Mr Bean	CB1	Hanskop Telkom uW	6.48	0.65	0	1.28	3.3	0.12	3	0	
301A	Mr Bean	CB2	Plessey South Tower	13.31	0.69	0	7.04	2.2	0.07	12	0	
301B	Mr Bean	CB2	Plessey South Tower	6.17	0	0	5.47	0.75	3.71	0	0	
301C	Mr Bean	CB2	Plessey South Tower	15.36	0.16	0	10.63	0.95	0	2	0	
306A	Mr Bean	CB1	Oudtshoorn EastBank Res	6.21	0.97	0	0.58	0.51	0	5	0	
310A	Mr Bean	CB3	Highveldt	10.45	0.19	0	1.48	2.53	0.6	1	0	
310B	Mr Bean	CB3	Highveldt	17.36	0.62	0	2.19	1.95	0	8	0	
310C	Mr Bean	CB3	Highveldt	7.26	0.74	0	0.98	5.84	0	3	0	
311A	Mr Bean	CB2	Tastic Silo	8.87	0.39	0	12.37	2.37	0.14	3	0	
311B	Mr Bean	CB2	Tastic Silo	18.54	0.19	0	8.31	3.14	0.08	3	0	
311C	Mr Bean	CB2	Tastic Silo	8.18	0.11	0	19.36	1.42	0.12	1	0	
312A	Mr Bean	CB1	Mooreesberg Telkom uW	3.52	1	0	79.14	1.88	0	2	0	
315A	Mr Bean	CB2	Monterey W/Reservoir	15.33	0.51	0.08	7.93	3.72	0.99	13	2	
316A	Mr Bean	CB2	Groote Schuur Hosp	18.66	0.37	0	11.65	3.54	2.3	8	0	
316B	Mr Bean	CB2	Groote Schuur Hosp	14.36	0.27	0	9.49	3.51	0	5	0	
316C	Mr Bean	CB2	Groote Schuur Hosp	3.11	0.91	0	4.96	4.25	0	4	0	
318A	Mr Bean	CB1	Saldanha Bay W/Res	6.26	0.92	0	0.91	3.61	0.6	5	0	
318B	Mr Bean	CB1	Saldanha Bay W/Res	11.2	1.12	0	0.86	1.04	0	9	0	
359A	Mr Ben	CB1	Hawston Mountain	6.41	1.26	0	1.59	2.39	3.6	7	0	

weekly busy hour analysis

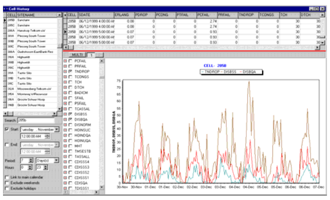
Traffic analysis on busy hour basis can also be made by marking the option " 2wkBH (2 weeks busy hours).

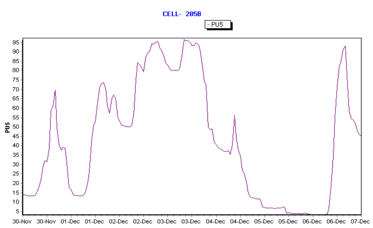
8.5.2 CELL RETAINABILITY

Section 8 – Evaluating Performance Data

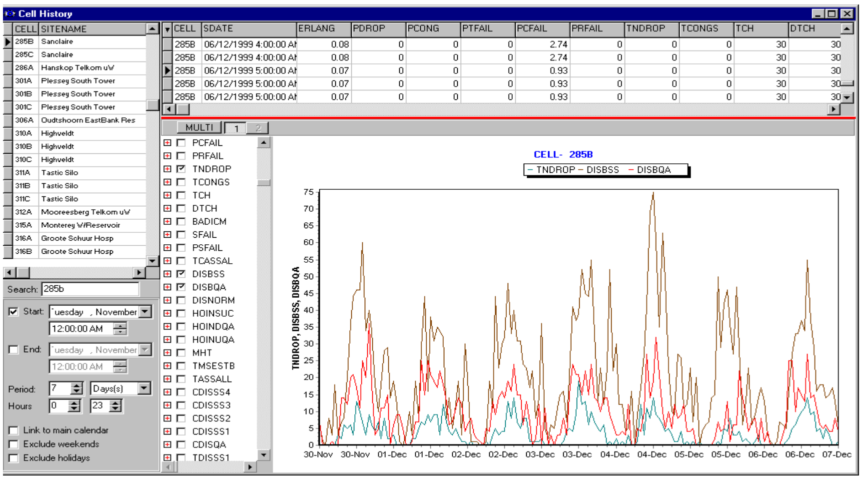
Weekly Counters – Cell Retainability

- **Measures ability to retain calls**
- **Frequently monitored using drops through poor RxQual or RxLev**





Weekly Counters – Cell Retainability



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It is important for a good network that there should be few call drops. Call drops can also be seen in trends on the weekly basis. The best way to observe the call drop trend is to monitor it with call drops on bad quality and on bad signal strength. Interference analysis can further clear the picture. e.g. cell site 285B below has a large number of Call drops due to the inconsistent quality and level issues.

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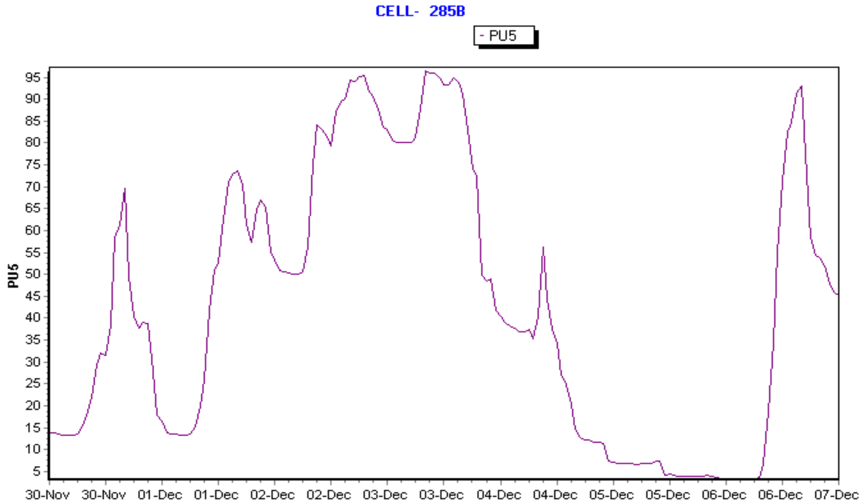
Weekly Counters – Cell Retainability



Percentage of idle channel measurement in the fifth band

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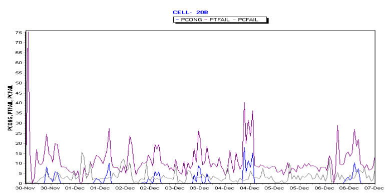
8.5.3 CELL ACCESSIBILITY

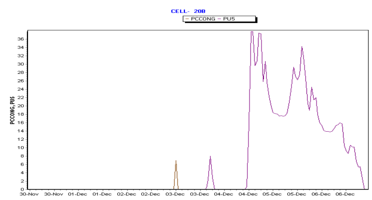
Call accessibility is an indication of the ability of the cell to establish calls. Some of the trends which can be monitored with cell accessibility are PCFAIL, PCCONGS, PCONGS and PTFAIL and PU5. The following slides represent some of the graphical analysis.

Section 8 – Evaluating Performance Data

Weekly Counters – Cell Accessibility

- **Measures ability to establish calls**
- **Uses PCFAIL, PCCONGS, PCONGS, PTFAIL counters**





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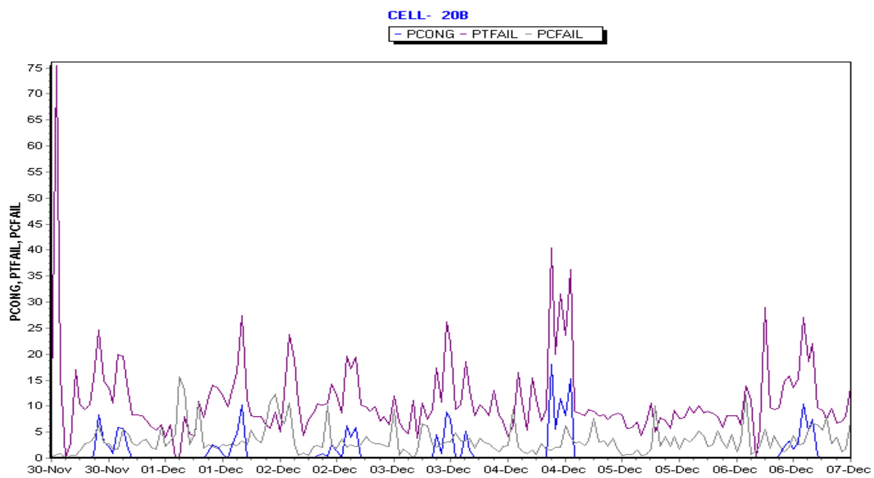
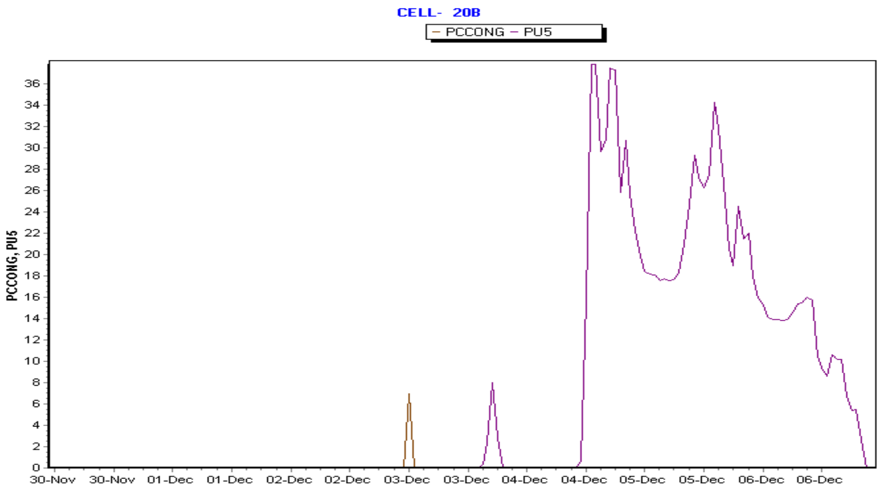
Weekly Counters – Cell Accessibility



Traffic failure analysis graph

Weekly Counters – Cell Accessibility



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The call set up trend illustrated above clearly indicates the call set up problem in cell site 20 B. The possible reason could be interference or traffic channel congestion. The trend shows that traffic channel congestion is also playing the major role for traffic channel set up failure.

8.6 Monthly Counters

The following counters can be used to monitor BSC performance:

- Processor load (Per BSC basis)
- Call success rate (per BSC basis)
- Handover Success Rate(per BSC basis)

Monthly Counters

- Processor Load
- Call Success Rate
- Handover Success Rate

8.6.1 PROCESSOR LOAD

This provides a useful means of investigating processor load trends and providing a warning when processor load tends to maximum. More processors should be added to the network switches thus avoiding overload. A comparison of Processor load is shown below. The processor load statistic is set for every hour.

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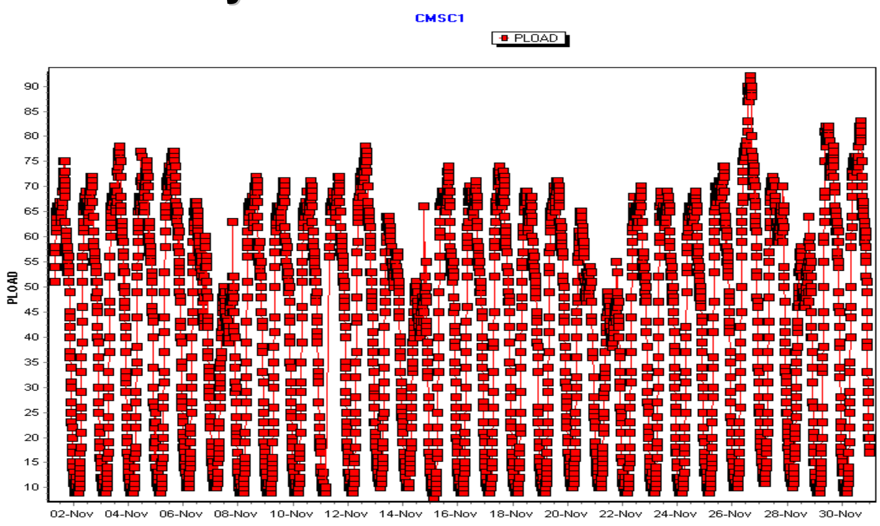
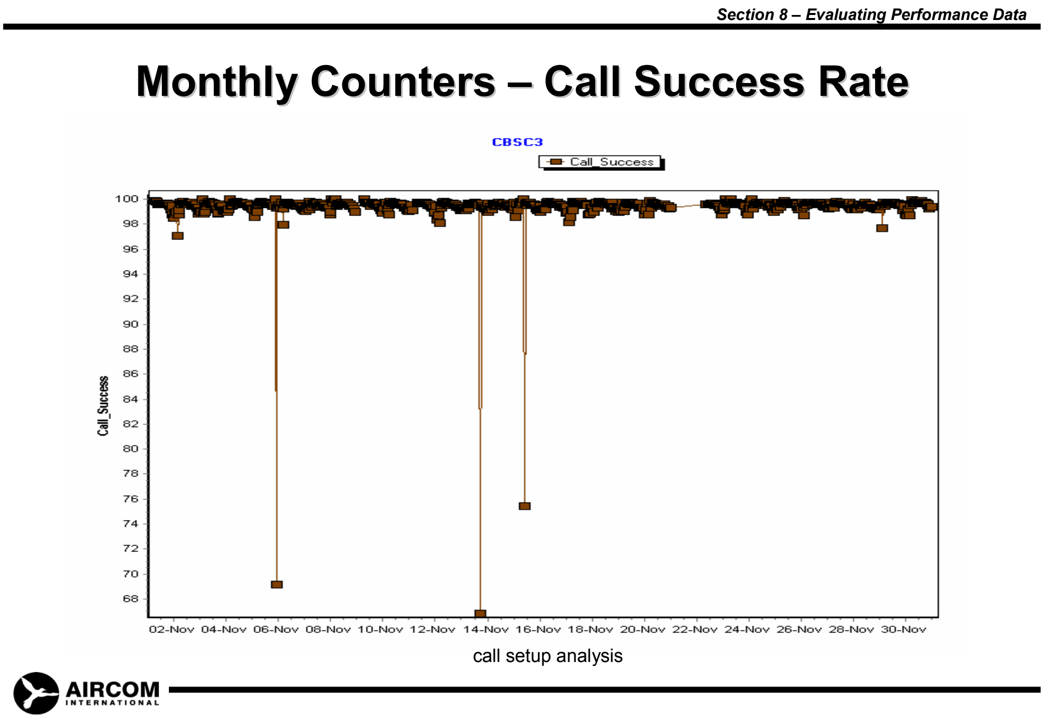
Monthly Counters – Processor Load



Processor Load of BSC CMSC1

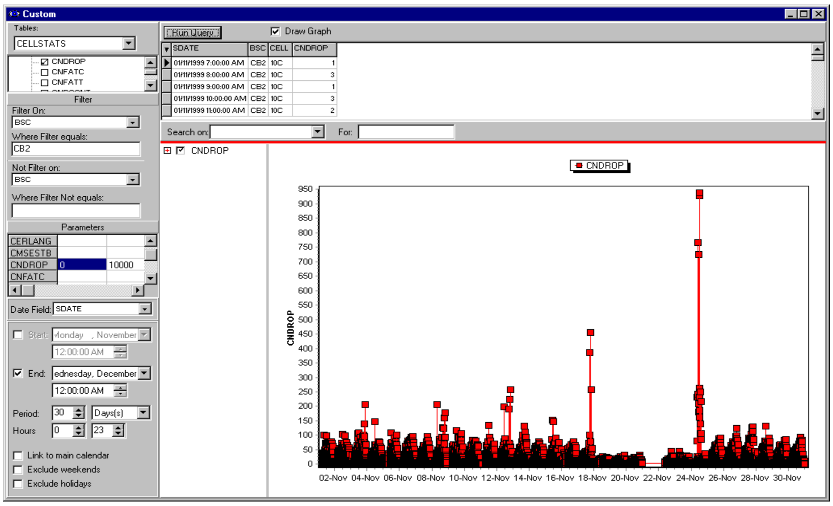
8.6.2 CALL SUCCESS RATE

Call success rate on monthly basis can reflect the overall network health and display the results of the optimisation procedure taken to improve the network quality. Routine procedures are defined to conduct the necessary actions after monitoring daily and weekly basis counters. Monthly counters describe that how effective the routine procedures are at optimising the network. Call Success Rate can be monitored on BSC basis. The following figure shows deterioration in call set up of BSC " CBSC3 " specifically on 6th, 14th and 16th November.



A more generalised display can be obtained by focussing on the particular cells which have higher dropped calls. Using custom queries, a specific BSC can be filtered and thresholds defined using the " parameter tab " allowing the user to correct the problematic cells. As the screen below shows BSC " CB2 " has higher call drops between 24th and 26th of November. The Graph shows the accumulated number of call drops for each hour taking into consideration the all cell sites within that BSC.

Monthly Counters – Call Success Rate



call drop analysis

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8.6.3 HANDOVER SUCCESS RATE

Handover success rate on monthly basis will show the overall " Hand off " behaviour of the network. Within OPTIMA, the handover window shows cell to cell handover data in statistical tables, graphs and histograms. You can analyse the network over a user-defined period of time to identify badly performing handovers.

