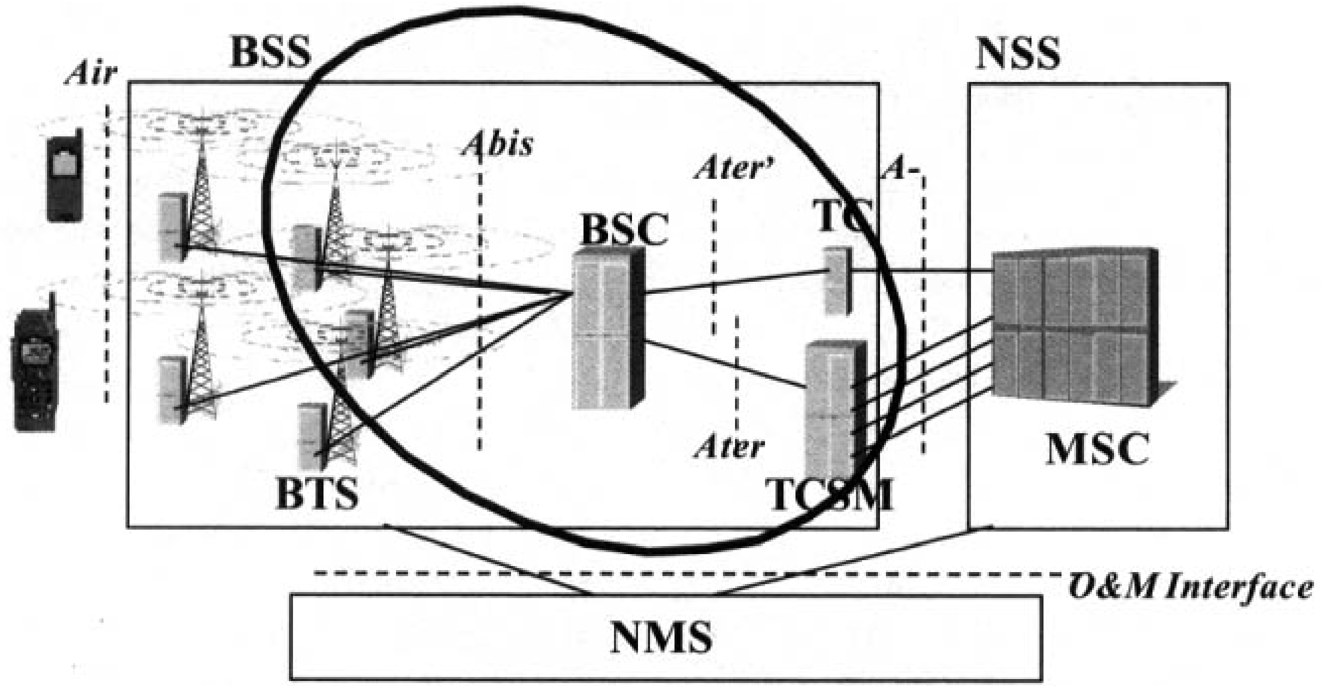
Transmission Network Planning and Optimization of 2G

The Scope of Transmission Network Planning

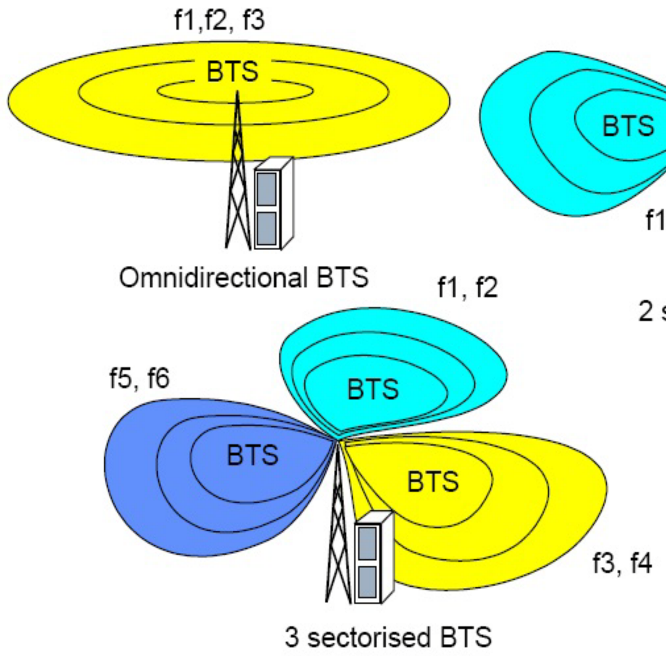
- The network between the base stations and the transcoder sub-multiplexers (TSCM).
- Connects the radio network to the mobile switching center (MSC).

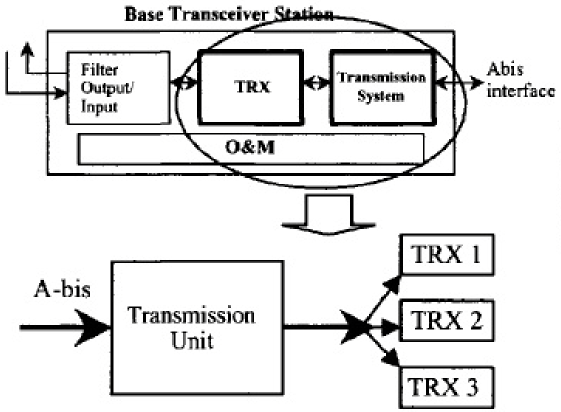


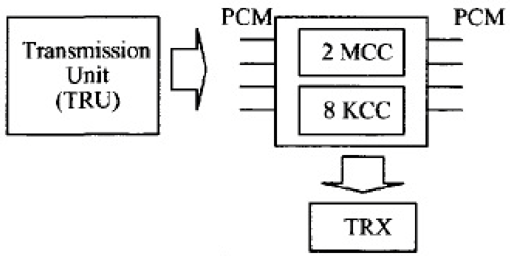
Elements in a Transmission Network

• BTS: The base station consists of a transmission unit (TRU). This unit interacts with the A_{bis} and A_{ter} interfaces.

•It also reallocates the traffic and the signaling channels to the correct transceiver (TRX).





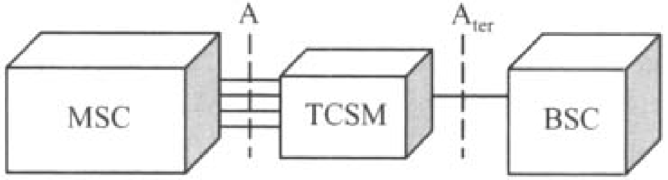


Base *Station Controller*

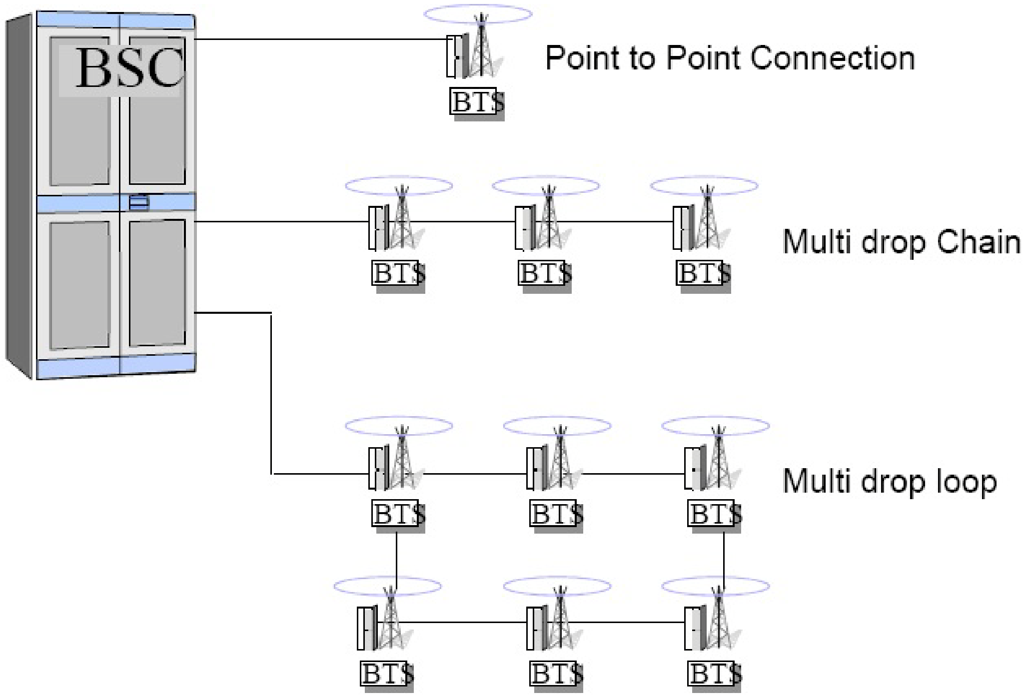
- BSC plays a role of a small digital exchange.
- It can be connected to many BTSs and it offloads a great deal of processing from MSC One BSC connects to several tens to couple of hundred BTS
- Radio channel management, Handover management and assessment of signal power, signal quality at the MS in both the uplink and downlink directions.
- Adjustments related to the minimization of interference in the radio network.
- Operation and maintenance & Power control

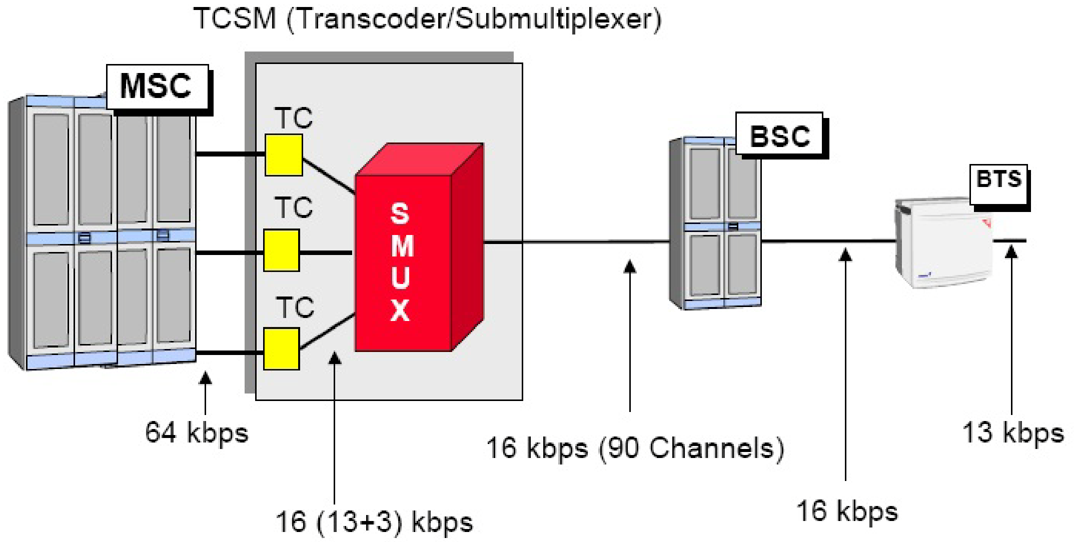
Transcoder and Sub-multiplexer (TCSM)

- The TCSM is capable of two functions: transcoding of speech signals and sub-multiplexing of PCM signals. The transcoder does the speech coding in the MS in downlink direction, and it decodes the speech signal in the uplink direction (13kbps to 64 kbps and vice versa)
- Sub-multiplexers are located at the same place as the transcoders and are responsible for multiplexing of the PCM links between the BSC and the MSC.