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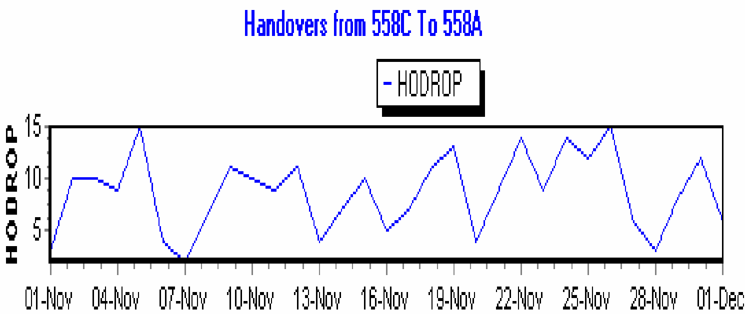
Monthly Counters – Handover Success Rate



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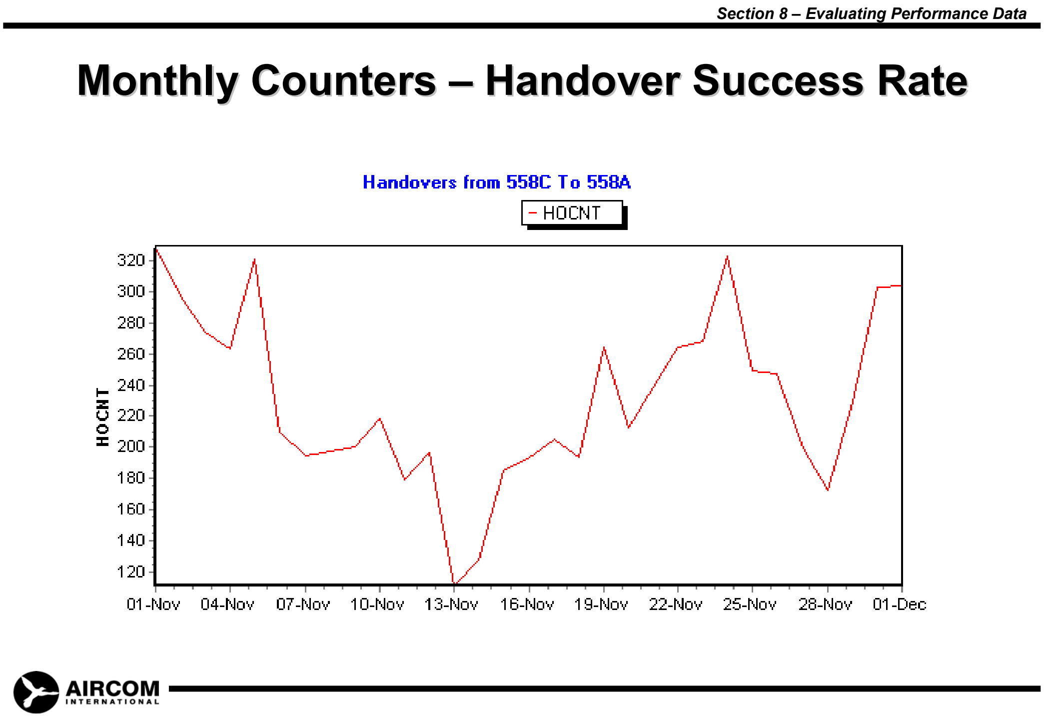
Handover drops have been shown for one of the cell sites and its neighbour for one month. HOCNT can also be monitored to check if the neighbours are defined accurately. In normal routines the Handover Success Rate (HSR) should be observed on BSC basis for monthly statistic.



8.7 Customised Queries and Reports

Most modern software counter/analysis tools provide functionality for creating user-defined reports. This functionality provides the flexibility for users to both create ad-hoc queries and to define reports to target specific parameter sets.

The following reports are examples of helpful report formats for analysing network quality:

- BSC capacity/traffic report
- BSC performance report

Customised Queries / Reports

- Most OMC Software tools allow customer-configurable reports
- Enables ad-hoc queries
- Enables targeting of specific parameter set
- Examples of useful customised reports include:
  - BSS Capacity / Traffic Report
  - BSC Performance Report

8.7.1 BSS CAPACITY / TRAFFIC REPORTS

Within BSC cells can be identified which are either carrying traffic 'too low' or 'too high '. If the site is carrying large amount of traffic 'load sharing' sites should be planned to cater increased amount of traffic. For the case where traffic is too low other performance counters like call set-up rate, dropped call rate and interference should be monitored.

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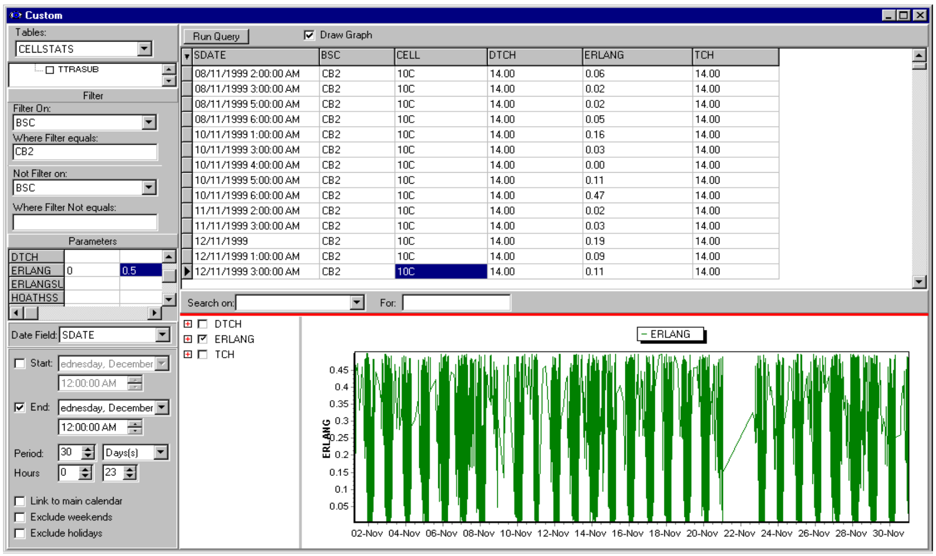
Customised Queries / Reports



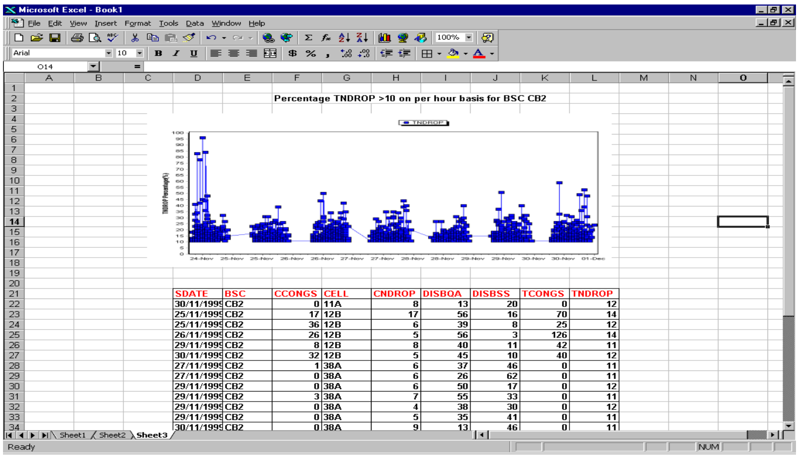
BSC capacity report

8.7.2 BSS PERFORMANCE REPORTS

BSC performance reports can identify those cells with RF issues. Keeping in mind the basic thresholds specified earlier, a BSC performance report should display total call drops, call drops at bad signal strength, call drops at bad quality, call congestion, handover success rate etc as shown below:

Section 8 – Evaluating Performance Data

Customised Queries / Reports



SDATE	BSC	CCONGS	CELL	CNDROP	DISBQA	DISBSS	TCONGS	TNDROP
30/11/1999	CB2	0	11A	8	13	20	0	12
25/11/1999	CB2	17	12B	17	56	16	70	14
25/11/1999	CB2	36	12B	6	39	8	25	12
26/11/1999	CB2	26	12B	5	56	3	126	14
29/11/1999	CB2	8	12B	8	40	11	42	11
30/11/1999	CB2	32	12B	5	45	10	40	12
27/11/1999	CB2	1	38A	6	37	46	0	11
27/11/1999	CB2	0	38A	6	26	62	0	11
29/11/1999	CB2	0	38A	6	50	17	0	12
29/11/1999	CB2	3	38A	7	55	33	0	11
29/11/1999	CB2	0	38A	4	38	30	0	12
29/11/1999	CB2	0	38A	5	35	41	0	11
30/11/1999	CB2	0	38A	9	13	46	0	11

BSC performance report

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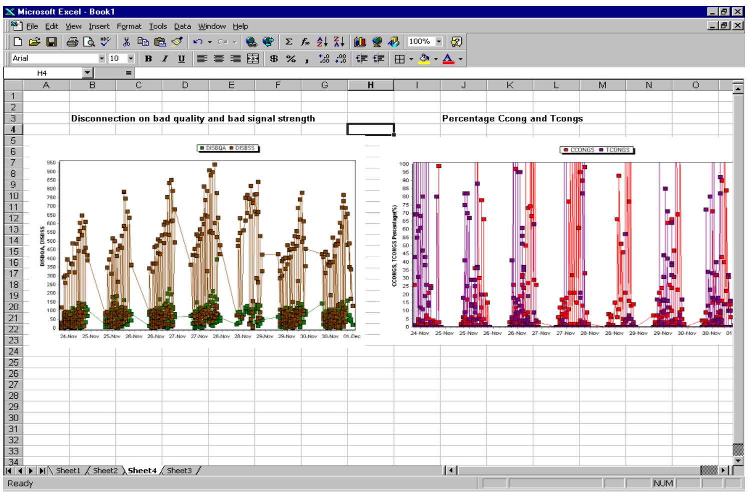
Section 8 – Evaluating Performance Data

Customised Queries / Reports



BSC performance report in excel format

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The tool can present the measurements on a per hour basis for every day taking into account all the cell sites within the same BSC. The best method to observe BSC counters is to define them on " busy hour averages " and they should represent the performance of the BSC as a whole.

8.8 Counter Descriptions

For completeness, this section provides an explanation for the counter types mentioned in the descriptions above

8.8.1 EXAMPLES OF CELL COUNTERS

The following counters are normally incremented on a per-cell basis

COUNTER	DESCRIPTION
CELL	Cell id as defined in switch
SDATE	Date and time of reading
TCALLS	Total number of traffic channel seizure attempts
TCONGS	Total number of traffic channel seizure attempts that result in congestion - no traffic channels available.
TNDROP	Total number of calls that have dropped.
TCASSAL	Total number of call set-up attempts that have succeeded.
TASSALL	Total number of call set-up attempts
TMSESTB	Total number of traffic channel seizure attempts that have succeeded.
MHT	Mean Holding Time per call (TMSESTB) in Seconds.
Erlang	Total traffic in Erlang/hour.
TCH	Average number of traffic channels available.
SITE NAME	Name of Site.
BSC	Name of BSC. J=JHB, D=DBN, C=CTN, R=RAN, P=PTA
% CONG	Percentage congestion = TCONGS/(TMSESTB+TCONGS)
% DROP	Percentage dropped calls = TNDROP/TMSESTB
% FAIL	Percentage set-up failures = 1-TCASSAL/TASSALL
dTCH	Number of defined traffic channels in cell.
HOupQA	Intra-cell handovers due to bad uplink quality.
HOdnQA	Intra-cell handovers due to bad downlink quality.
HOsuc	Number of successful intra-cell handover.
DisNorm	Number of normal disconnections. (DO NOT USE)
DisBQA	Number of disconnection's due to bad radio link quality.

COUNTER	DESCRIPTION
DisBSS	Number of disconnection's due to bad signal strength.
DisETA	Number of disconnection's due to excessive timing advance.
Ccalls	Number of control channel seizure attempts
CCong	Number of control channel seizure attempts that result in congestion.
% CCong	Percentage control channel congestion.
% CTCong	Percentage of time control channels were congested.
CNDrop	Total number of control calls that have dropped.
% CDrop	Percentage of control calls that have dropped.
SMSdn	SMS messages sent on the downlink (2 messages=1 SMS)
SMSup	SMS messages received on uplink (2 messages=1 SMS)
CCH	Number of control channels (8 for 1,2,3 TRXS, 16 for 4 TRXS)
T/CdisQA (i.e. TDISQA and CDISQA)	Dropped calls (T=traffic channel, C=control channel) at low quality down or up-link.
T/CDisSS1	Dropped calls class 1 mobile low signal strength or down/uplink.
T/CDisSS2	Dropped calls class 2 mobile low signal strength or down/uplink.
T/CDisSS3	Dropped calls class 3 mobile low signal strength or down/uplink.
T/CDisSS4	Dropped calls class 4 mobile low signal strength or down/uplink.
T/CDisSS5	Dropped calls class 5 mobile low signal strength or down/uplink.
T/CDisTA	Dropped calls excessive timing advance.

8.8.2 EXAMPLES OF MSC COUNTERS

The counters below are normally incremented on a per-route basis.

COUNTER	DESCRIPTION
NBIDS	Number of calls (bids) attempted
NBANSW	Number of calls (bids) answered
MHT	Mean holding time per calls (bids) attempted in seconds
ERLANGS	Traffic volume of route in Erlang
CCONG	Number of calls (bids) attempts that resulted in congestion (unavailable time slots)

9. Optimisation Activities

9.1 Introduction

This section of the course provides guidance on how to improve the performance of the network by adjusting performance parameters. The performance monitoring phase will have identified any irregularities in the network by analysing the performance measurement parameters.

9.2 BSS Database Parameter Review

9.2.1 REVIEW DATABASE SETTINGS

BSS Configuration Parameter Review

- Review current settings as related to performance measurement results
- Recommend changes to improve/optimise performance of specific features.
- Review includes:
  - Handover parameters, timers, thresholds and margins
  - Power control thresholds
  - Voting and average mechanisms for handover and power control
  - Call setup parameters to maximise resource utilisation
  - C1/C2 cell reselection parameters
  - Any vendor-specific advance traffic management algorithms

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The BSS database parameter review is intended to review existing BSS database parameter settings in the light of performance measurement results, and recommend changes necessary to improve or optimise the performance of specific features. This review includes the following:

- Handover parameters, timers, thresholds and margins (including inter-layer and inter-band handovers where applicable).
- Power Control thresholds (power window settings, power up/down step size, adaptive power control parameters, and so on).
- Voting and averaging mechanisms for handover and power control decisions.
- Call setup and handover timers to maximise resource utilisation and availability
- C1/C2 cell reselection parameters.
- Advanced traffic management algorithms (Congestion-based handovers, inter-band and inter-layer traffic distribution)

9.2.2 DATABASE CONSISTENCY AND CHANGE CONTROL

BSS Database Parameter Consistency

- Within a network, different site types are defined (e.g. urban micro, rural macro etc) by a standard template
- Each site type database will comprise a default parameter set
- Each site may modify default set to suit local conditions
- Consistency of the default parameter sets should be checked across BSS types
- Change control management processes should be reviewed to ensure procedural consistency

Review of all BSS databases to identify inconsistencies and discrepancies, and a review of change control, datafill and database management processes. For example:

- Define pre-configured parameter templates for a variety of site types (micro, highway 2/2, urban 3/3/3, etc.).
- Identify sets of parameters allowed for optimisation on permissions basis (fully configurable permissions per BSC, region, etc).
- Check consistency of live network data against planned configuration.

9.2.3 BSS CONFIGURATION PARAMETER SETS

Each BSS performs in accordance with its software configuration. Generally, there will be a common set of default parameters for each BSS, for example, the handover algorithms. However, each BSS will be programmed with certain parameters which are tailored to suit specific actions, locations and/or applications. Examples of BTS-specific parameters include the cell ID and power output settings.

BSS Configuration Parameter Sets

- Each BSS operates in accordance with its software configuration
- All BSS are configured with certain standard default parameters
- Each BSS will have a subset of BSS-specific parameters
- Parameters defined by:
  - ETSI GSM Recommendations (GSM 12.04)
  - Proprietary Parameter Implementation
- Potentially hundreds of configuration parameters
- Many parameters are inter-dependant
- Often vendor-specific abbreviations/acronyms used for same parameter

The number of configurable BSS parameters run into their hundreds and are defined in two sources:

- ETSI GSM Recommendations. ETSI has defined a primary set of parameters which are listed in the GSM 12.04) document.
- Proprietary Parameters. These are additional parameters created by individual vendors to enhance the capabilities of their equipment when compared that of their competitors.

This multitude of parameters allows for very sophisticated control of the BSS behaviour. However, the complexity can also lead to problems:

- Many parameters are inter-related so changing one can have a corresponding effect on others.
- Many equipment manufacturers use different abbreviations or acronyms for the same GSM-recommended parameter, leading to potential confusion when a network comprises equipment for more than one manufacturer.

9.2.4 BSS PARAMETER TYPES

As mentioned above, the number of performance configuration parameters in a BSS runs into three figures. Within the scope of this overview course, the following provides an overview of the type of parameters stored:

BSS Configuration Parameter Types

- Identifiers:
  - CI, LAI, GCI, BSIC etc
- Channel Configuration:
  - TCH channels, Signalling channel configuration (e.g. CCCH)
- Timers:
  - Location Updates, C2 calculations etc
- Thresholds:
  - RxLev, RxQual for handover decisions etc
- Offsets:
  - Hysteresis for handovers etc
- Control Features:
  - SFH, DTX, DRX etc

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Identifiers.
This includes such parameters as the Cell Identity (CI), Cell Global Identity (CGI) Location Area Identity (LAI) and Base Station Identity Code (BSIC) etc

Channel Configuration Parameters.
These parameters define the number of traffic channels and control channels. For example, the configuration of CCCH on the signalling channel (i.e. combined/non-combined multiframes).

Timer Parameters
Timers are counters which are set at the start of a certain time period and count down. If an event has not happened by the time the counter reaches zero, an alternative action may be triggered. For example, the time periods between periodic location updates (T3212) or the penalty timer for C2 calculations (see Cell Reselection in Section 1 for details).

Threshold Parameters
Thresholds are certain values which, when exceeded, trigger a certain event. For example, received signal strength or bit error rate thresholds which may trigger cell handovers.

Offset Parameters
Offsets are fixed values applied for the purposes of applying bias to certain actions. An example is the hysteresis bias value applied to BTS at location area boundaries.

Control Feature Parameters

A number of parameter settings exist to identify the implementation of certain functions and features. Such features include Frequency Hopping, DTX etc

9.2.5 ADJUSTING BSS CONFIGURATION PARAMETERS

Section 9 – Optimisation Activities

Adjusting BSS Configuration Parameters

- Effected from:
  - PC connected directly to hardware
  - Remotely from OMC/NMC
- Can be individually addressed or broadcast
- May require hardware reset to effect change
- Be aware of hierarchical changes (MSC→BSC→ BTS)
- Only implement during low-traffic periods
- Use test BSS where available
- Avoid simultaneous multiple parameter changes

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It is normally possible to carry out parameter changes from:

- BSS – directly into the BSS database via a PC connected to the BSS.
- OMC/NMC – Many OMC/NMC systems allow parameters to be transmitted to the BSS remotely including a broadcast capability where a specific parameter change needs to be transmitted to several network entities simultaneously.

Adjustment of parameters on live network elements should be deferred until low traffic periods in order to minimise any disruption to existing users. This is particularly important when a configuration change requires a hardware rest to become effective. A change BSC parameter is changes it may affect all BTSs associated with that BSC.

Some network operators reserve a BSS for test purposes. This has the advantage of being able to assess the impact of a parameter change before making the adjustment to a live network. However, it is a non-revenue generating asset.

Making simultaneous multiple parameter changes should also be avoided where possible for two reasons:

- If an unexpected problem arises as a result of a multiple parameter change, it will be difficult to identify the specific parameter or parameter combination causing the problem.
- Similarly if a performance improvement is observed, it may be difficult to identify which of the parameters are causing which part of the performance improvement.

9.3 Identify and Fix Hardware Problems

Identification of BSS hardware problems can be identified though the analysis of OMC statistical data, drive test data, A-Bis and A-Interface logs. 'Worst Performing Cells' can be identified through analysis of established KPI's.

Section 9 – Optimisation Activities

Identify Hardware Problems

- Problems identified through analysis of performance measurement counters from:
  - OMC Statistics
  - Driver \Test data
  - A-bis and A interface logs
- Identify 'worst performing cells' according to established KPI benchmarks

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Typical examples of hardware problems include:

Typical Hardware Problems

- Misaligned Antennas
  - Increased interference, coverage degradation
- Wrongly/poorly connected feeders
  - Reduced power output, reduced coverage, cell imbalance, distortion
- Poor transmission line performance (water ingress, corrosion, physical damage etc
  - High VSWR, high Insertion losses, reduced power output, reduced coverage, cell imbalance, distortion
- Poorly calibrated TRXs
  - Inconsistent TRX performance
- Incorrectly configured combiners/duplexers etc
  - Reduced power output, reduced coverage, cell imbalance, distortion

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9.4 Identify and Fix Neighbour Problems

In GSM, several neighbour cells can be defined for a serving cell. Usually, handovers should be made to the strongest neighbour, but in some cases frequent handovers to this best neighbour can result in congestion in the neighbour cell, affecting the users initiating calls from that cell.

The situation can also occur in reverse, when a handover required to the best neighbour can result in a rejection due to unavailability of resources, causing the handover to be attempted to the next best neighbour, which can delay the process and deteriorate the quality further.

Under certain circumstances, it may be necessary to remove a potential neighbour from the neighbour list and provide alternatives. Usually, such decisions are made using demographic considerations.

Optimising Neighbour Lists

- Effects of poor maintenance:
  - Unwanted legacy neighbours
  - Oversized neighbour lists
  - Co-channel neighbour definitions
  - Missing neighbours
  - Unintentional 1-way neighbour definitions
- Optimise by:
  - Analyse neighbour performance form statistics.
  - Utilise automated neighbour detection
  - Identify inconsistent neighbour profiles
  - Modify appropriate neighbour lists

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The BCH analyser in the GSM receiver makes it easier to determine these alternative neighbours. It can be used to create a list of all the possible BCH carriers in the nearby vicinity and perform the RxLev measurement (linked to the phone's RxQual performance) on each of these carriers.

When the RxQual reaches the handover decision threshold, we can determine the potential neighbours at that stage and set one of those as the optimum neighbour. This can also be done by the MS, but in this case the choice is limited to the BA list set in the network, which may not include all good potential neighbours.

Optimisation includes a combined study of neighbour performance statistics and network planning data, using automated neighbour detection techniques via A-Bis traces where supported by the vendor's OMC tool set. The neighbour list is reviewed to identify missing, redundant and 1-way neighbours, and updating of neighbour lists with required changes.

Lack of neighbour maintenance leads to:

- Unwanted legacy neighbours
- Over-sized neighbour lists (impossible to add neighbours for new sites, and reduced handover performance)
- Co-channel neighbour definitions
- Missing neighbours
- Unintentional 1-way neighbour definitions

9.5 Identify and Fix Frequency Plan Problems

9.5.1 FREQUENCY OPTIMISATION ACTIVITIES

Frequency optimisation activities involve identification of interference issues due to a poorly-maintained frequency plan, and rectification through a process of coverage optimisation and frequency plan modifications.

This includes firstly ensuring the issues have been identified:

- Identify interference issues
- Identify coverage optimisation issues impacting frequency plan quality (excessive coverage overlaps, coverage splashes, etc.)

Having ensured that the issues have been identified correctly, optimisation techniques can be employed to optimise the frequency plan. Such techniques could include:

Section 9 – Optimisation Activities

Frequency Optimisation Activities

- Identify problem areas:
  - Interference issues (internal and external)
  - Coverage issues (excessive overlaps, coverage gaps, high sites etc)
- Recommend appropriate frequency optimisation techniques
  - BCCH and TCH Frequency Plans
  - Frequency Diversity (space, polarity)
  - Frequency Hopping
  - DTX
  - Antenna Down tilting
  - Advanced Optimisation Techniques

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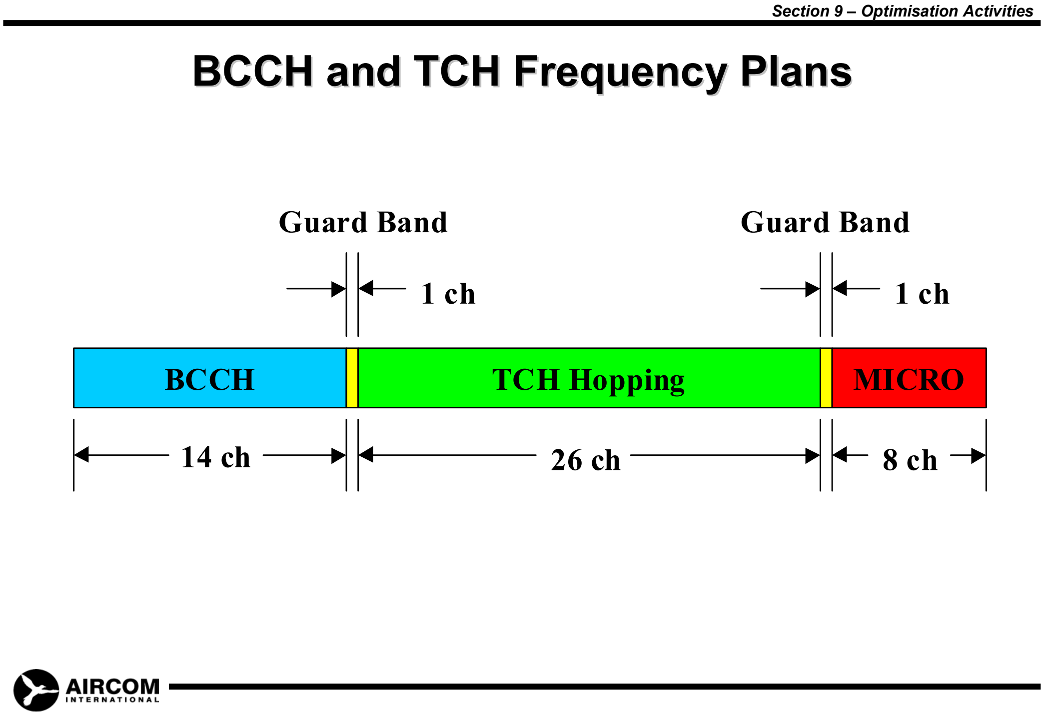
9.5.2 BCCH AND TCH FREQUENCY PLANS

The Spectrum allocation should be considered to determine if a change to frequency allocation is necessary. The diagram below shows a typical frequency allocation for the 900 band.



The number of channels required to make a good BCH plan will vary according to a number of factors:

- Site design (high sites etc.)
- Terrain and topography
- Subscriber distribution
- Regularity of cell plan

In a well optimised network, it is generally possible to produce a high quality BCCH plan within 14-15 channels.

The same issues with the BCCH plan also affect frequency planning of the non-BCCH (TCH) carriers. However there are additional techniques available for the TCH layer to improve re-use efficiency and increase capacity, such as:

- Synthesizer Frequency Hopping
- Baseband Frequency Hopping
- MRP (Multiple Reuse Pattern)
- Concentric Cell

BCCH and TCH Frequency Plans

- BCCH is typically planned with low frequency re-use (long re-use distance) in order to ensure high quality.
- The BCCH plan should take into account: site design, terrain and topography and subscriber distribution. A good BCCH plan can generally be achieved with 14 - 15 carriers.

- The TCH plan requires the same considerations as BCCH, but may also employ:
  - Frequency hopping - synthesiser or baseband
  - Multiple Re-use Patterns - giving tighter re-use on lower TCH layers
  - Concentric multi-layer cell arrangements in which BCCH is only required on one band

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9.5.3 HIGH SITE REPLACEMENT

In terms of RF design, the problem with this approach is that the legacy sites from the launch rollout phase tend to be high and prominent, and increasingly contribute uplink and downlink interference into the network as the number of lower sites around them increases. The net effect of this is to minimise frequency re-use efficiency and limit the capacity of the network. Therefore a process is required to identify and eliminate these interferers to allow network growth to continue and high quality to be maintained.

A typical process for replacing or modifying high sites would be as follows:

- From BSS performance statistics and call trace logs, identify those cells which contribute the most interference to the largest number of other cells.

- Develop a plan for de-commissioning the site, or lowering the antennas to a position consistent with surrounding sites if possible. Include the possible requirements for additional in-fill sites due to the loss of coverage from the high site.

- As new low sites are integrated, de-commission or modify the high site in such a way as to cause minimum disruption to coverage. Prioritise the integration of any required new sites to target high sites in order of severity.

High Site Problems

- Initial roll-out tends to concentrate on higher sites
- High sites potentially cause excessive interference with subsequent lower site roll-out
- A Typical process for replacement could include:
  - From performance parameters, identify those cell interference-contributing the most interference to the most cells
  - Develop plan to lower antennas or decommission these sites. This may require additional lower sites to cover any coverage gaps
  - Prioritise decommissioning and integration of new sites to minimise disruption to services

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9.5.4 ANTENNA DOWN-TILTING

Section 9 – Optimisation Activities

Antenna Down-Tilting

- An option for adjusting cell coverage
  - e.g. down tilting may direct coverage deeper into a building
- Antenna tilt may be:
  - mechanical – operator set – affects directional coverage
  - Electrical – manufacturer set – affects omni-directional coverage
- Omni antennas may have electrical tilt but not mechanical
- New technologies allow for remote electrical tilting

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9.5.5 ANTENNA SELECTION

Antenna specifications have a significant impact on network performance. The suitability of antennas should be reviewed according to the observed performance problems in the network, and recommendations made as necessary, for example:

- Vertical and Horizontal Beamwidth
- Gain
- Front-to-Back Ratio
- Null Fill
- Downtilt (electrical/mechanical)

Section 9 – Optimisation Activities

Antenna Selection

- Factors to consider with Antenna selection:
  - Vertical and Horizontal Beamwidth
  - Gain
  - Front-to-Back Ratio
  - Null Fill
  - Downtilt (electrical/mechanical)

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Antenna positioning is also important with respect to minimising interference and unwanted radiation. This should also be studied in relation to the RF design strategy.

9.5.6 ANTENNA CONFIGURATION OPTIONS

Antenna Configuration Options

- Combining:
  - Economical with antenna elements
  - Reduced coverage due to power loss

- Diversity Choice:
  - Horizontal space diversity
  - Vertical space diversity
  - Polarisation diversity

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10. Optimising Networks for New Services

10.1 Introduction

When adding new services such as HSCSD or GPRS to the network, careful consideration should be given to the additional capacity requirements. The integration of additional circuit-switched data services such and HSCSD involves significantly different planning than for packet-switched services such as GPRS.

This section of the notes provides an overview of some of the planning techniques and considerations when planning for both circuit-switched and packet-switched services.

10.2 Dimensioning Networks for New Services

GSM was originally a designed to be primarily a voice system. Developments have included an increasing proportion of the traffic offered being in the form of data, either High Speed Circuit Switched Data (HSCSD) or General Packet Radio Service (GPRS). The HSCSD service entails a user seizing more than one timeslots on a carrier for a single session whereas GPRS will initially use spare capacity on the air interface to dynamically allocate packet data.

Therefore, different traffic dimensioning techniques will be required to accommodate both voice and data (HSCSD/GPRS) services.

Dimensioning a Multi-Service System

- The Erlang B formula relies on the variance of the demand equalling the mean (a Poisson distribution).
- If a particular service requires more than one “trunk” per connection, the demand is effectively linearly scaled and the variance no longer equals the mean.
- Methods to investigate:
  - Equivalent Erlangs
  - Post Erlang-B
  - Campbell’s Theorem

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10.2.1 EQUIVALENT ERLANG TRAFFIC DIMENSIONING

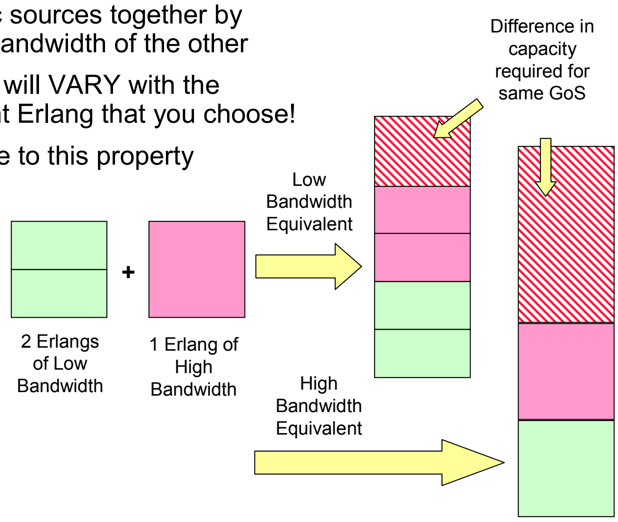
The Erlang B formula is the generally accepted method of calculating capacity within a cellular radio network. However, one of the assumptions on which the Erlang B formula is based is that a single call will require a single trunk for a specific duration. Unfortunately, the Erlang B formula ceases to be as accurate for predicting the required number of timeslots when the resource is shared amongst services requiring more than one channel per subscriber as is the case with HSCSD or possibly GPRS.

A service such a voice that requires a single channel (timeslot) per session is said to have an 'amplitude' of 1. Where a service requires, for example, 2 or 3 channels per session, it is said to have an amplitude of 2 and 3 respectively.

Using the Equivalent Erlangs approach, the bandwidth of one service is converted to its equivalent bandwidth in the other service and the total capacity requirement is then calculated as a single service.

Equivalent Erlangs

- Combine the two traffic sources together by converting one to the bandwidth of the other
- The trunking efficiency will VARY with the bandwidth of equivalent Erlang that you choose!
- Not suitable for use due to this property



Section 10 – New Service Optimisation

Equivalent Erlangs Example

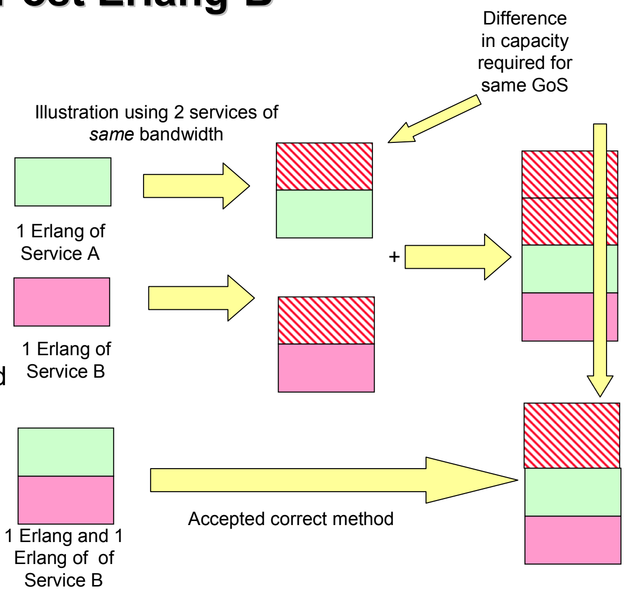
- Consider 2 services sharing the same resource:
  - Service 1: uses 1 trunk per connection. 12 Erlangs of traffic.
  - Service 2, uses 3 trunks per connection. 6 Erlangs of traffic.
- We could regard the above as equivalent to 30 Erlangs of service 1:
  - 30 Erlangs require 39 trunks for a 2% Blocking Probability
- Alternatively, we could regard the above as equivalent to 10 Erlangs of service 2.
  - 10 Erlangs require 17 trunks, (equivalent to 51 "service 1 trunks") for a 2% blocking probability
- Prediction varies depending on what approach you choose.

It can be seen that by taking the Equivalent Erlang approach, different channel capacities will be required depending on which service is selected for conversion to the equivalent of the other. Clearly, this cannot be the most accurate appraisal of the capacity requirements.

10.2.2 POST ERLANG B TRAFFIC DIMENSIONING

Post Erlang-B

- Combine the two traffic sources together after calculating required capacity
- The trunking efficiency variation with magnitude is not considered - pessimistic about offered traffic supported to the same GoS
- Not suitable for use due to this property



Section 10 – New Service Optimisation

Post Erlang-B

- Consider 2 services sharing the same resource:
  - Service 1: uses 1 trunk per connection. 12 Erlangs of traffic.
  - Service 2: uses 3 trunks per connection. 6 Erlangs of traffic.
- We could calculate the requirement separately
  - Service 1: 12 Erlangs require 19 trunks for a 2% Blocking Probability
  - Service 2: 6 Erlangs require 12 trunks (equivalent to 36 "service 1 trunks").
- Adding these together gives 55 trunks.
- This method is known to over-estimate the number of trunks required as can be demonstrated by considering services requiring an equal number of trunks.