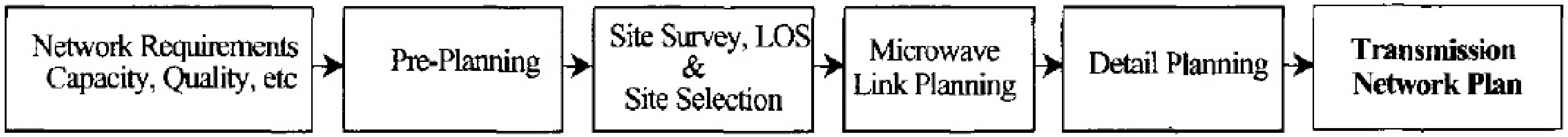


Transmission between BTS and BSC





TRANSMISSION NETWORK PLANNING PROCESS



- Includes five main phases before the final plan is generated.
- Begins with data collection, including the requirements for capacity and quality that lay the foundation of the whole process.
- Transmission planning including link budget calculations, topologies that can be used, etc.
- The pre-planning phase focuses on the dimensioning aspects of the transmission network. The pre-planning starts with the inputs from the radio planning engineers (no. of BTS, BSC, topology).
- Selection of sites is basically to find sites that have the desired lines of sight (LOS) with other sites. The line-of-sight process should be done very professionally, because once a site is *constructed* and there is no LOS with another site, that represents a big loss for the network owner.
- When microwave is the chosen medium of transmission, link budget calculations are generally based on ITU recommendations.
- The detailed planning phase consists of frequency allocation/frequency planning, defining of the time slot allocation plans, routing of the PCM signals, synchronization principles, and network management planning.

PRE-PLANNING IN TRANSMISSION NETWORK

- The task of a transmission planning engineer will be to connect BTS sites with BSC of the existing network infrastructure.
- This process is dependent upon the traffic generated by each base station, the ability to cross-connect and groom each site so as to make complete use of the PCM links.
- One PCM line consists of 32 time slots.
- Time slot 0 (TSO) is used for link management.
- TS1 to TS31 are used for traffic and signaling.
- The bit rate of each TS is 64kbps.
- Depending on the type of signaling the TCH can be 16, 32 or 64kbps.
- The PCM shown in Figure is the PCM on the A_{bis} interface.
- It contains the TCHs that carry the traffic from the transceiver (TRX)

Bits

Time slots	1 2	3 4	5 6	7 8
0	LINK MANAGEMENT			
1	TCH.1	TCH.2	TCH.3	TCH.4
2	TCH.5	TCH.6	TCH.7	TCH.8
3	TCH.1	TCH.2	TCH.3	TCH.4
4	TCH.5	TCH.6	TCH.7	TCH.8
5	TCH.1	TCH.2	TCH.3	TCH.4
6	TCH.5	TCH.6	TCH.7	TCH.8
7	TCH.1	TCH.2	TCH.3	TCH.4
8	TCH.5	TCH.6	TCH.7	TCH.8
9	TCH.1	TCH.2	TCH.3	TCH.4
10	TCH.5	TCH.6	TCH.7	TCH.8
11	TCH.1	TCH.2	TCH.3	TCH.4
12	TCH.5	TCH.6	TCH.7	TCH.8
13	TCH.1	TCH.2	TCH.3	TCH.4
14	TCH.5	TCH.6	TCH.7	TCH.8
15	TCH.1	TCH.2	TCH.3	TCH.4
16	TCH.5	TCH.6	TCH.7	TCH.8
17	TCH.1	TCH.2	TCH.3	TCH.4
18	TCH.5	TCH.6	TCH.7	TCH.8
19	TCH.1	TCH.2	TCH.3	TCH.4
20	TCH.5	TCH.6	TCH.7	TCH.8
21	TCH.1	TCH.2	TCH.3	TCH.4
22	TCH.5	TCH.6	TCH.7	TCH.8
23	TCH.1	TCH.2	TCH.3	TCH.4
24	TCH.5	TCH.6	TCH.7	TCH.8
25	TRXSIG1	OMUSIG1	TRXSIG2	OMUSIG2
26	TRXSIG3	OMUSIG3	TRXSIG4	OMUSIG4
27	TRXSIG5	OMUSIG5	TRXSIG6	OMUSIG6
28	TRXSIG7	OMUSIG7	TRXSIG8	OMUSIG8
29	TRXSIG9	OMUSIG9	TRXSIG10	OMUSIG10
30	TRXSIG11	OMUSIG11	TRXSIG12	OMUSIG12
31	x	x	x	x

PCM Requirements on the A_{bis} and A_{ter} Interface

- Blocking parameters need to be defined also for the Abis and Ater interfaces. Typically, the value of the air-interface blocking is 1-2% and that of the Ater interface is 0.1-0.5%.
- Radio planning engineers determine the number of BTS and transceivers in the network.
- Transmission planners start with information about the radio planning dimensioning, i.e. the number of transceivers per base station.
- One TRX needs 2 x 64 kbps time slots, while for the signaling 16, 32 or 64 kbps time slots may be required.
- Once that is done, then based on the number of channels that can be multiplexed on the A_{ter}, the capacity of the A_{ter} interface can be calculated.