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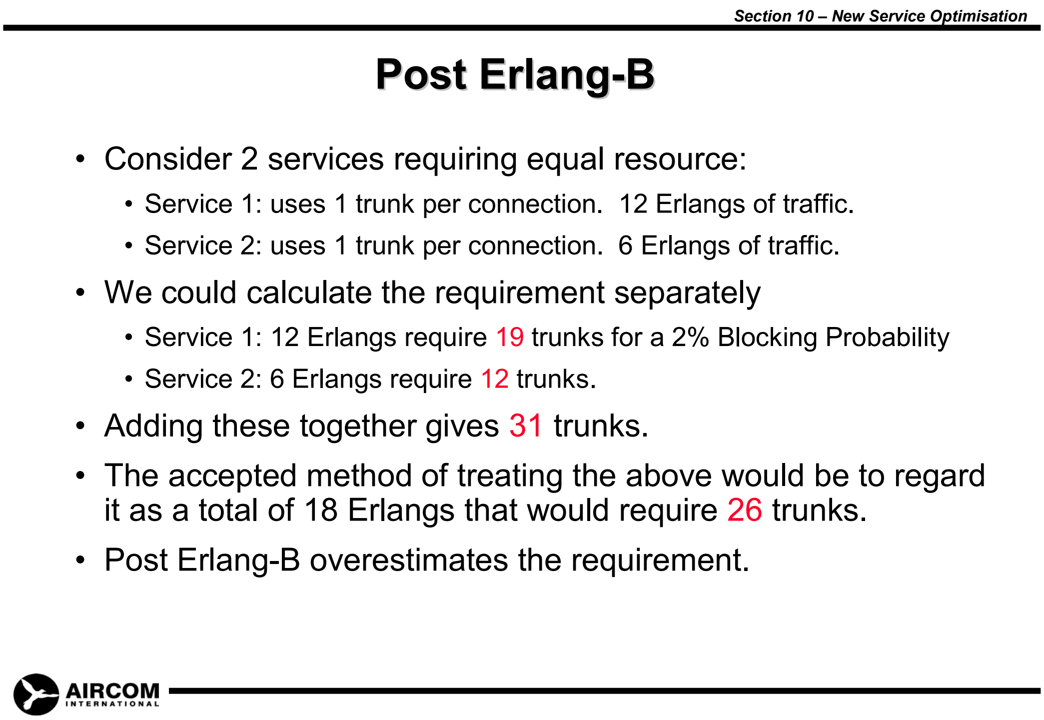
The Post-Erlang B approach differs from the equivalent Erlang approach in that it calculates the capacity requirements of each service individually and simply adds them together to determine the overall capacity requirement.



The Post Erlang B approach is simpler than Equivalent Erlangs and gives a constant result regardless of which service capacity is estimated first. However, it has been shown to overestimate the actual overall capacity requirements.

10.2.3 TRAFFIC DIMENSIONING USING CAMPBELL'S THEOREM

An alternative to the two above capacity estimation approaches is the formula devised by Campbell. Campbell's Theorem is seen as an appropriate way to establish the required resource when a certain amount of mixed traffic is offered.

It is best understood as a procedure. Suppose we needed to establish the required resource to accommodate 12 Erlangs of voice and 6 Erlangs of HSCSD traffic of amplitude 3:

Campbell's Theorem

- Campbell's theorem creates a composite distribution where:

$$Capacity = \frac{(C_i - a_i)}{c} \qquad OfferedTraffic = \frac{\alpha}{c}$$

$$c = \frac{\nu}{\alpha} = \frac{\sum_i \gamma_i a_i^2 b_i}{\sum_i \gamma_i a_i b_i} \qquad \text{Service Offered Traffic} = \gamma_i b_i$$

C_i = available capacity
α = mean
υ = variance
γ_i = arrival rate
a_i = amplitude of service
b_i = mean holding time
c = capacity factor

- The amplitude (a_i) used in the capacity is the amplitude of the target service
- Once the equivalent offered traffic and capacity are derived, GoS can be derived with Erlang-B
- Required capacity can be calculated if offered traffic and GoS target is known

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The first step is to calculate the mean: $\alpha = (12 \times 1) + (6 \times 3) = 30$

Next we calculate the variance: $\upsilon = (12 \times 1^2) + (6 \times 3^2) = 66$

From these two parameters a capacity factor is derived.

$$\text{capacity factor, } c = \frac{\text{variance}}{\text{mean}} = 2.2$$

The equivalent offered traffic is calculated by dividing the mean by the capacity factor:

$$\text{offered traffic} = \frac{30}{2.2} = 13.6 \text{ Erlangs}$$

From the Erlang B table, 21 trunks would be required.

To convert this into equivalent voice trunks, this figure must be multiplied by the capacity factor.

$$\text{Equivalent voice trunks} = 21 \times 2.2 = 46.2$$

A minor adjustment must be made depending on which service is defined as the 'target' or priority service. This is to reflect the fact that if two services share the same resource, the one that demands the higher unit resource will experience a worse grade of service. So, if the HSCSD service is deemed to be the target service, a total of 46+3 = 49 timeslots should be available.

Campbell's Theorem Example

- Consider the same 2 services sharing the same resource:
  - Service 1: uses 1 trunk per connection. 12 Erlangs of traffic.
  - Service 2, uses 3 trunks per connection. 6 Erlangs of traffic.
- In this case the mean is:

$$\alpha = \sum \gamma_i b_i a_i = \sum \text{Erlangs} \times a_i = (1 \times 12) + (3 \times 6) = 30$$

- The variance is:

$$\nu = \sum \gamma_i b_i a_i^2 = \sum \text{Erlangs} \times a_i^2 = (12 \times 1^2) + (6 \times 3^2) = 66$$

Note: $\gamma_i b_i$ = traffic in Erlangs

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Section 10 – New Service Optimisation

Campbell's Theorem Example

- Capacity Factor c (average trunks per connection):

$$c = \frac{\nu}{\alpha} = \frac{66}{30} = 2.2$$

- Equivalent offered traffic:

$$\text{Equivalent Offered Traffic} = \frac{\alpha}{c} = \frac{30}{2.2} = 13.63$$

- Trunk capacity for equivalent traffic at 2% GoS = 21

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Campbell's Theorem Example

- Actual trunk requirement is trunk capacity x capacity factor:

  = 21 x 2.2 = 46.2 or 46 trunks

- Required Capacity is modified depending upon target service for GoS (in service 1 Erlangs):

  - Target is Service 1 C_1=(2.2 x 21) + 1 = 47
  - Target is Service 2, C_2=(2.2 x 21) + 3 = 49

- Different services will require a different capacity for the same GoS depending oin the amplitude

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10.2.4 COMPARISON OF TRAFFIC ANALYSIS METHODS

Traffic Analysis Methods Compared

- Equivalent Erlangs
  - Optimistic if you use the smallest amplitude of trunk (39)
  - Pessimistic if you use the largest amplitude of trunk (51)
- Post Erlang-B
  - Pessimistic (55)
  - Trunking efficiency improvement with magnitude ignored
- Campbell's theorem
  - Middle band (47 - 49)
  - Different capacities required for different services - realistic
  - Preferred solution for dimensioning, but not ideal...

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10.2.5 CAPACITY DIMENSIONING USING CAMPBELL'S THEOREM

Suppose a particular area was to be forecast to offer 250 Erlangs of voice traffic and 63 Erlangs of HSCSD traffic with an amplitude of 2. The calculation detailed below suggests that, if each cell is capable of providing 15 timeslots, 56 cells will be required to service that demand with each cell then capturing 4.46 Erlangs of voice traffic and 1.13 Erlangs of HSCSD.

Capacity Dimensioning with Campbell's Theorem

- Consider the following service definition and traffic forecast.

Service	Amplitude	Forecast
Voice	1	250 E
HSCSD	2	63 E

- Based on a theoretical availability of 15 voice trunks per cell and using voice as the 'benchmark' service, determine the number of cells required to serve the above traffic levels and the traffic offered per cell for each service

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Capacity Dimensioning with Campbell's Theorem

- Assuming we have n cells, we can determine the loading per cell.

$$\text{mean} = \frac{250}{n} + \frac{63 \times 2}{n} = \frac{376}{n}$$

$$\text{variance} = \frac{250}{n} + \frac{63 \times 2^2}{n} = \frac{502}{n}$$

$$c = \frac{\text{variance}}{\text{mean}} = \frac{502}{376} = 1.335$$

$$\text{offered traffic} = \frac{\text{mean}}{c} = \frac{376}{1.335 \times n} = \frac{282}{n}$$

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Capacity Dimensioning with Campbell's Theorem

- Considering the equation: $\text{Capacity} = \frac{C_i - a_i}{c}$
- C_i (available capacity) is predefined as 15. a_i (amplitude) depends on the service we use as our "benchmark" or priority service. Choosing the voice service as the "benchmark" service make a_i equal to 1.

$$C_i = \frac{(15-1)}{1.335} = 10.5$$

- 10.5 (rounded to 10) trunks will service 5.08 Erlangs.

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Capacity Dimensioning with Campbell's Theorem

- Each cell requires 10 trunks to service 5.08 Erlangs.
- Therefore:

$$\text{Number of cells required} = \frac{\text{Equivalent Traffic}}{\text{Traffic per Cell}}$$

$$= \frac{282}{5.08} = 55.5$$

- Cell requirement is established at 56 cells.
- Each of the cells will service:
    - 4.46 Erlangs of voice
    - 1.13 Erlangs of HSCSD.

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10.2.6 ASSESSING CELL LOADING USING CAMPBELL'S THEOREM

Campbell's Theorem can be used to indicate the number of carriers that should be provided following a "traffic capture" exercise. An example is given below:

Assessing Cell Loading using Campbell's Theorem

- After placing sites on the coverage map and spreading the traffic, the next stage is to assess the cell loading (timeslots required).
- If mixed services are used, it is necessary to use Campbell's Theorem to assess the required number of timeslots to satisfy the likely demand.
- Consider the case where a particular cell captures 7 Erlangs of voice and 2 Erlangs of HSCSD traffic that requires 2 timeslots per connection.

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Assessing Cell Loading using Campbell's Theorem

- Using Campbell's Theorem:

$$\text{mean} = (7\times 1) + (2\times 2) = 11$$
$$\text{variance} = (7\times 1^2) + (2\times 2^2) = 15$$
$$\text{Capacity Factor } (c) = \frac{15}{11} = 1.36$$
$$\text{Equivalent offered traffic} = \frac{11}{1.36} = 8.09 \text{ Erlangs}$$

From Erlang B, 14 trunks required.
Taking voice as benchmark : $(14\times 1.36)+1 = 20$

- Hence 20 timeslots required.

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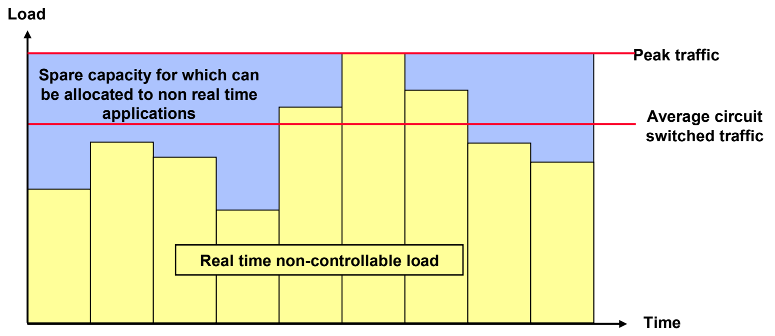
10.3 Mixing Packet and Circuit-Switched Traffic

Evaluating Traffic Requirements

Data may be packet switched, in which case it can be made to "fill the gaps" in the demand for voice services.



Section 10 – New Service Optimisation

Evaluating Traffic Requirements

- To evaluate the required cell capacity:
  - First assume that the packet data can be scheduled to fill the spare real time capacity.
  - When all the spare real time capacity has been exhausted we must convert the remaining capacity to an equivalent data capacity.
- One GSM timeslot can carry 13 kb/s of data.

Traffic Requirement Example

- A cell captures 2 Erlangs of voice traffic and is assigned a GSM carrier with 7 timeslots. The grade of service is 2%.
  Estimate the amount of data traffic that can be handled.
  How much of this must be packet data and how much can be circuit switched?

- Solution:

  Timeslots available on average = 7 - 2 = 5
  This represents a total data rate of 5 x 13 = 65 kb/s

  2 Erlangs voice traffic requires 6 trunks (timeslots) for 2% blocking.

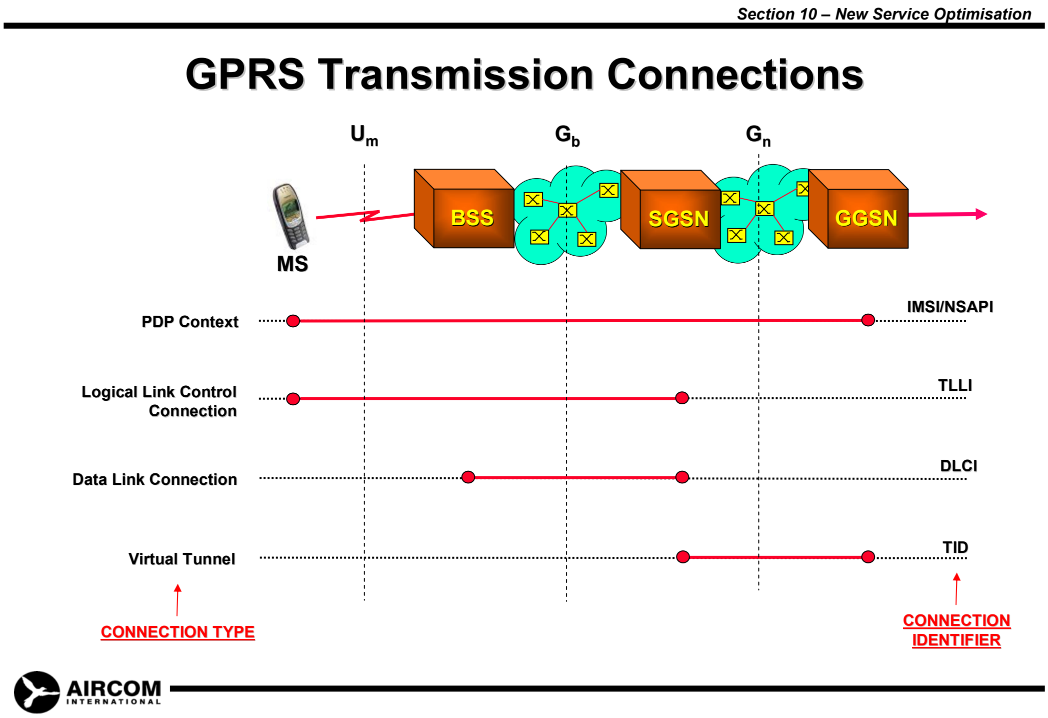
  1 timeslot can be dedicated (circuit switched) for data, i.e. 13 kb/s
  Remaining data must be packet switched = 65 - 13 = 52 kb/s.

10.4 GPRS Performance Monitoring

In a number of areas, GPRS functionality differs significantly from that of GSM. Therefore a number of new GPRS performance monitoring parameters need to be defined. This section looks at some of these parameters including:

Examples of GPRS-Specific Parameters

- Cell Reselection
- Service Exceptions
- Average Response Times
- Suspend/Resume Procedures
- Attach/Detach Procedures
- Routing Area (RA) Update Procedures
- PDP Context Activations
- Data Volumes and Rates



10.4.1 CELL RESELECTION

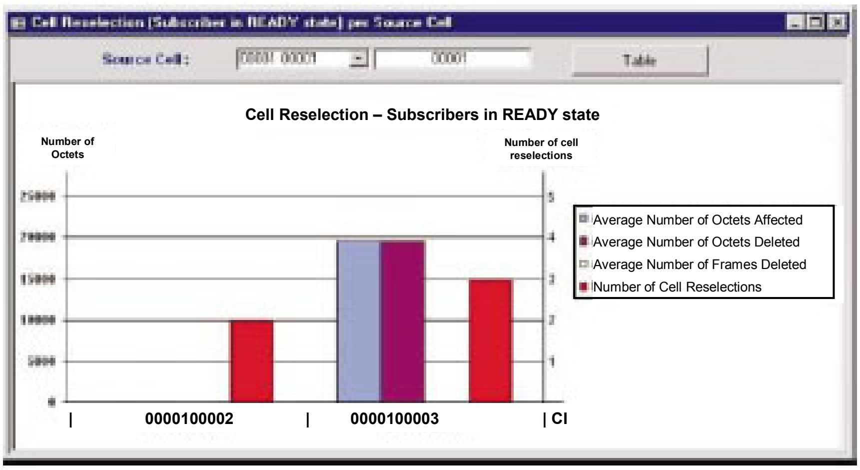
Within a GPRS network, the cell reselection procedure with the mobile station (MS) in ready mode differs fundamentally from the handover procedure in GSM. In GPRS, this procedure is generally initiated by the MS, unlike GSM mode. The MS indicates to the network that it has changed cells, sending the network a data sequence that it transmits directly to the target cell.

The GPRS network has to implement a number of procedures designed to deliver a continuous data stream to the subscriber. More specifically, it must:

- Detect the cell reselection.
- Attempt to transfer all of the data buffered by the source cell and not transmitted to the buffer of the target cell. If this transfer fails, it must erase the data intended for the subscriber from the source cell buffer and inform the SGSN.
- Ensure routing of new data intended for the MS to the target cell.

Any malfunction of these procedures can be detected and recorded, together with any incorrect parameter settings in the MS, cell and BSS.

GPRS Cell Reselection



Cell Reselection per source cell

10.4.2 SERVICE EXCEPTIONS

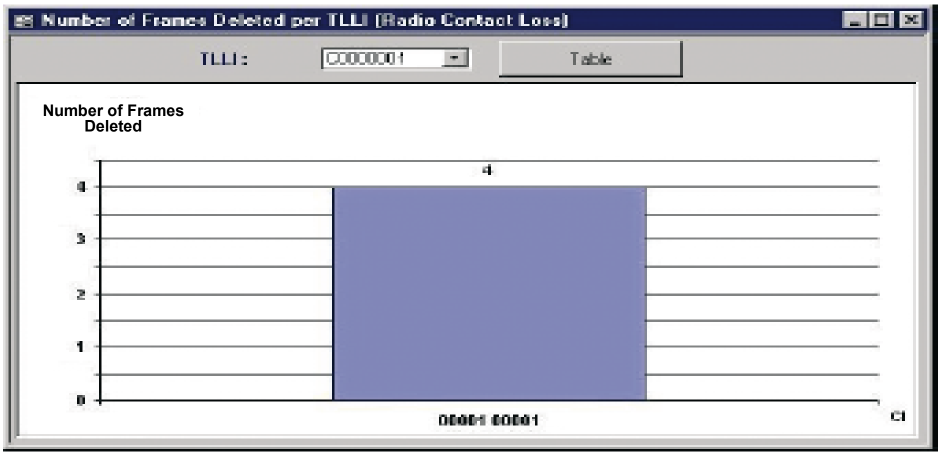
In a GPRS network, the SGSN must be informed about disruptions on the radio link between the MS and BTS. The ETSI GPRS standard lists three possible disruption types:

- The radio link to the MS was lost.
- The quality of the radio link has degraded beyond being able to continue the session within the negotiated service quality.
- The BSS requires the MS to carry out cell reselection.

Cases 1 and 2 mean that exchanges between the MS and the network via the current cell must be suspended while the exception is processed. These procedures can be monitored and summarised by cell and/or TLLI in order to detect:

1. Possible malfunctions of:
    - The radio subsystem
    - Certain cells, causing holes in the coverage (case 1)
    - Certain cells causing high BERs
    - Certain MSs
2. Cell reselections imposed by the network on the MS.

GPRS Service Exception



Number of frames deleted per TLLI

By detecting these malfunctions, it is possible to take corrective action:

- Locate holes in the coverage and then make corrections at the BTS level (tilt, power, etc.)
- Identify and remove the interference or change one or more frequencies assigned to the BTS.

10.4.3 SUSPEND/RESUME PROCEDURE

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Suspend / Resume Procedures

- Suspend Procedure:
  - Enables a GPRS Class B MS to suspend GPRS mode in order to make a circuit-switched connection
- Resume Procedure:
  - Enables a GPRS Class B MS to resume GPRS mode having made a circuit switched connection
- Monitoring:
  - Procedure can be monitored and failures can be displayed by TLLI, cell or cause

The suspend procedure allows a class B mobile station connected in GPRS mode to suspend operation in GPRS mode and move to GSM mode in order to make a circuit-mode connection. Checks of the suspend procedure can be performed and failures summarised by TLLI, by cell and/or by cause.

The resume procedure allows a GPRS class B MS connected in GSM mode to resume its operation in GPRS mode after a Suspend procedure. Checks can also be carried out on the resume procedure and similarly, failures can be summarised by TLLI, by cell and/or by cause.

10.4.4 AVERAGE RESPONSE TIME

The average response time of the network or mobile station can be measured and recorded. Using the recorded values, the QoS experienced by the subscriber can be estimated to a degree. For example, a response time can be measured between paging request message to an MS and the first message with data content returned by this MS, as this first message is deemed to be the response to the paging message.

This measurement can be summarised at cell level, per BVCI (**B**SSGP protocol **V**irtual **C**ircuit **I**dentifier) in order to provide mean representative statistics.

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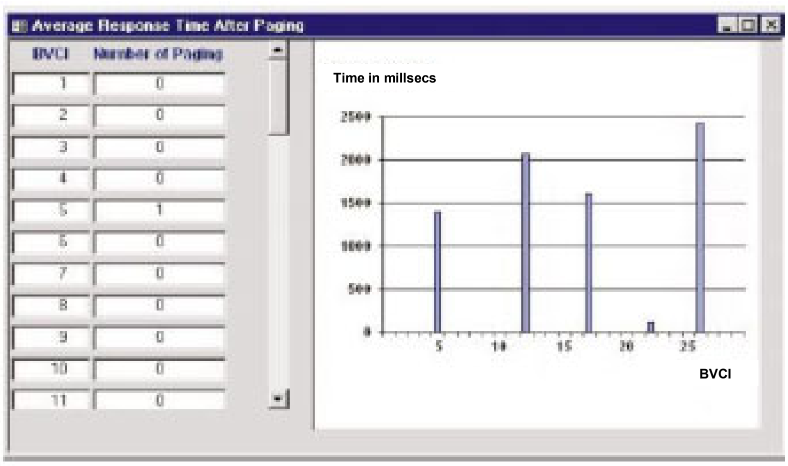
GPRS Average Response Times



Average response time after paging, per BVCI

This information:

- Allows the defined paging repetition period to be compared with the average response time of the subscribers: For example, a repeat paging request time of 2 seconds when the average response time is greater than 2 seconds results in wasted repetitions of paging messages.
- Highlights cells with an abnormal response time.

By detecting such problems, it is possible to:

- Modify the paging repetition period in order to reduce the network signalling channel load.
- Investigate the appropriateness of these cell parameters (e.g. lack of paging, interference, etc.).

10.4.5 ATTACH/DETACH PROCEDURES

The GMM attach procedure entails an MS switching from *Idle* state to *Ready* state in order to exchange data in GPRS mode. The GMM detach procedure is the reverse, i.e. reverting from *Ready* state to *Idle* state on completion of GPRS data exchange.

The following checks can be carried out on these GPRS procedures:

- Request for GPRS attach by MS
- Attach acceptance response by the network
- Acknowledgment of acceptance by MS.

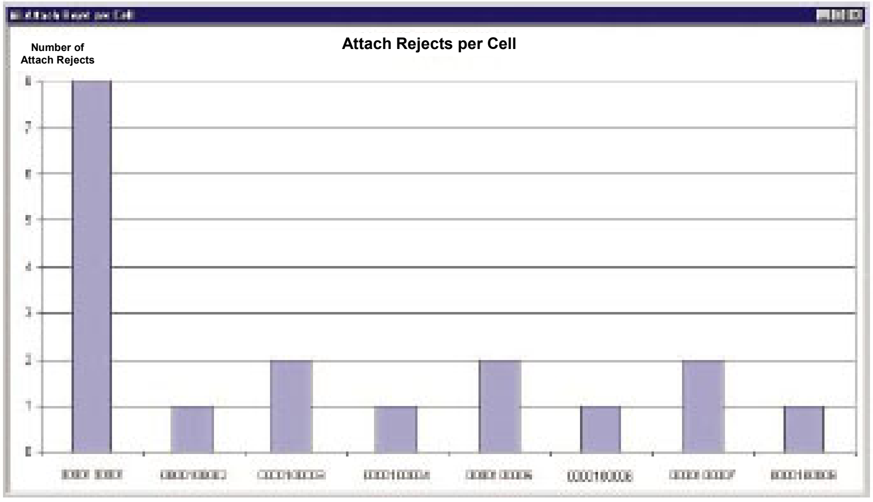
Any procedure that does not follow these three phases indicates an error condition.

Detection of one or more subscribers who are failing to correctly attach may indicate an SGSN VLR that might not be furnishing the correct subscriber profile information

Based on these elements, the following corrective measures can be requested from the services involved:

- Checking of links to the HLR
- Checking of VLR parameters
- Checking of roaming parameters

GPRS Attach/Detach Procedures



Number of Attach Reject Messages per Cell

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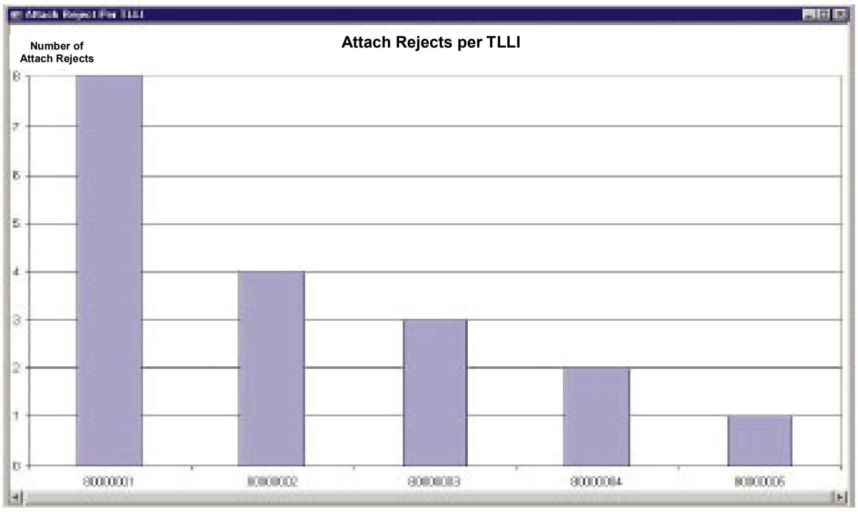
GPRS Attach/Detach Procedures



Number of Attach Reject Messages per Subscriber (TLLI)

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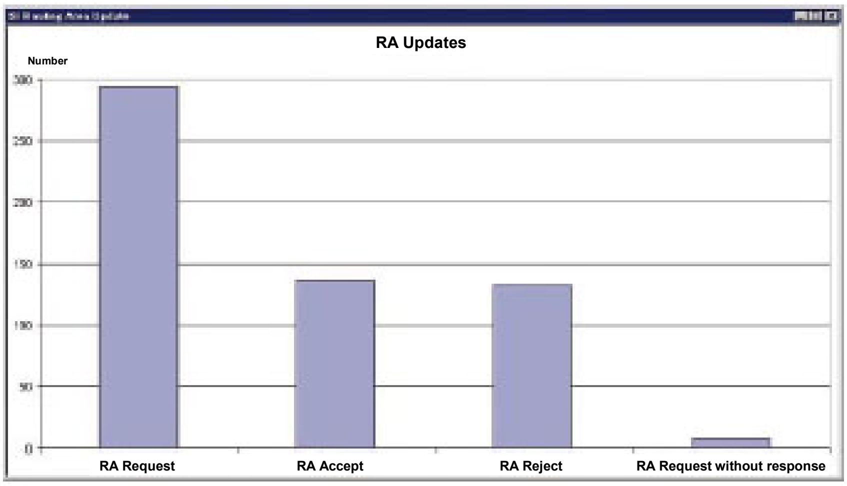
10.4.6 RA UPDATE PROCEDURE

The GMM Routing Area (RA) update procedure is initiated each time a GPRS MS in *Ready* or *Standby* mode changes Routing Areas. This procedure can be checked as follows:

- Location Update request by MS
- Request acceptance response by network
- Acknowledgment by MS

Any procedure that does not follow these three phases is incorrect.

GPRS RA Update Procedures



Number of RA Update Messages

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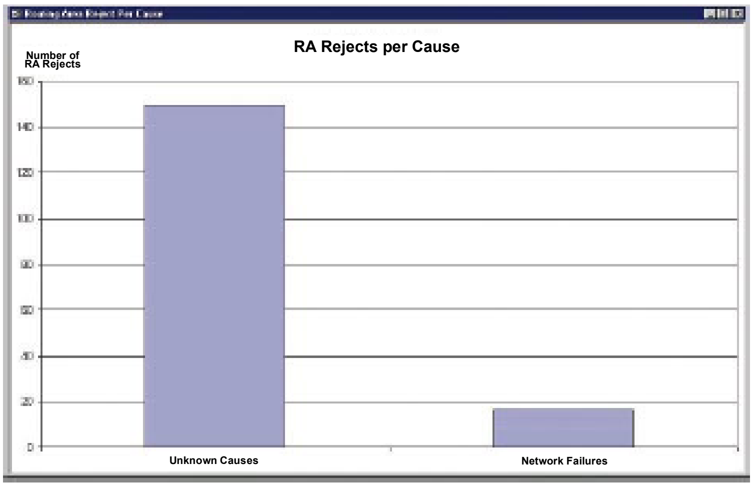
GPRS RA Update Procedures



Number of RA Update Rejects by Cause

10.4.7 PDP CONTEXT ACTIVATION/DEACTIVATION

PDP context activation takes place when packet data communication between an MS and a GGSN is initiated. It can be monitored as follows:

- MS activation request message
- Network acceptance or rejection response.

The different cases can then be summarised as shown below:

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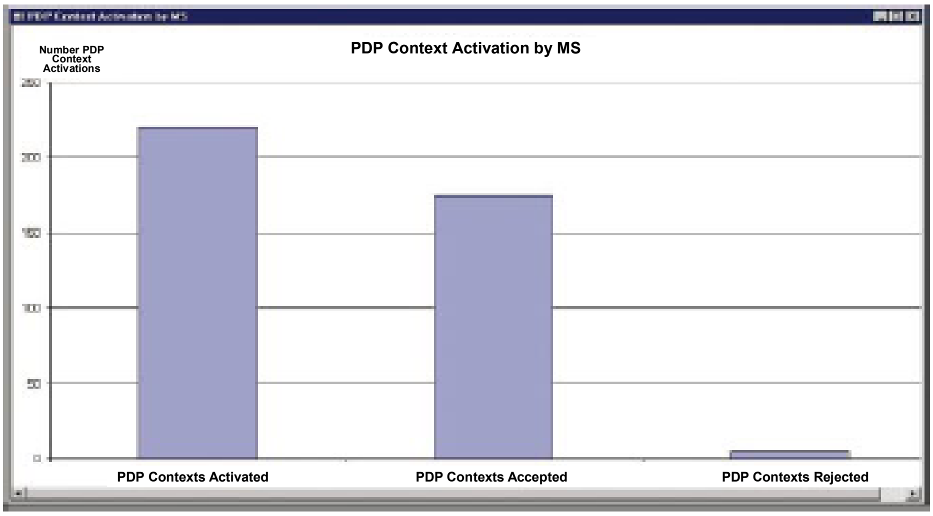
GPRS PDP Contexts



Number of PDP Context Activation Messages

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The PDP Context activation procedure comprises the following elements:

- The ID of the entity initiating the activation (MS or network)
- LLC SAPI requested
- LLC SAPI assigned
- QoS requested
- QoS assigned
- The GGSN access point (if available)
- Rejection cause (if any)

Summaries of these procedures can be created by cell and/or by TLLI. The different procedural elements described above allow précis identification of any failure cause. e.g. Malfunction of an access point, etc.

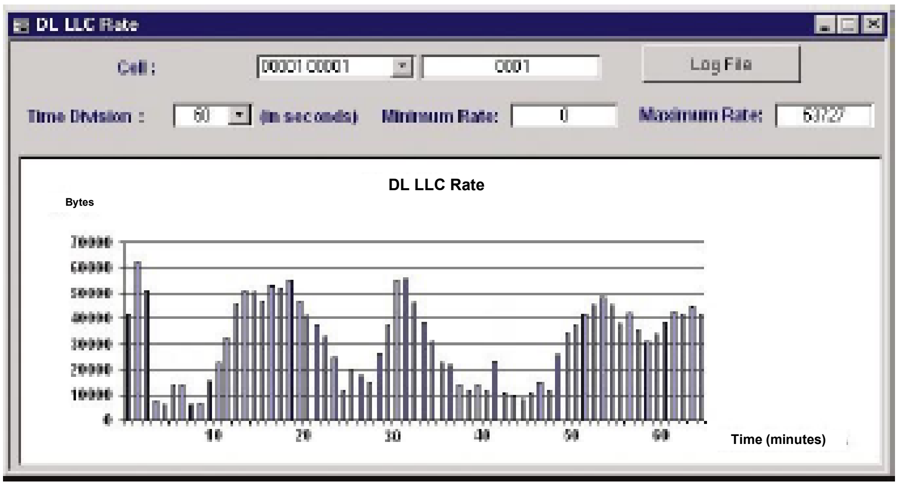
PDP context deactivation procedures are similar (but in reverse) to the activation procedures described above.

10.4.8 DATA VOLUME EXCHANGED AND RATES

Cell

The volume of LLC data exchanged and LLC data rates for both UL and DL can be monitored for each cell. This is useful for instant troubleshooting of a cell where problems have been identified or which is regularly pushed to its rate limit. Moreover, periods of heavy usage or even saturation can be detected immediately.

GPRS Data Volumes and Rates



Downlink Data Rate of a Cell

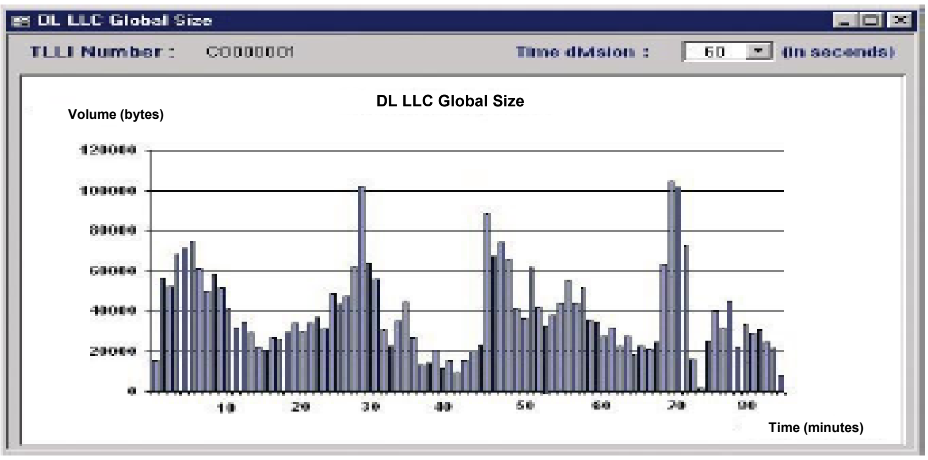
Such analysis is useful for modifying the parameters related to cell dimensioning in order to provide better QoS to the subscribers.

Mobile Station

The volume of LLC data exchanged and LLC data rate activity for both UL and DL can be monitored and displayed for each MS. From this it is possible to:

- Precisely determine the resources used by a mobile station
- Immediately troubleshoot a mobile station that is malfunctioning
- Obtain the data you need for dimensioning cells

GPRS Data Volumes and Rates



Downlink Data Rate of a Mobile Station

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Appendix A
Glossary of Terms

A3	Authentication algorithm
A5	Ciphering algorithm
A8	Ciphering key computation
A	Interface between MSC and BSC
Abis	Interface between BSC and BTS
ACK	Acknowledgement protocol
ADM	Adaptive delta modulation
ADPCM	Adaptive differential pulse-code modulation
ADSL	Asymmetric Digital Subscriber Line. A technique for dramatically increasing the data rates available on copper wiring.
AMPS	Analogue Mobile Phone System. The US analogue cellular standard.
ARFCN	Absolute Radio Frequency Channel Number
ARQ	Automatic repeat request
ATM	Asynchronous Transfer Mode
AuC	Authentication Centre. The part of the GSM system responsible for authenticating the mobiles and providing ciphering keys.
BCCH	Broadcast Control Channel. A GSM logical control channel providing information to the mobile as to the channel configuration in the cell.
BER	Bit error rate
BP	Burst Period. The duration of a single burst, when one mobile transmits within the GSM framing structure.
BS	Base station. The part of the radio system which transmits the signal to the mobile.
BSC	Base Station Controller. The part of the GSM system responsible for controlling the base stations.
BSS	Base Station Sub-system. The combination of the BTS and BSC.
BSSMAP	BSS Management Part. The protocol used for BSS management on the Abis interface.
BT	Bandwidth-Time product. A means of measuring the amount of filtering applied to the pulse during the modulation process.
BTS	Base Transceiver Station. Another name for BS.
CAI	Common air interface – as in CT2 standard.
CDMA	Code Division Multiple Access. The use of different codes to allow users to access the same spectrum at the same time.
CC	Call Control. The protocol layer within GSM responsible for overall control of the call.
CELP	Code-excited linear prediction, vocoder.
CEPT	European Committee for Post and Telecommunications. The European body Responsible for radio spectrum management.
COST	Co-operation in Science and Technology programme (Europe).