Example: Capacity requirements on the Ater interface

Assume, that radio planners have decided that there are five sites of 2 + 2 configuration under a single BSC. Air interface blocking is 2% and Ater 0.1%

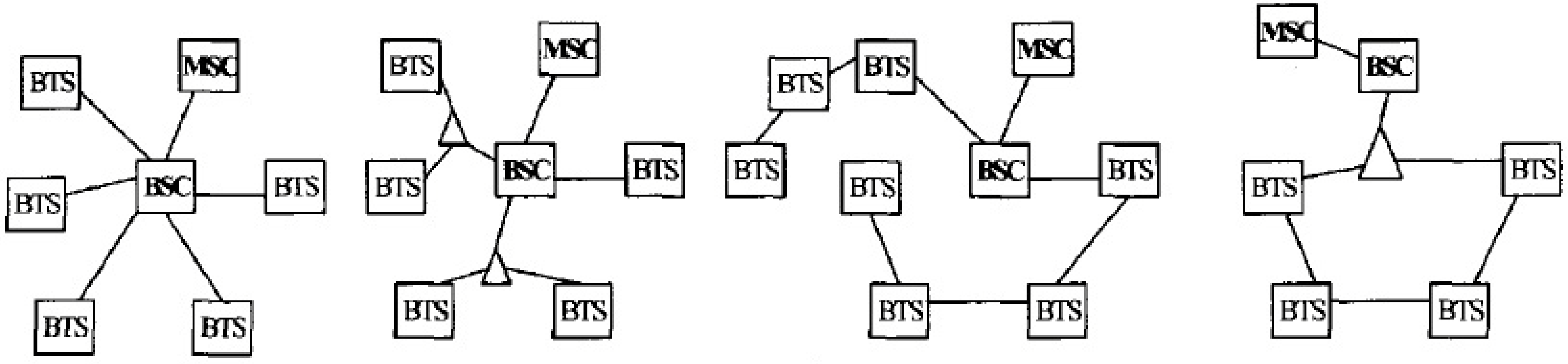
5 sites of 2 + 2 configuration = 10 cells, each having 15 TCH

- Air interface blocking = 2%
- Using Erlang B tables, 15 TCH support = 9.07 Erl of traffic.
- Traffic offered to the BSC = 10 x 9.01 = 90.1 Erl.
- If A_{te}r blocking probability is 0.1%, then the number of traffic channels supported =117(approx.)
- If the number of traffic channels that can be multiplexed on the Ater = 120
- Then A_{ter} interface capacity would be = 117/120=0.975 ~ 1 El

Equipment Location

The base station and TCSM locations need to be decided during the nominal planning phase itself. For Example :If the TCSMs were placed physically near the MSC, it would save transmission costs.

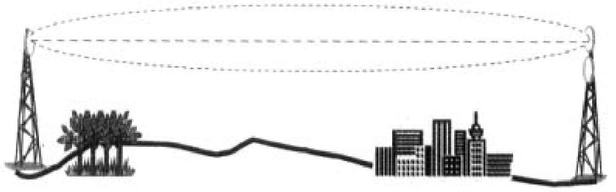
Network Topology

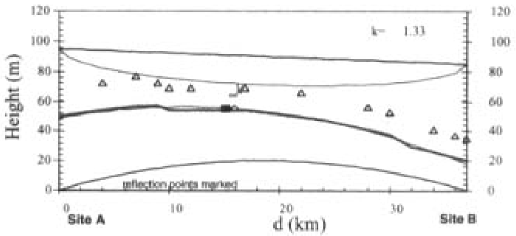


Point-to-Point topology   Star topology   Chain topology   Loop topology

Site Selection and Line-of-Sight Survey

- Transmission planning engineers prefer sites that are very high, so that connectivity to a large number of other sites is possible.

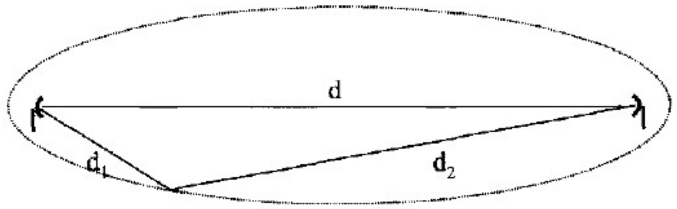




Line-of Sight Survey

- Area that is covered by an imaginary ellipsoid drawn between the transmitting and receiving antennas in such as way that the distance covered by the ray being reflected from the surface of the ellipsoid and reaching the receiving antenna is half a wavelength longer than the distance covered by the direct ray travelling from the transmitting to the receiving antennas, i.e.

$$d_1 + d_2 = d + \lambda/2.$$



The Fresnel zone is dependent upon two factors: frequency of transmission and the distance covered. Mathematically, the radius of the Fresnel zone can be calculated as:

$$F_1 = 12.75(d_1^* d_2 / f^* D)^{1/2}$$

Microwave Link Planning

Link Budget Calculations

- The aim of link budget calculations is to find out what path length would be suitable for getting the desired signal level. This received signal level is then used for calculation of the fade margin.

$$\mathrm{FSL}\ (L_{\mathrm{fs}}) = 92.5 + 20\log d + 20\log f \tag{3.2}$$

The second factor required is the gain of the antenna. The antenna should have sufficient gain so as to receive the signal at a desired level. The gain of a microwave antenna is given as:

$$G = 10\log(4\pi^* A^* e/\lambda^2) \tag{3.3}$$

where G is the gain of the antenna in dB, A is the area of the antenna aperture, e is the efficiency of the antenna, and λ is the wavelength (same units as A). Equation 3.3 can also be written as (for parabolic antennas):

$$G = 20\log D_{\mathrm{a}} + 20\log f + 17.5 \tag{3.4}$$

where G is the gain of the antenna in dB, D_{a} is the diameter of the antenna in metres, and f is the frequency of operation in GHz.