COST 231	COST committee dealing with future mobile system.
CT-0	The original analogue VHF/LF cordless phone technology as used in UK, France and elsewhere.
CT-1	Cordless Telephone Generation One – 900MHz analogue FM cordless Technology standardised by CEPT.
CT-2	Cordless Telephone Generation 2. An early UK digital cordless standard.
CT-3	Early Swedish (Ericsson) digital cordless standard.
CTM	Cordless terminal mobility – an application concept and an ETSI project.
DCS	Digital cellular system (eg DCS1800).
DECT	Digital European Cordless Telephone. The European cordless telephone standard.
Downlink	Transmission path from radio fixed part to portable part.
Duplex	Simultaneous two-way conversation.
DTAP	Direct Transfer Application Part. The protocol used on the Abis interface to Distinguish between messages for mobiles and for BTSs.
DTX	Discontinuous transmission
EDGE	Enhanced Data rates for GSM Evolution. Method of increasing data rates in GSM by using 8PSK modulation
8PSK	Eight Phase Shift Keying. Modulation techniques encoding 3 bits to each symbol.
EIR	Equipment Identity Register. Part of the GSM system responsible for keeping details of the mobile units and their status.
ETR	ETSI technical report.
ETS	ETSI technical standard.
ETSI	European Telecommunications Standards Institute.
FACCH	Fast Associated Control Channel. A logical channel used for sending emergency information to the mobile by suppressing traffic information.
FCCH	Frequency Control Channel. A logical control channel within GSM used to allow the mobile to lock onto the transmitted signal.
FDMA	Frequency Division Multiple Access. The division of the radio frequency into narrow slots, each one being given to a different user.
FEC	Forward error correction.
FH	Frequency Hopping. Changing rapidly from frequency to frequency to avoid problematic propagation effects.
FPLMTS	Future Public Land Mobile Telecommunications Service. The US name for third generation radio systems.
FSK	Frequency-shift keying.
FT	Fixed termination.
GAP	Generic access profile of DECT.
GFSK	Gaussian-filtered FSK modulation.
GIP	GSM interworking profile of DECT.
G-MSC	Gateway Mobile Switching Centre. The part of the GSM system providing the link into the PSTN.
GMSK	Gaussian Minimum Shift Keying. The modulation technique used in GSM, a form of phase modulation.

GoS	Grade of Service.
GPRS	General Packet Radio Service.
GSM	Global System for Mobile telecommunications. *also* Groupe Speciale Mobile
Handoff	A frequently used American term for handover.
Handover	Procedure whereby an existing call is is automatically routed via an alternative base station when necessary to maintain or improve communications.
HLR	Home Location Register. The part of the GSM system responsible for holding records about mobiles and for keeping track of the parent MSC area.
HSCSD	High Speed Circuit Switched Data. 2.5 G enhancement to GSM giving higher data rates
IAP	ISDN access profile for DECT.
ISI	Inter-Symbol Interference. A radio propagation effect whereby echoes of received signals cause previous symbols transmitted to interference with current symbols.
IMEI	International Mobile Equipment Identity. The GSM number given to each mobile.
IMSI	International Mobile Subscriber Identity. The phone numbering system used within GSM.
IMT2000	International Mobile Telecommunications system for the year 2000.
IN	Intelligent Network.
IP	Internet Protocol, a layer 3 network protocol
IS54	US digital AMPS standard.
IS95	US CDMA digital cellular standard.
ISDN	Integrated Services Digital Network. A protocol for sending digital information over copper landlines.
ITU	International Telecommunications Union. The international body responsible for spectrum management.
IWP	Inter-working profile.
IWU	Inter-working unit.
LA	Location Area
LAC	Location Area Code
LAI	Location Area Identity
LAPD	Link Access Protocol on interface D. Part of the ISDN protocol stack also used in GSM.
LEO	Low Earth Orbiting satellite system. A proposed communications system based on up to 66 satellites.
LLME	Lower layer management entity (DECT).
LNA	low noise amplifier.
LOS	Line-Of-Sight
LPC	Linear Predictive Coding.
MAC	Medium Access Control. The means whereby mobiles access radio channels which are not permanently reserved for their own particular use.
MAP	Mobile Application Part. Part of the SS7 protocol dealing with mobile services.

MM	Mobility Management. The protocol layer within GSM responsible for keeping track of mobiles and performing security functions.
MoU	Memorandum of Understanding
MS	Mobile Station.
MSC	Mobile Switching Centre. The part of the GSM system responsible for switching calls.
MSISDN	Mobile Subscriber Integrated Services Digital Number. The numbering system used to contact GSM mobiles from other networks.
MSK	Minimum shift keying modulation.
MTP	Message Transfer Part. Part of the SS7 protocol stack.
NADC	North American Digital Cellular
NCC	National Colour Code
NMT	Nordic Mobile Telephone system. The Nordic analog cellular standard.
O&M	Operations and maintenance
OAM	Operations, administration and maintenance.
OMC	Operations and Maintenance Centre. The part of the GSM system responsible for monitoring network function.
PABX	private automatic branch exchange.
PAGCH	Paging and Access Grant Channel. A GSM logical control channel providing paging information and allowing mobiles to make access attempts.
PBX	Private Branch Exchange (today has same meaning as PABX).
PCM	Pulse Code Modulation. A simple form of speech coding.
PCN	Personal communications network.
PCS1900	Personal Communications System at 1900 MHz. A variant of GSM working at 1900MHz designed for the US.
PDC	Personal Digital Cellular. The Japanese cellular standard.
PHL	Physical layer – lowest protocol layer.
PHS	Personal Handiphone System. The Japanese cordless telephone standard.
PLMN	Public Land Mobile Network.
PMR `	Private (*or Professional*)Mobile Radio. A radio system owned by the users typically large companies.
POTS	Plain old telephone service.
PP	Portable part.
PSK	Phase shift keying modulation.
PSTN	Public Switched Telephone Network.
PT	Portable termination.
QPSK	Quadrature Phase Shift Keying. A form of modulation whereby orthogonal carriers are used to gain the maximum information from the channel.
Quantisation	A process of representing samples of an analogue waveform by the nearest whole number of predefined voltage steps.
RACH	Random Access Channel. A GSM logical control channel used for making uplink access attempts.
RAP	Radio access profile for DECT.
RAN	Radio Access Network
RFP	Radio fixed part.

RIL	Radio Interface Layer. The protocol within GSM responsible for maintenance of the radio interface.
RLAN	Radio local area network.
RLL	Radio local loop.
RPE-LTP	Regular pulse excitation – long term predictor – speech coder user in GSM.
RR	Radio Resource. The protocol layer within GSM responsible for providing a service over the air interface.
RSSI	Received signal strength indication.
SACCH	Slow Associated Control Channel. A logical channel used alongside a traffic channel to send signalling information to and from the mobile.
SCCH	Synchronisation Control Channel. A GSM logical control channel providing synchronisation to the mobile.
SCCP	Signalling Control and Connection Part. Part of the SS7 protocol stack.
SID	Silence Descriptor
SIM	Subscriber Identity Module. A small card within GSM mobiles which contains the subscriber identity.
Simplex	One-way communication.
SMS	Short Message Service. A feature within GSM whereby messages of up to 160 characters can be transmitted to mobiles.
SMS-SC	SMS Service Centre. The part of the GSM system which handles short messages.
SRES	Signed RESult . Produced by authentication algorithm.
TA	Timing Advance
TACS	Total Access Communications System. The UK (and other European countries) analogue cellular standard.
TBR	Technical basis for regulation – ETSI standards.
TCH	Traffic Channel. The channel used in GSM to send subscriber information.
TCAP	Transaction Capability Application Part. Part of the SS7 protocol stack.
TDD	time division duplex.
TDM	Time division multiplex.
TDMA	Time Division Multiple Access. A system where users access all the frequency but only for a limited time.
TETRA	TErrestrial Trunk RAdio
TMN	Telecommunications Management Network. The concept of managing the network from a single point using a networked operations and maintenance system.
TMSI	Temporary Mobile Subscriber Identity. A GSM number given to the mobile during an encrypted call to prevent eavesdroppers being able to located the mobile.
TRAU	Transcoder and Rate Adapter Unit
TRX	Transmit/Receiver module. The GSM term for a single carrier card within a BTS.
UMTS	Universal Mobile Telecommunications Service. One name for the third generation mobile radio system.
Uplink	Communications path from portable part to fixed part.

UPT	Universal Personal Telecommunications. The fixed network equivalent of third generation systems.
VAD	Voice Activity Detection
VLR	Visitors Location Register. The part of the GSM system responsible for keeping track of a mobile's position to the nearest location area.
VSAT	Very Small Aperture Terminal. A satellite communication system based on dishes around 1m across.
WAP	Wireless Application Protocol
WLL	Wireless Local Loop. The use of radio to replace copper wiring as a means of connecting the home to the PSTN.
WPABX	Wireless PABX.
WPBX	Wireless PBX.
WRC	World Radio Conference. The bi-annual international conferences to determine the use of the radio spectrum.
WRS	Wireless relay station.

Appendix B– Erlang B Tables

n	Grade of Service										n
	0.00001	**0.00005**	**0.0001**	**0.0005**	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.006**	
1	.00001	.00005	.00010	.00050	.00100	.00200	.00301	.00402	.00503	.00604	**1**
2	.00448	.01005	.01425	.03213	.04576	.06534	.08064	.09373	.10540	.11608	**2**
3	.03980	.06849	.08683	.15170	.19384	.24872	.28851	.32099	.34900	.37395	**3**
4	.12855	.19554	.23471	.36236	.43927	.53503	.60209	.65568	.70120	.74124	**4**
5	.27584	.38851	.45195	.64857	.76212	.89986	.99446	1.0692	1.1320	1.1870	**5**
6	.47596	.63923	.72826	.99567	1.1459	1.3252	1.4468	1.5421	1.6218	1.6912	**6**
7	.72378	.93919	1.0541	1.3922	1.5786	1.7984	1.9463	2.0614	2.1575	2.2408	**7**
8	1.0133	1.2816	1.4219	1.8298	2.0513	2.3106	2.4837	2.6181	2.7299	2.8266	**8**
9	1.3391	1.6595	1.8256	2.3016	2.5575	2.8549	3.0526	3.2057	3.3326	3.4422	**9**
10	1.6970	2.0689	2.2601	2.8028	3.0920	3.4265	3.6480	3.8190	3.9607	4.0829	**10**
11	2.0849	2.5059	2.7216	3.3294	3.6511	4.0215	4.2661	4.4545	4.6104	4.7447	**11**
12	2.4958	2.9671	3.2072	3.8781	4.2314	4.6368	4.9038	5.1092	5.2789	5.4250	**12**
13	2.9294	3.4500	3.7136	4.4465	4.8306	5.2700	5.5588	5.7807	5.9638	6.1214	**13**
14	3.3834	3.9523	4.2388	5.0324	5.4464	5.9190	6.2291	6.4670	6.6632	6.8320	**14**
15	3.8559	4.4721	4.7812	5.6339	6.0772	6.5822	6.9130	7.1665	7.3755	7.5552	**15**
16	4.3453	5.0079	5.3390	6.2496	6.7215	7.2582	7.6091	7.8780	8.0995	8.2898	**16**
17	4.8502	5.5583	5.9110	6.8782	7.3781	7.9457	8.3164	8.6003	8.8340	9.0347	**17**
18	5.3693	6.1220	6.4959	7.5186	8.0459	8.6437	9.0339	9.3324	9.5780	9.7889	**18**
19	5.9016	6.6980	7.0927	8.1698	8.7239	9.3515	9.7606	10.073	10.331	10.552	**19**
20	6.4460	7.2854	7.7005	8.8310	9.4115	10.068	10.496	10.823	11.092	11.322	**20**
21	7.0017	7.8834	8.3186	9.5014	10.108	10.793	11.239	11.580	11.860	12.100	**21**
22	7.5680	8.4926	8.9462	10.180	10.812	11.525	11.989	12.344	12.635	12.885	**22**
23	8.1443	9.1095	9.5826	10.868	11.524	12.265	12.746	13.114	13.416	13.676	**23**
24	8.7298	9.7351	10.227	11.562	12.243	13.011	13.510	13.891	14.204	14.472	**24**
25	9.3240	10.369	10.880	12.264	12.969	13.763	14.279	14.673	14.997	15.274	**25**
26	9.9265	11.010	11.540	12.972	13.701	14.522	15.054	15.461	15.795	16.081	**26**
27	10.537	11.659	12.207	13.686	14.439	15.285	15.835	16.254	16.598	16.893	**27**
28	11.154	12.314	12.880	14.406	15.182	16.054	16.620	17.051	17.406	17.709	**28**
29	11.779	12.976	13.560	15.132	15.930	16.828	17.410	17.853	18.218	18.530	**29**
30	12.417	13.644	14.246	15.863	16.684	17.606	18.204	18.660	19.034	19.355	**30**
31	13.054	14.318	14.937	16.599	17.442	18.389	19.002	19.470	19.854	20.183	**31**
32	13.697	14.998	15.633	17.340	18.205	19.176	19.805	20.284	20.678	21.015	**32**
33	14.346	15.682	16.335	18.085	18.972	19.966	20.611	21.102	21.505	21.850	**33**
34	15.001	16.372	17.041	18.835	19.743	20.761	21.421	21.923	22.336	22.689	**34**
35	15.660	17.067	17.752	19.589	20.517	21.559	22.234	22.748	23.169	23.531	**35**
36	16.325	17.766	18.468	20.347	21.296	22.361	23.050	23.575	24.006	24.376	**36**
37	16.995	18.470	19.188	21.108	22.078	23.166	23.870	24.406	24.846	25.223	**37**
38	17.669	19.178	19.911	21.873	22.864	23.974	24.692	25.240	25.689	26.074	**38**
39	18.348	19.890	20.640	22.642	23.652	24.785	25.518	26.076	26.534	26.926	**39**
40	19.031	20.606	21.372	23.414	24.444	25.599	26.346	26.915	27.382	27.782	**40**
41	19.718	21.326	22.107	24.189	25.239	26.416	27.177	27.756	28.232	28.640	**41**
42	20.409	22.049	22.846	24.967	26.037	27.235	28.010	28.600	29.085	29.500	**42**
43	21.104	22.776	23.587	25.748	26.837	28.057	28.846	29.447	29.940	30.362	**43**
44	21.803	23.507	24.333	26.532	27.641	28.882	29.684	30.295	30.797	31.227	**44**
45	22.505	24.240	25.081	27.319	28.447	29.708	30.525	31.146	31.656	32.093	**45**
46	23.211	24.977	25.833	28.109	29.255	30.538	31.367	31.999	32.517	32.962	**46**
47	23.921	25.717	26.587	28.901	30.066	31.369	32.212	32.854	33.381	33.832	**47**
48	24.633	26.460	27.344	29.696	30.879	32.203	33.059	33.711	34.246	34.704	**48**
49	25.349	27.206	28.104	30.493	31.694	33.039	33.908	34.570	35.113	35.578	**49**
50	26.067	27.954	28.867	31.292	32.512	33.876	34.759	35.431	35.982	36.454	**50**
51	26.789	28.706	29.632	32.094	33.332	34.716	35.611	36.293	36.852	37.331	**51**
	0.00001	**0.00005**	**0.0001**	**0.0005**	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.006**	

n	Grade of Service										n
	0.007	**0.008**	**0.009**	**0.01**	**0.02**	**0.03**	**0.05**	**0.1**	**0.2**	**0.4**	
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	**1**
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	**2**
3	.39664	.41757	.43711	.45549	.60221	.71513	.89940	1.2708	1.9299	3.4798	**3**
4	.77729	.81029	.84085	.86942	1.0923	1.2589	1.5246	2.0454	2.9452	5.0210	**4**
5	1.2362	1.2810	1.3223	1.3608	1.6571	1.8752	2.2185	2.8811	4.0104	6.5955	**5**
6	1.7531	1.8093	1.8610	1.9090	2.2759	2.5431	2.9603	3.7584	5.1086	8.1907	**6**
7	2.3149	2.3820	2.4437	2.5009	2.9354	3.2497	3.7378	4.6662	6.2302	9.7998	**7**
8	2.9125	2.9902	3.0615	3.1276	3.6271	3.9865	4.5430	5.5971	7.3692	11.419	**8**
9	3.5395	3.6274	3.7080	3.7825	4.3447	4.7479	5.3702	6.5464	8.5217	13.045	**9**
10	4.1911	4.2889	4.3784	4.4612	5.0840	5.5294	6.2157	7.5106	9.6850	14.677	**10**
11	4.8637	4.9709	5.0691	5.1599	5.8415	6.3280	7.0764	8.4871	10.857	16.314	**11**
12	5.5543	5.6708	5.7774	5.8760	6.6147	7.1410	7.9501	9.4740	12.036	17.954	**12**
13	6.2607	6.3863	6.5011	6.6072	7.4015	7.9667	8.8349	10.470	13.222	19.598	**13**
14	6.9811	7.1155	7.2382	7.3517	8.2003	8.8035	9.7295	11.473	14.413	21.243	**14**
15	7.7139	7.8568	7.9874	8.1080	9.0096	9.6500	10.633	12.484	15.608	22.891	**15**
16	8.4579	8.6092	8.7474	8.8750	9.8284	10.505	11.544	13.500	16.807	24.541	**16**
17	9.2119	9.3714	9.5171	9.6516	10.656	11.368	12.461	14.522	18.010	26.192	**17**
18	9.9751	10.143	10.296	10.437	11.491	12.238	13.385	15.548	19.216	27.844	**18**
19	10.747	10.922	11.082	11.230	12.333	13.115	14.315	16.579	20.424	29.498	**19**
20	11.526	11.709	11.876	12.031	13.182	13.997	15.249	17.613	21.635	31.152	**20**
21	12.312	12.503	12.677	12.838	14.036	14.885	16.189	18.651	22.848	32.808	**21**
22	13.105	13.303	13.484	13.651	14.896	15.778	17.132	19.692	24.064	34.464	**22**
23	13.904	14.110	14.297	14.470	15.761	16.675	18.080	20.737	25.281	36.121	**23**
24	14.709	14.922	15.116	15.295	16.631	17.577	19.031	21.784	26.499	37.779	**24**
25	15.519	15.739	15.939	16.125	17.505	18.483	19.985	22.833	27.720	39.437	**25**
26	16.334	16.561	16.768	16.959	18.383	19.392	20.943	23.885	28.941	41.096	**26**
27	17.153	17.387	17.601	17.797	19.265	20.305	21.904	24.939	30.164	42.755	**27**
28	17.977	18.218	18.438	18.640	20.150	21.221	22.867	25.995	31.388	44.414	**28**
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	**29**
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	**30**
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	**31**
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	**32**
33	22.155	22.429	22.678	22.909	24.626	25.844	27.721	31.301	37.524	52.718	**33**
34	23.001	23.281	23.536	23.772	25.529	26.776	28.698	32.367	38.754	54.379	**34**
35	23.849	24.136	24.397	24.638	26.435	27.711	29.677	33.434	39.985	56.041	**35**
36	24.701	24.994	25.261	25.507	27.343	28.647	30.657	34.503	41.216	57.703	**36**
37	25.556	25.854	26.127	26.378	28.254	29.585	31.640	35.572	42.448	59.365	**37**
38	26.413	26.718	26.996	27.252	29.166	30.526	32.624	36.643	43.680	61.028	**38**
39	27.272	27.583	27.867	28.129	30.081	31.468	33.609	37.715	44.913	62.690	**39**
40	28.134	28.451	28.741	29.007	30.997	32.412	34.596	38.787	46.147	64.353	**40**
41	28.999	29.322	29.616	29.888	31.916	33.357	35.584	39.861	47.381	66.016	**41**
42	29.866	30.194	30.494	30.771	32.836	34.305	36.574	40.936	48.616	67.679	**42**
43	30.734	31.069	31.374	31.656	33.758	35.253	37.565	42.011	49.851	69.342	**43**
44	31.605	31.946	32.256	32.543	34.682	36.203	38.557	43.088	51.086	71.006	**44**
45	32.478	32.824	33.140	33.432	35.607	37.155	39.550	44.165	52.322	72.669	**45**
46	33.353	33.705	34.026	34.322	36.534	38.108	40.545	45.243	53.559	74.333	**46**
47	34.230	34.587	34.913	35.215	37.462	39.062	41.540	46.322	54.796	75.997	**47**
48	35.108	35.471	35.803	36.109	38.392	40.018	42.537	47.401	56.033	77.660	**48**
49	35.988	36.357	36.694	37.004	39.323	40.975	43.534	48.481	57.270	79.324	**49**
50	36.870	37.245	37.586	37.901	40.255	41.933	44.533	49.562	58.508	80.988	**50**
51	37.754	38.134	38.480	38.800	41.189	42.892	45.533	50.644	59.746	82.652	**51**
	0.007	**0.008**	**0.009**	**0.01**	**0.02**	**0.03**	**0.05**	**0.1**	**0.2**	**0.4**	

n	Grade of Service										n
	0.00001	**0.00005**	**0.0001**	**0.0005**	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.006**	
51	26.789	28.706	29.632	32.094	33.332	34.716	35.611	36.293	36.852	37.331	**51**
52	27.513	29.459	30.400	32.898	34.153	35.558	36.466	37.157	37.724	38.211	**52**
53	28.241	30.216	31.170	33.704	34.977	36.401	37.322	38.023	38.598	39.091	**53**
54	28.971	30.975	31.942	34.512	35.803	37.247	38.180	38.891	39.474	39.973	**54**
55	29.703	31.736	32.717	35.322	36.631	38.094	39.040	39.760	40.351	40.857	**55**
56	30.438	32.500	33.494	36.134	37.460	38.942	39.901	40.630	41.229	41.742	**56**
57	31.176	33.266	34.273	36.948	38.291	39.793	40.763	41.502	42.109	42.629	**57**
58	31.916	34.034	35.055	37.764	39.124	40.645	41.628	42.376	42.990	43.516	**58**
59	32.659	34.804	35.838	38.581	39.959	41.498	42.493	43.251	43.873	44.406	**59**
60	33.404	35.577	36.623	39.401	40.795	42.353	43.360	44.127	44.757	45.296	**60**
61	34.151	36.351	37.411	40.222	41.633	43.210	44.229	45.005	45.642	46.188	**61**
62	34.900	37.127	38.200	41.045	42.472	44.068	45.099	45.884	46.528	47.081	**62**
63	35.651	37.906	38.991	41.869	43.313	44.927	45.970	46.764	47.416	47.975	**63**
64	36.405	38.686	39.784	42.695	44.156	45.788	46.843	47.646	48.305	48.870	**64**
65	37.160	39.468	40.579	43.523	45.000	46.650	47.716	48.528	49.195	49.766	**65**
66	37.918	40.252	41.375	44.352	45.845	47.513	48.591	49.412	50.086	50.664	**66**
67	38.677	41.038	42.173	45.183	46.692	48.378	49.467	50.297	50.978	51.562	**67**
68	39.439	41.825	42.973	46.015	47.540	49.243	50.345	51.183	51.872	52.462	**68**
69	40.202	42.615	43.775	46.848	48.389	50.110	51.223	52.071	52.766	53.362	**69**
70	40.967	43.405	44.578	47.683	49.239	50.979	52.103	52.959	53.662	54.264	**70**
71	41.734	44.198	45.382	48.519	50.091	51.848	52.984	53.848	54.558	55.166	**71**
72	42.502	44.992	46.188	49.357	50.944	52.718	53.865	54.739	55.455	56.070	**72**
73	43.273	45.787	46.996	50.195	51.799	53.590	54.748	55.630	56.354	56.974	**73**
74	44.045	46.585	47.805	51.035	52.654	54.463	55.632	56.522	57.253	57.880	**74**
75	44.818	47.383	48.615	51.877	53.511	55.337	56.517	57.415	58.153	58.786	**75**
76	45.593	48.183	49.427	52.719	54.369	56.211	57.402	58.310	59.054	59.693	**76**
77	46.370	48.985	50.240	53.563	55.227	57.087	58.289	59.205	59.956	60.601	**77**
78	47.149	49.787	51.054	54.408	56.087	57.964	59.177	60.101	60.859	61.510	**78**
79	47.928	50.592	51.870	55.254	56.948	58.842	60.065	60.998	61.763	62.419	**79**
80	48.710	51.397	52.687	56.101	57.810	59.720	60.955	61.895	62.668	63.330	**80**
81	49.492	52.204	53.506	56.949	58.673	60.600	61.845	62.794	63.573	64.241	**81**
82	50.277	53.012	54.325	57.798	59.537	61.480	62.737	63.693	64.479	65.153	**82**
83	51.062	53.822	55.146	58.649	60.403	62.362	63.629	64.594	65.386	66.065	**83**
84	51.849	54.633	55.968	59.500	61.269	63.244	64.522	65.495	66.294	66.979	**84**
85	52.637	55.445	56.791	60.352	62.135	64.127	65.415	66.396	67.202	67.893	**85**
86	53.427	56.258	57.615	61.206	63.003	65.011	66.310	67.299	68.111	68.808	**86**
87	54.218	57.072	58.441	62.060	63.872	65.897	67.205	68.202	69.021	69.724	**87**
88	55.010	57.887	59.267	62.915	64.742	66.782	68.101	69.106	69.932	70.640	**88**
89	55.804	58.704	60.095	63.772	65.612	67.669	68.998	70.011	70.843	71.557	**89**
90	56.598	59.526	60.923	64.629	66.484	68.556	69.896	70.917	71.755	72.474	**90**
91	57.394	60.344	61.753	65.487	67.356	69.444	70.794	71.823	72.668	73.393	**91**
92	58.192	61.164	62.584	66.346	68.229	70.333	71.693	72.730	73.581	74.311	**92**
93	58.990	61.985	63.416	67.206	69.103	71.222	72.593	73.637	74.495	75.231	**93**
94	59.789	62.807	64.248	68.067	69.978	72.113	73.493	74.545	75.410	76.151	**94**
95	60.590	63.630	65.082	68.928	70.853	73.004	74.394	75.454	76.325	77.072	**95**
96	61.392	64.454	65.917	69.791	71.729	73.896	75.296	76.364	77.241	77.993	**96**
97	62.194	65.279	66.752	70.654	72.606	74.788	76.199	77.274	78.157	78.915	**97**
98	62.998	66.105	67.589	71.518	73.484	75.681	77.102	78.185	79.074	79.837	**98**
99	63.803	66.932	68.426	72.383	74.363	76.575	78.006	79.096	79.992	80.760	**99**
100	64.609	67.760	69.265	73.248	75.242	77.469	78.910	80.008	80.910	81.684	**100**
101	65.416	68.589	70.104	74.115	76.122	78.364	79.815	80.920	81.829	82.608	**101**
	0.00001	**0.00005**	**0.0001**	**0.0005**	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.006**	

n	Grade of Service										n
	0.007	0.008	0.009	0.01	0.02	0.03	0.05	0.1	0.2	0.4	
51	37.754	38.134	38.480	38.800	41.189	42.892	45.533	50.644	59.746	82.652	51
52	38.639	39.024	39.376	39.700	42.124	43.852	46.533	51.726	60.985	84.317	52
53	39.526	39.916	40.273	40.602	43.060	44.813	47.534	52.808	62.224	85.981	53
54	40.414	40.810	41.171	41.505	43.997	45.776	48.536	53.891	63.463	87.645	54
55	41.303	41.705	42.071	42.409	44.936	46.739	49.539	54.975	64.702	89.310	55
56	42.194	42.601	42.972	43.315	45.875	47.703	50.543	56.059	65.942	90.974	56
57	43.087	43.499	43.875	44.222	46.816	48.669	51.548	57.144	67.181	92.639	57
58	43.980	44.398	44.778	45.130	47.758	49.635	52.553	58.229	68.421	94.303	58
59	44.875	45.298	45.683	46.039	48.700	50.602	53.559	59.315	69.662	95.968	59
60	45.771	46.199	46.589	46.950	49.644	51.570	54.566	60.401	70.902	97.633	60
61	46.669	47.102	47.497	47.861	50.589	52.539	55.573	61.488	72.143	99.297	61
62	47.567	48.005	48.405	48.774	51.534	53.508	56.581	62.575	73.384	100.96	62
63	48.467	48.910	49.314	49.688	52.481	54.478	57.590	63.663	74.625	102.63	63
64	49.368	49.816	50.225	50.603	53.428	55.450	58.599	64.750	75.866	104.29	64
65	50.270	50.723	51.137	51.518	54.376	56.421	59.609	65.839	77.108	105.96	65
66	51.173	51.631	52.049	52.435	55.325	57.394	60.619	66.927	78.350	107.62	66
67	52.077	52.540	52.963	53.353	56.275	58.367	61.630	68.016	79.592	109.29	67
68	52.982	53.450	53.877	54.272	57.226	59.341	62.642	69.106	80.834	110.95	68
69	53.888	54.361	54.793	55.191	58.177	60.316	63.654	70.196	82.076	112.62	69
70	54.795	55.273	55.709	56.112	59.129	61.291	64.667	71.286	83.318	114.28	70
71	55.703	56.186	56.626	57.033	60.082	62.267	65.680	72.376	84.561	115.95	71
72	56.612	57.099	57.545	57.956	61.036	63.244	66.694	73.467	85.803	117.61	72
73	57.522	58.014	58.464	58.879	61.990	64.221	67.708	74.558	87.046	119.28	73
74	58.432	58.930	59.384	59.803	62.945	65.199	68.723	75.649	88.289	120.94	74
75	59.344	59.846	60.304	60.728	63.900	66.177	69.738	76.741	89.532	122.61	75
76	60.256	60.763	61.226	61.653	64.857	67.156	70.753	77.833	90.776	124.27	76
77	61.169	61.681	62.148	62.579	65.814	68.136	71.769	78.925	92.019	125.94	77
78	62.083	62.600	63.071	63.506	66.771	69.116	72.786	80.018	93.262	127.61	78
79	62.998	63.519	63.995	64.434	67.729	70.096	73.803	81.110	94.506	129.27	79
80	63.914	64.439	64.919	65.363	68.688	71.077	74.820	82.203	95.750	130.94	80
81	64.830	65.360	65.845	66.292	69.647	72.059	75.838	83.297	96.993	132.60	81
82	65.747	66.282	66.771	67.222	70.607	73.041	76.856	84.390	98.237	134.27	82
83	66.665	67.204	67.697	68.152	71.568	74.024	77.874	85.484	99.481	135.93	83
84	67.583	68.128	68.625	69.084	72.529	75.007	78.893	86.578	100.73	137.60	84
85	68.503	69.051	69.553	70.016	73.490	75.990	79.912	87.672	101.97	139.26	85
86	69.423	69.976	70.481	70.948	74.452	76.974	80.932	88.767	103.21	140.93	86
87	70.343	70.901	71.410	71.881	75.415	77.959	81.952	89.861	104.46	142.60	87
88	71.264	71.827	72.340	72.815	76.378	78.944	82.972	90.956	105.70	144.26	88
89	72.186	72.753	73.271	73.749	77.342	79.929	83.993	92.051	106.95	145.93	89
90	73.109	73.680	74.202	74.684	78.306	80.915	85.014	93.146	108.19	147.59	90
91	74.032	74.608	75.134	75.620	79.271	81.901	86.035	94.242	109.44	149.26	91
92	74.956	75.536	76.066	76.556	80.236	82.888	87.057	95.338	110.68	150.92	92
93	75.880	76.465	76.999	77.493	81.201	83.875	88.079	96.434	111.93	152.59	93
94	76.805	77.394	77.932	78.430	82.167	84.862	89.101	97.530	113.17	154.26	94
95	77.731	78.324	78.866	79.368	83.134	85.850	90.123	98.626	114.42	155.92	95
96	78.657	79.255	79.801	80.306	84.100	86.838	91.146	99.722	115.66	157.59	96
97	79.584	80.186	80.736	81.245	85.068	87.826	92.169	100.82	116.91	159.25	97
98	80.511	81.117	81.672	82.184	86.035	88.815	93.193	101.92	118.15	160.92	98
99	81.439	82.050	82.608	83.124	87.003	89.804	94.216	103.01	119.40	162.59	99
100	82.367	82.982	83.545	84.064	87.972	90.794	95.240	104.11	120.64	164.25	100
101	83.296	83.916	84.482	85.005	88.941	91.784	96.265	105.21	121.89	165.92	101
	0.007	0.008	0.009	0.01	0.02	0.03	0.05	0.1	0.2	0.4	

RADIO ENGINEERING SOLUTIONS

Extract of Optimisation Project Example Report

AIRCOM
INTERNATIONAL

Revision History

Revision	Date	Name	Comments

Objective

This document is a summary of an example Optimisation Project. The project took place in a European network between June 1999 and June 2000, and achieved substantial performance improvements through the application of a methodical process of problem identification, analysis and corrective action.

Project Summary

The first stage in a network optimisation project is to establish a set of key metrics defining system performance, and then to assess network performance according to these chosen metrics.

A Network Performance Review was carried out according to the process defined in the document 'Process for Network Performance Audit'. Following from this, a network status review was carried out to help understand the current issues, as summarised below:

Network Design Status Review

2.1.1 Network Design Summary

- **3 MSC**
- 14 BSC
- 316 BTS, 614 Cells
  - 57 3-Sector
  - 184 2-Sector
  - 74 1-Sector
  - 1 Omni
  - 13 1-carrier, 237 2-carrier, 272 3-carrier, 91 4-carrier, 1 5-carrier
- 35 BTS in original RF plan - High Sites (most 4/4/4)
- Aggressive rollout planned (2000 sites in 12 months)

2.1.2 Spectrum Allocation

- 10MHz Spectrum Allocated

	(10)
	(40)
Total	(50)

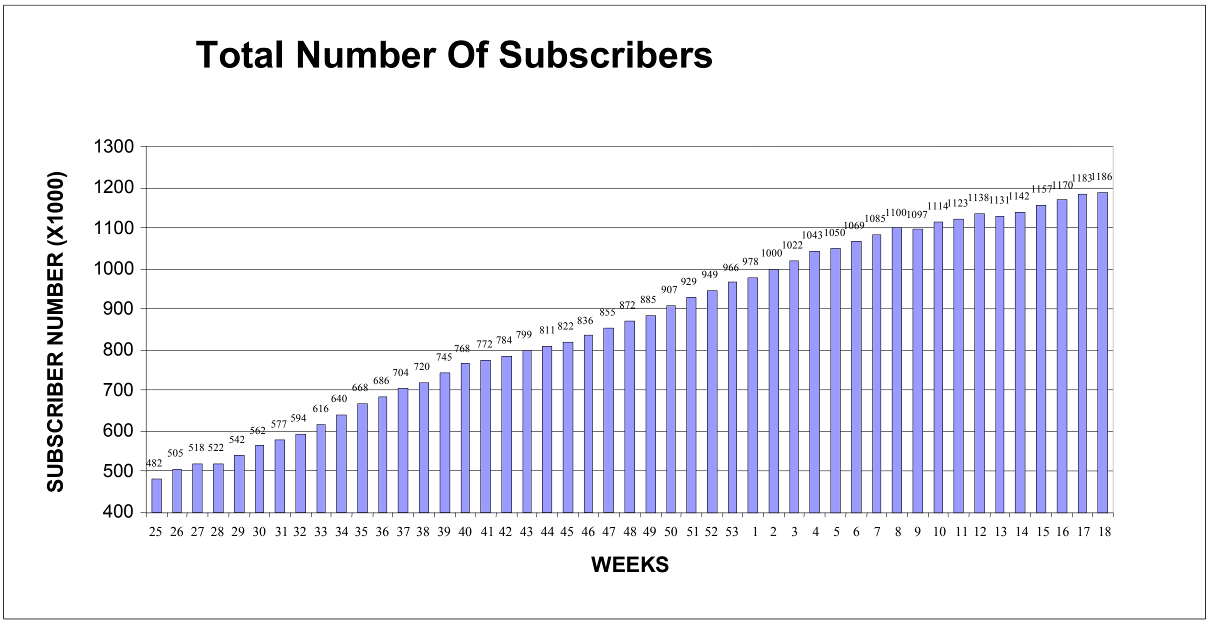
- Channels 50 & 56 not used due to BSS H/W issue.