Based on the above, the hop loss L_{h} can be calculated as:

$$L_{\mathrm{h}} = L_{\mathrm{fs}} - G_{\mathrm{t}} - G_{\mathrm{r}} + L_{\mathrm{ext}} + L_{\mathrm{atm}} \tag{3.5}$$

where G_{t} is the gain of the transmitting antenna, G_{r} is the gain of the receiving antenna, L_{ext} is extra attenuation (due to radome, etc.), and L_{atm} stands for atmospheric losses due to water vapour and oxygen. The received signal level P_{rx} can then be calculated as:

$$P_{\mathrm{rx}} = P_{\mathrm{t}} - L_{\mathrm{h}}. \tag{3.6}$$

Mathematically, the fade margin can be described as the difference between the received signal power and the receiver threshold (R_{xth}):

$$FM = P_{\mathrm{rx}} - R_{\mathrm{xth}}. \tag{3.7}$$

Example 2: Calculation of fade margin

Calculate the fade margin of a microwave link whose dimensions are as follows:

- Hop length = 10 km, Frequency =15 GHz, Antenna diameter = 0.6 m, Transmit power = 20 dBm Extra attenuation = OdB, Atmospheric attenuation = 0 dB, Receiver threshold = —75 dB

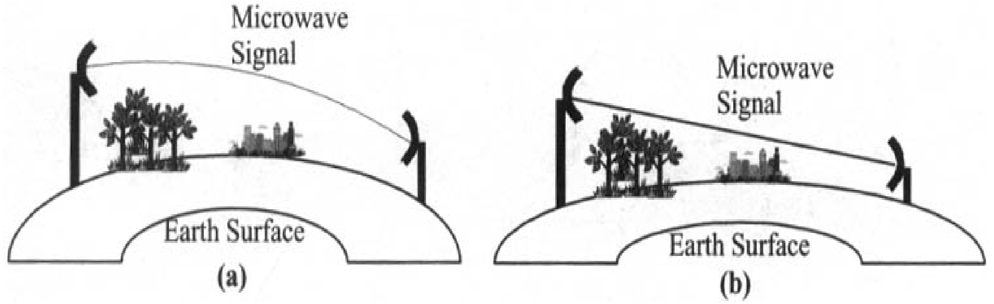
Using equations 3.2 to 3.7:

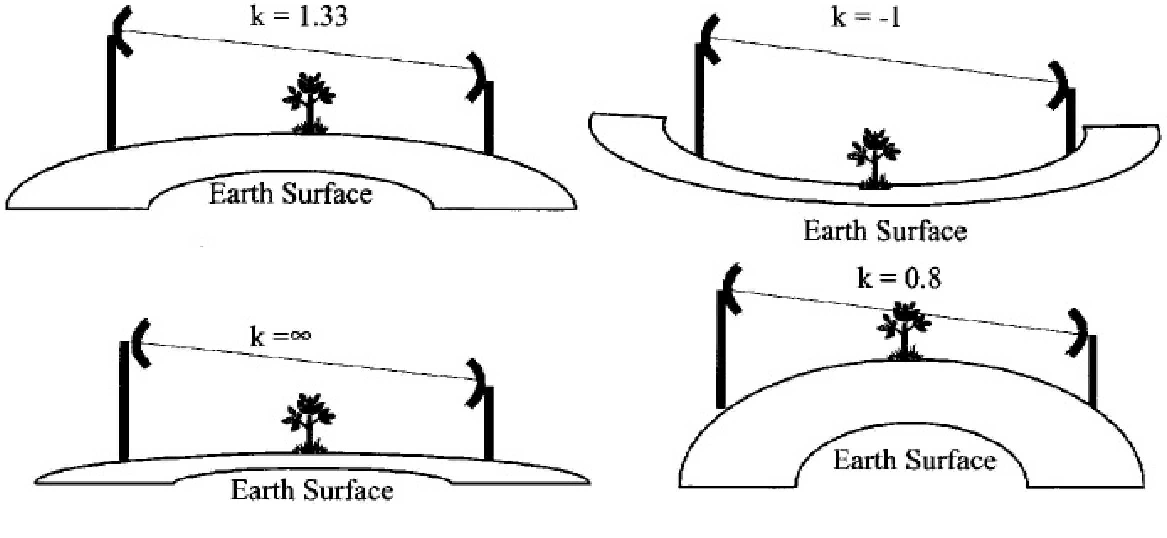
- FSL (Lfs) = 92.5 + 20 log (10) + 20 log (15) = 136.02 dB
- Gain of antenna (Gt and Gr) = 20 log (0.6) + 20 log (15) + 17.5 = 36.58 dBm
- Hop loss (Lh) = 136.02 - 36.58 - 36.58 -0-0 = 62.86 dB
- Received signal level (Prx) = 20- 62.86 = - 42.86 dB

- Thus, Fade Margin (FM) = -42.86 - (-75) = 32.14 dB

Propagation Phenomena

- Microwave signal trajectory
- Refractivity
- Antenna Height
- K Factor





Variation of the *k*-factor

$$\eta = V_{fs} / V_m$$

radio refractivity, N, which is defined as:

$$N = (\eta - 1)^{*}10^6$$

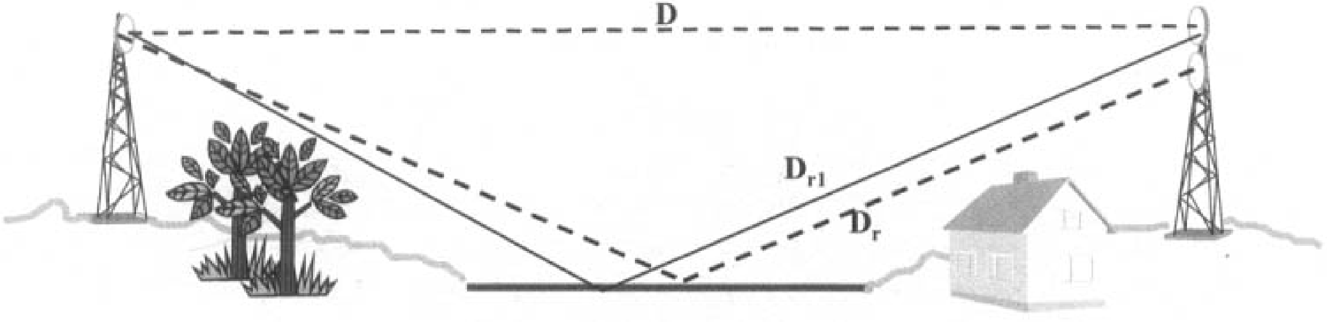
$$3.57\left(\sqrt{Kh_1} + \sqrt{Kh_2}\right)$$

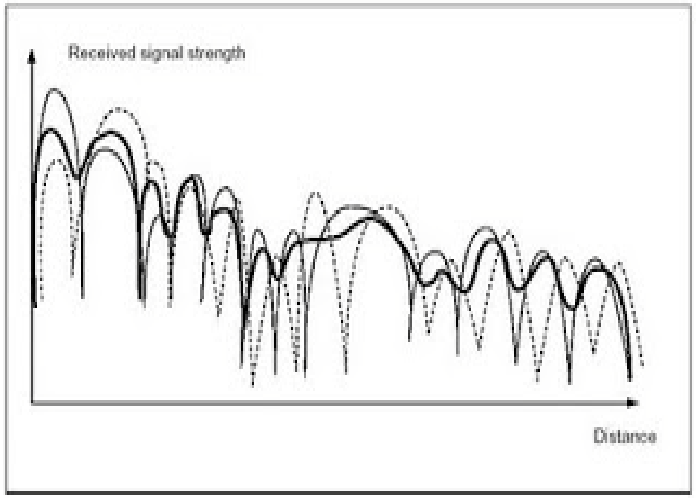
- h_1 = height of antenna one
- h_2 = height of antenna two

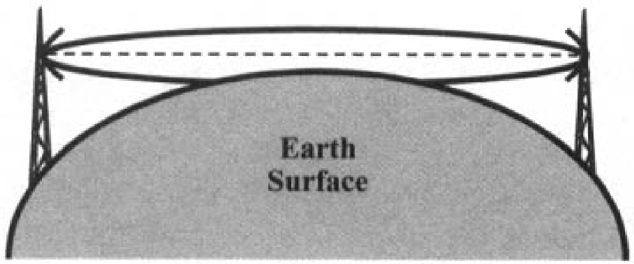
Multipath Propagation

Fading

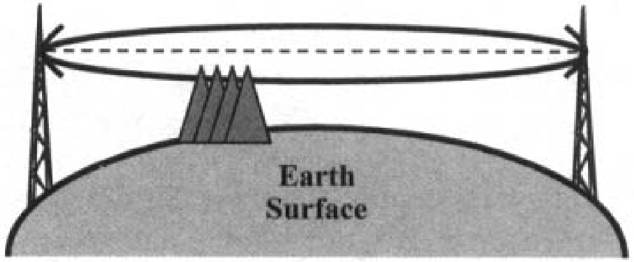
- Flat Fading (Ducting effect and rain attenuation)
- Selective Fading (only one or specific signal is affected)
- K fading (Variations in K factor)
- Diffraction Fading (Smooth and Knife Edge)







Smooth Sphere diffraction



Knife-edge diffraction

Design Principles for a Microwave Link

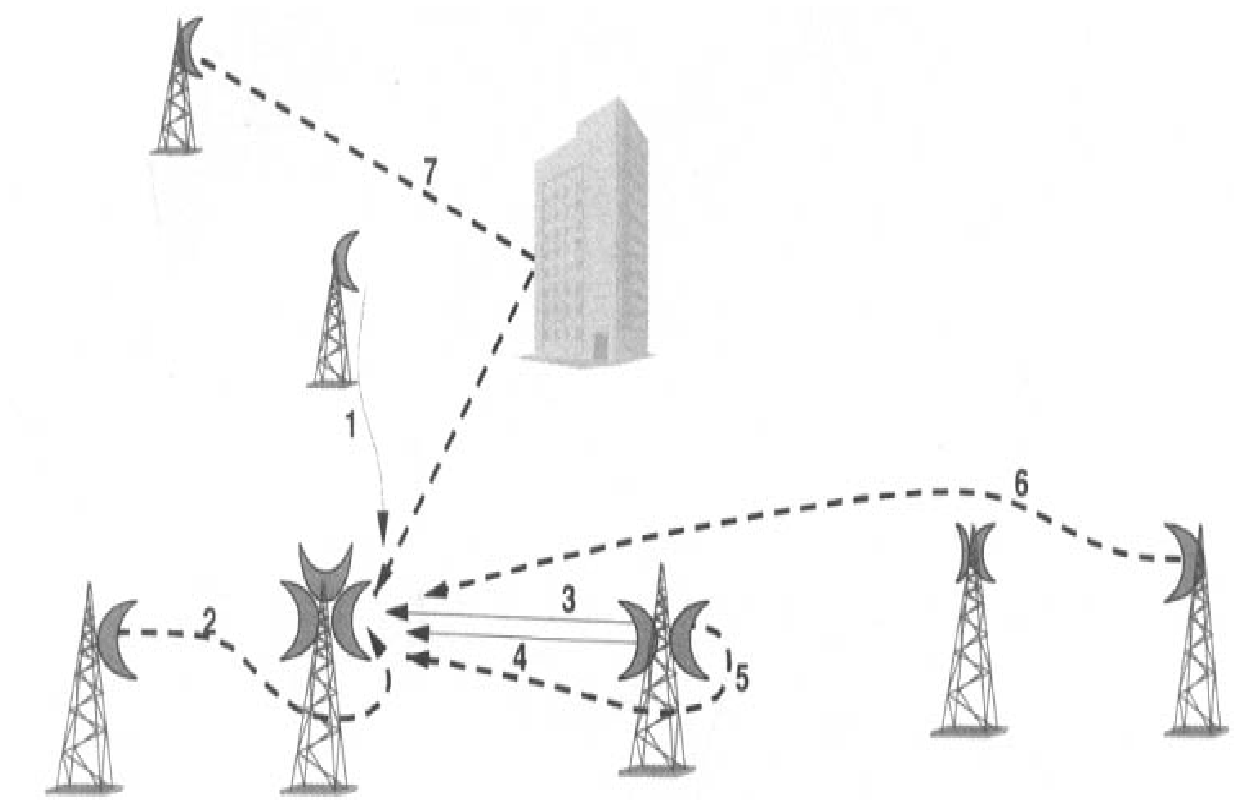
- The fade margin should be sufficiently large. It should be able to handle degradation in the signal level due to rain, multipath fading, k-fading, etc.
- The clearance should be checked for various fade margins — k= 1.33, 0.6, 0.5, etc.
- The first Fresnel zone should be free of obstacles for k = 1.33.
- For hops respectively under or over 15 km, the clearance should be zero for k factors of 0.3 and 0.5.
- Over-water hops should be avoided. If they are unavoidable, the antenna heights should be chosen such that the reflection point is not falling over water.
- In regions where the ducting phenomenon is high, choose higher antennas, as it is easier to move an antenna down rather than up on the tower (especially if the antenna is placed near the top of the tower).
- Choose higher antennas if the probability of k-fading is high in the region.