- Channels 70-75 uplink interfered by US cordless phones.

2.1.3 RF Design and Frequency Plan

- BCCH Plan:
  - 21-30 and 40-49 (20 Channels total)
- 1x1 SFH Plan:
  - Low Sites: 51-68 (18 Channels)
  - High Sites: 62-79 (18 Channels)
  - Common channels (low + high): 62-68 (7 channels)
- RF design and BCCH plan very irregular.
- Old sites are very high and new sites are generally very low (microcell design, below roof height).
- Umbrella-cell effect of high sites impacts quality of BCCH and hopping plans.

2.1.4 Subscriber Growth



2.2 Summary of Identified Issues

Based on observations, issues were categorised as follows:

- O&M (Operations and Maintenance)
- BSS (Base Station Subsystem) Database Optimisation
- BSS Design
- RF Design and Optimisation

2.2.1 O&M Issues

- Clock calibration and Synch issues.
- Field Calibration of TRX's.
- Performance monitoring, analysis and troubleshooting seems to be inadequate.
- Poorly performing cells often take too long to fix.
- No external alarms at any BSS sites.
- No air-conditioning at some sites.
- Regular maintenance seems to be inadequate.

2.2.2 BSS Database Optimisation

- Inconsistency of some cell parameters:
  - Ul/Dl power control
  - RxQual and Intracell HO's
  - Channel resource parameters (SDCCH, CCCH etc)
  - Call setup timers and handover timers
- Possible neighbour list problems:
  - Missing or 1-way neighbours
  - Co-channel neighbours
- LAC planning not optimum - high SDCCH usage.
- Most parameters set on BSC basis - not enough time for cell-wise optimisation.
- Ineffective change control procedure - no master DB.

2.2.3 BSS Design Issues

- Some inappropriate hardware configurations not fully supporting Synthesiser Frequency Hopping
- Inappropriate choice of TX combining at some sites leading to reduction of coverage after site expansion. Use X-polar antennas and air-combining.

- Incorrect antennas at some sites due to stock availability issues or site acquisition constraints.
- No diversity at some sites due to antenna availability and/or site design constraints. May be important for some sites, but generally not for micro's.

2.2.4 RF Design and Optimisation Issues

- Poor performance of hopping system due to RF design issues - poor speech quality.
- Antenna downtilt or change required for many sites. Detailed report submitted by local team 3-4 months ago. Some work done but not enough. Low priority for operator due to fast rollout and limited resources.
- Umbrella sites causing quality problems. Need to de-commission or lower antennas asap. Plan in place but is dependent on integration of new sites.
- Co-BCCH Co-BSIC interference problems - only 1 NCC, need to plan more.
- External interference issues, especially uplink.

2.3 Action Plan

The following outline action plan was developed, based on the observed performance issues:

Categorise activities to align with issues:

- O&M activities
- BSS Site Design and Performance Review
- Database Review and Optimisation
  - Cell-specific
  - Network-wide
- RF Design and Frequency Planning Optimisation
- Change Control Procedure

2.3.1 O&M Activities

- Investigation and rectification of Top Ten bad cells.
  - Prioritise from weekly report and daily events.
  - Analysis with call trace and stats.
- Clock calibration.
  - Replace faulty clocks.
  - Re-implement clock Sync and monitor.

- Set up OMC tools and use for performance monitoring - performance-related ‘alarms’.
- Implementation of External Alarms.
- Implement ‘O&M Best Practices’ as per recommendations
- Review regular maintenance activities.

2.3.2 BSS Site Design and Performance Review

- Prioritise on per-BSC basis
- Collect call trace data for all cells and analyse with call trace tools.
- Closer analysis of BSS statistics.
- A-Interface analysis
- Analyse and identify problems:
  - Hardware failures
  - Cabling errors
  - Antenna optimisation issues (incl. choice of antenna)
  - BSS design problems (diversity, combining etc.)
  - Frequency Plan and external interference problems
  - Calibration problems
- Feed into site problem report for O&M attention.
- Feed into planning group for RF optimisation issues.
- Feed into BSS/Database design group for database changes.

2.3.3 BSS Database Optimisation

- Review and agree global parameter settings:
  - Handover and Power Control
  - Congestion Relief
  - DTX
  - Call Setup and Handover timers
- Review LAC plan and paging parameters.
- Ensure consistency of parameters across databases.

2.3.4 RF Design and Frequency Plan

- Hopping Plan Performance
  - Further separation of frequency allocations between high and low sites.
  - Gradual reduction in traffic at high sites:
  - Modify Congestion Relief parameters for high sites
  - Investigate use of microcellular HO's where underlay exists
  - Reduce traffic and number of carriers gradually
- BCCH Plan Performance
  - Suggest BCCH frequency changes where problems identified.
  - Co-BCCH Co-BSIC interference
  - Assist operator in re-planning with additional NCC's

2.3.5 Database Change Control

- Assist operator in implementing effective change control procedures:
- Keep master database record
- Strict change management and removal of unauthorised changes/trials
- Use of tools: Identify suitable database management tools

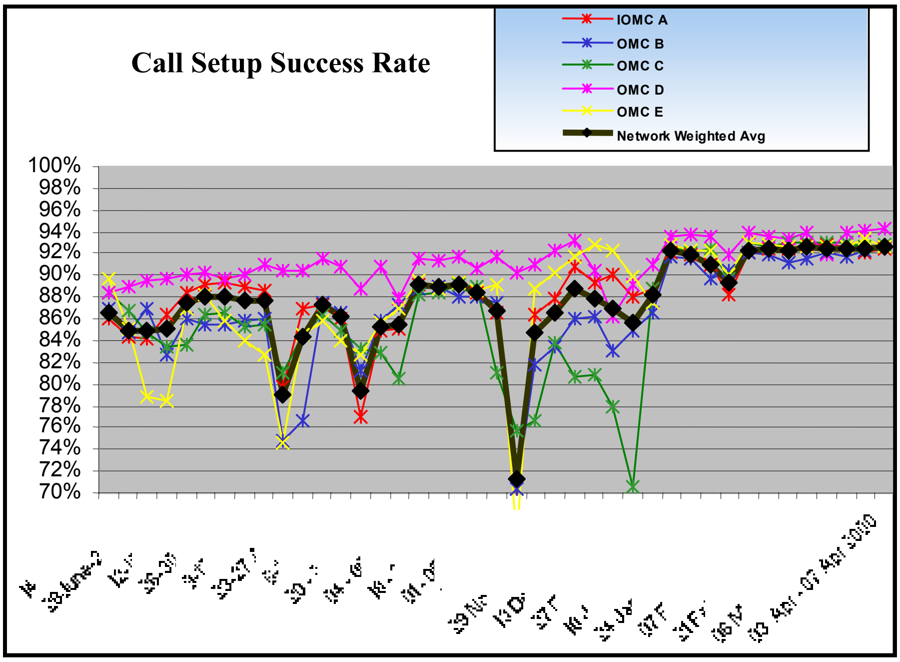
3 ACTION PLAN EXAMPLE

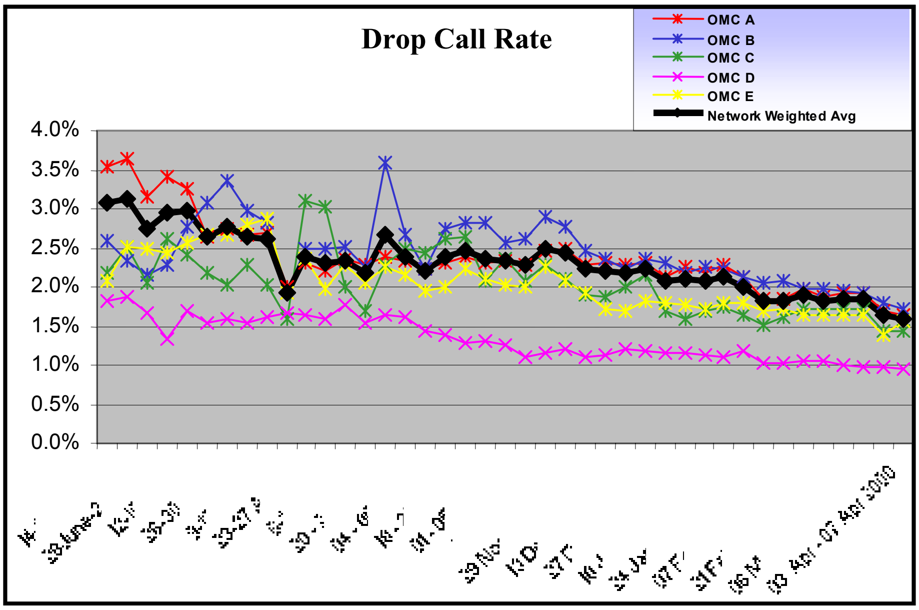
Below is an example of an action plan spreadsheet used to track progress in this project. Many more detailed spreadsheets were used to track each activity.

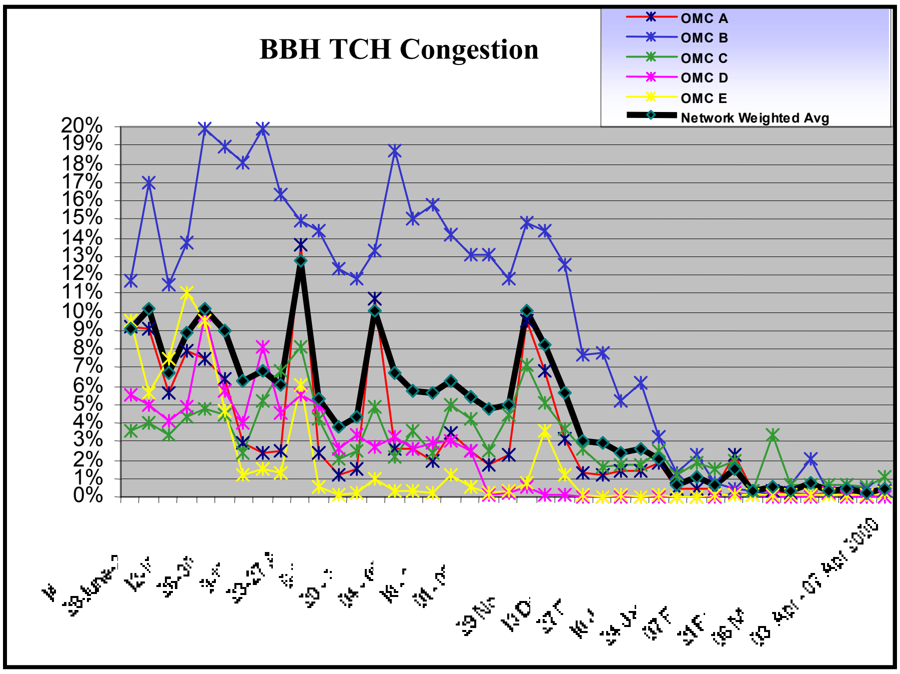
No.	Issue Description	Action	Respon-sibility	Comments	Target	Complete
1	Hopping channels optimisation	Separate hopping allocations for umbrella cells and other cells. Temporary solution pending action on umbrella sites issue. Implement and benchmark to measure effectiveness.	Joint	Drive test being undertaken before and after to assess impact	########	
2	Call re-establishment enabled in BSS but not supported by MSC. Unnecessary SDCCH usage.	Disable call re-establishment feature in BSS.	Joint	To be reestablished when MSC feature enabled	########	
3	Congestion Relief optimisation	Review use of congestion relief feature and re-optimise if required.	Joint	Screen Istanbul BSS Database at a rate of one (raising to two) BSC per week and correct inconsistencies. Use Datagen screening tool.	As BSCs are audited	
4	Power control and RxQual handover parameters inconsistent.	Review power control and RxQual parameters per cell and correct if required.	Joint	Screen Istanbul BSS Database at a rate of one (raising to two) BSC per week and correct inconsistencies. Use Datagen screening tool.	As BSCs are audited	
5	Some database errors, and no master database record. Change control procedure not effective.	Audit all BSC databases and correct any mistakes. Create master database. Implement strict change control procedure to ensure master database is updated for every approved change.	Joint	Set up a Network Database Administration team to establish processes and provide training on Network Management and Administration Tools.	As BSCs are audited	
6	High SDCCH congestion at some sites.	Review location area planning and improve if possible. Review SDCCH allocation at affected sites.	Joint	Conclusion and recommendation to be available next week	########	
7	Channel 50/56 problem	Sites are being retrofitted starting with those currently using Ch 50-56	Joint	Sites will be completed at a rate in excess than 100 per week	TBD	
8	External interference in some uplink channels from cordless phones (Channels 70-74)	Ensure interfered channels are not used for BCCH. Also minimise their use in hopping carriers where possible.	Joint	Collect evidence of such interference (Spectrum Analyzer) and write a report to claim to the Telecommunications Authority	TBD	
9	Some cells performing very badly (Top Ten Report/Action Plan)	Investigate performance problems on per-cell basis according to Top Ten priority. Identify problems (RF, O&M, Database etc.) and rectify. Use CTP. Revise Top Ten Report regularly.	Joint	Identify the affected sites via CTP. Top ten sites to be reviewed on a weekly basis.	Every week starting 31/05/99	
10	Coverage reduction due to combining losses.	Review combining arrangements at critical cells. Use air combining and duplexers to overcome problem. Antenna change if necessary.	Joint	Identify the affected sites for Motorola to provide site audit, recommendations and solutions	########	
11	No diversity at some cells - contributing to poor uplink in places.	Establish which cells are operating without diversity. Find out why and correct if possible with cross-polar antennas and duplexers.	Joint	Identify the affected sites for Motorola to provide site audit, recommendations and solutions	########	
12	GCLK Calibration status unclear. Confusion about use of GCLK Sync feature.	Clarify status of GCLK calibration. Provide explanation for use of GCLK Sync feature, and investigate its effectiveness based on link quality.	Joint	Responded in letter	########	
13	TCU/DRCU calibration requirements unclear.	Review the field procedures for changing radios. Use of store_cal_data feature, or TX and bay level calibration.	Joint	Responded in letter	########	
14	Antenna downtilting (except for umbrella sites) required to reduce interference.	Coverage analysis for existing sites done using CTP. Review downtilt plan, prioritise and implement.	Joint	Assist in prioritising antenna downtilting. A top-ten list of antenna downtilting/changes (excluding umbrella sites) to be implemented and monitored on a weekly basis	########	
15	Antennas not ideal at some sites, causing some interference problems.	Review antennas types used at all existing and new sites. List sites which require antenna change and prioritise.	Joint	Assist in identifying and prioritising antenna changes, to be implemented and monitored on a weekly basis	########	
16	Umbrella sites to be modified or removed to reduce interference and improve frequency re-use.	Review plan for removing/lowering existing high umbrella sites. Prioritise and implement.	Joint	Expedite the acquisition and build of replacement sites	End of August	
17	High TCH congestion at some sites.	Review rollout plan and re-prioritise to tackle congestion if necessary. Identify which new sites are required to reduce congestion.	Joint	Expedite the acquisition and build of replacement sites	End of August	
18	Stats reporting to track performance improvements	Archive unload stats from OMC every 5-7 days, for later use on MARS. Produce weekly summary report per BSC to track changes.	Motorola	Stats being archived now on a daily basis	Every week starting 31/05/99	
19	Co-channel co-BCCH interference issue	plan extra NCC's?	Telsim	Replan the BSIC plan and inform of the new NCCs used	########	

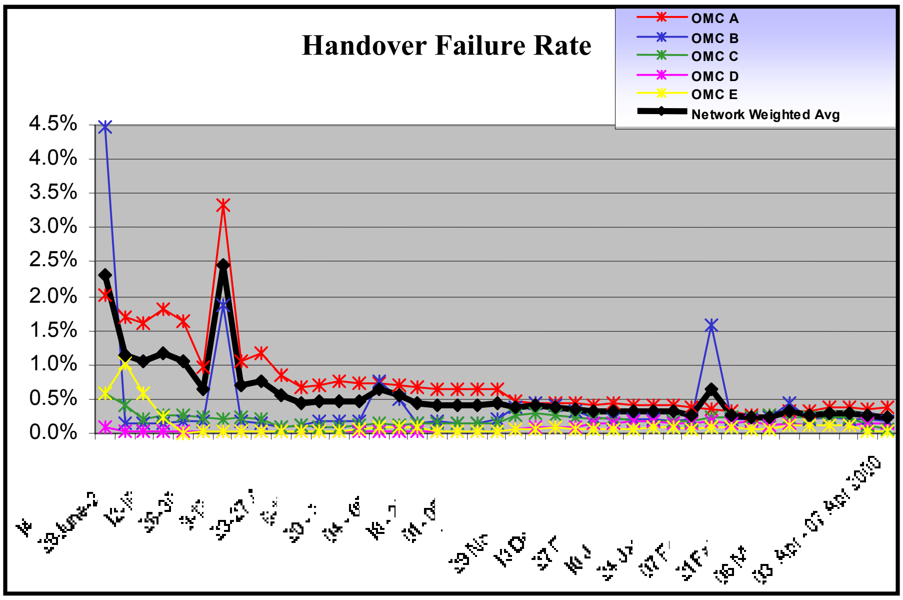
4 Results

The following results show the change in key performance metrics over the course of the optimisation project. They show a dramatic improvement in network performance.






BBH TCH Congestion
OMC A
OMC B
OMC C
OMC D
OMC E
Network Weighted Avg
20%
19%
18%
17%
16%
15%
14%
13%
12%
11%
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%


Handover Failure Rate
OMC A
OMC B
OMC C
OMC D
OMC E
Network Weighted Avg
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%