DETAILED TRANSMISSION NETWORK PLANNING

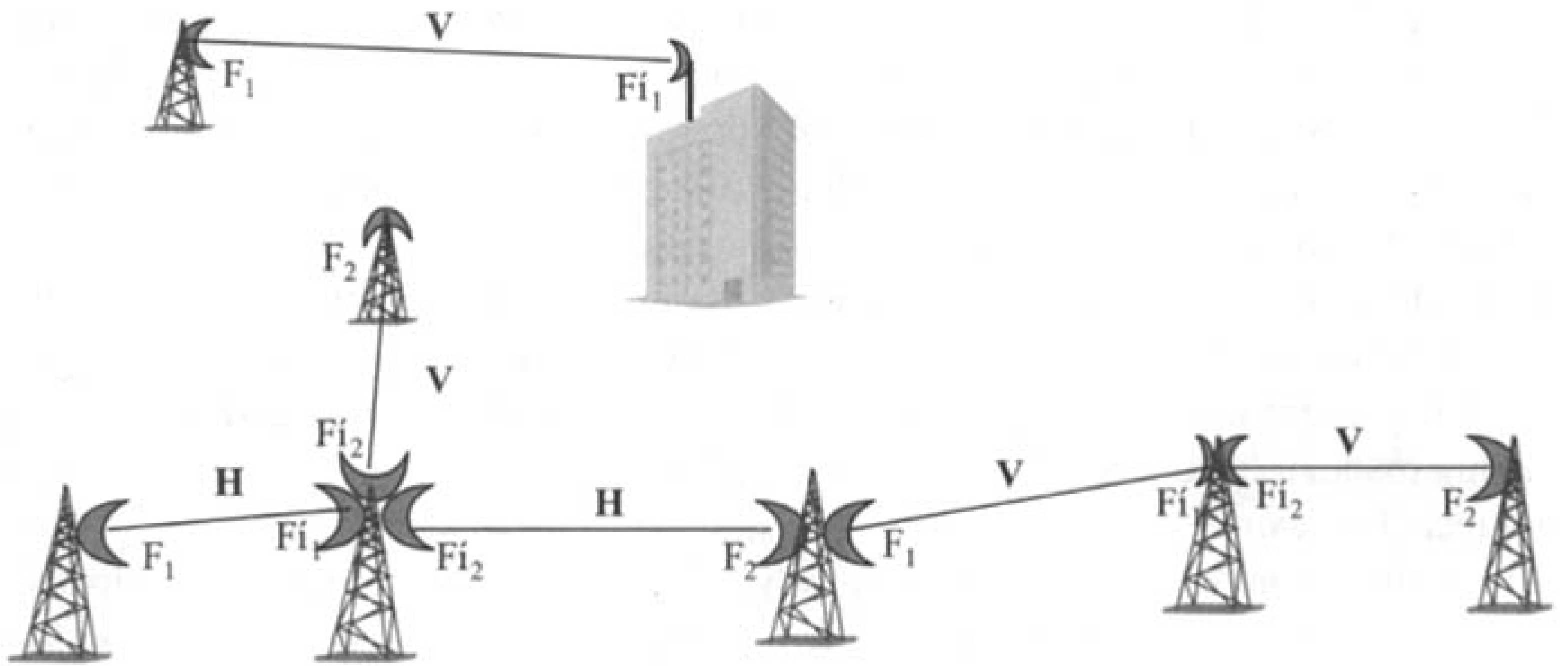
Frequency plan

- A microwave link is rarely situated in an isolated environment. There are usually many microwave links in a given region, of the same and/or different network operators. So it is very important to construct correct frequency plans for one's own network.

- **intra-system interference (noise, imperfections, etc.)**
- **inter-channel interference (adjacent/co-channel, etc.)**
- **inter-hop interference (front-to-back, over-reach)**
- **external interference (other systems, radar, etc.).**

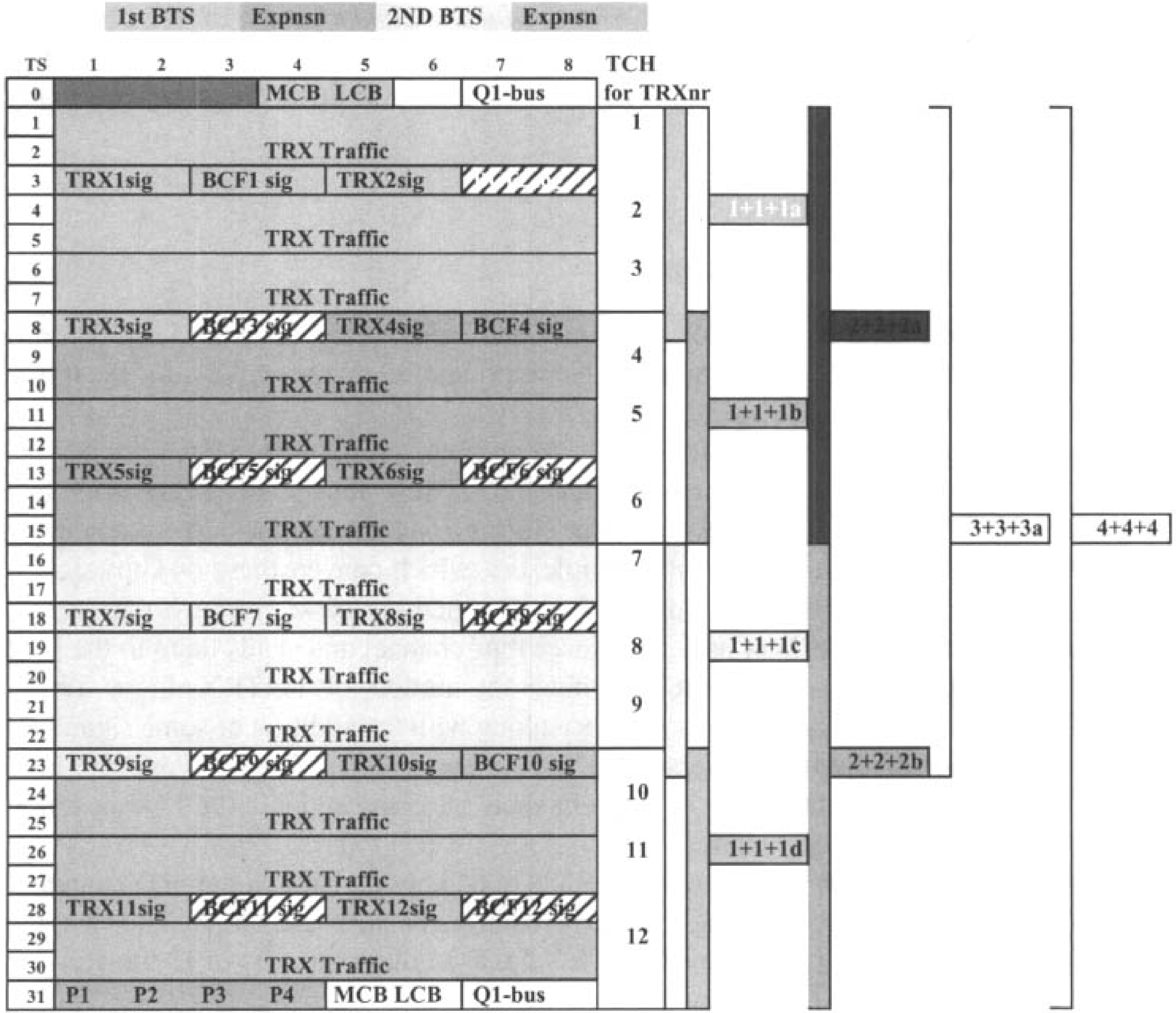


- Sometimes interferences are detected in a network, even though frequency plans are perfect. This may be due to possible reflections that might be taking place in the network.
- In these kinds of situations, again, techniques like antenna tilting, or reducing power to the transmitting antenna (interfering source), can be used.
- Interferences 1, 3 and 4 (from Figure 3.17) can be cured by using different frequency bands and polarizations. Interferences from 2, 5 and 6 can be removed by using a polarization-altering technique (i.e. altering the horizontal and vertical polarizations).



Time-slot Allocation / 2mbps Planning

- On the A-interface, one 2 Mbps consists of 32 time slots. TSO is used for link management. Each of The next stop for the 2 Mbps signal is the transcoder/sub-multiplexers, which convert these 64 kbps signals into 16 kbps traffic channels.
- Sub-multiplexer then maps them into a single 2 Mbps channel and sends them to the base station. The traffic at the base station determines the number of the TRXs there.
- Traffic channels remain at 16 kbps on the Abis interface along with the addition of some signaling channels required for the transceivers and the base station signaling.
- Beyond the base station (i.e. on the air interface), the 16 kbps channels are converted into the 13 kbps traffic channels.
- One TRX has a handling capacity of 12 transceivers (this may vary from equipment to equipment).


1st BTS
Expnsn
2ND BTS
Expnsn
TS
1
2
3
4
5
6
7
8
TCH for TRXnr
0
MCB LCB
Q1-bus
TRX Traffic
TRX1sig
BCF1 sig
TRX2sig
TRX3sig
BCF3 sig
TRX4sig
BCF4 sig
TRX5sig
BCF5 sig
TRX6sig
BCF6 sig
TRX7sig
BCF7 sig
TRX8sig
BCF8 sig
TRX9sig
BCF9 sig
TRX10sig
BCF10 sig
TRX11sig
BCF11 sig
TRX12sig
BCF12 sig
P1
P2
P3
P4
MCB LCB
Q1-bus
1+1+1a
1+1+1b
1+1+1c
1+1+1d
2+2+2a
2+2+2b
3+3+3a
4+4+4

Synchronization Planning

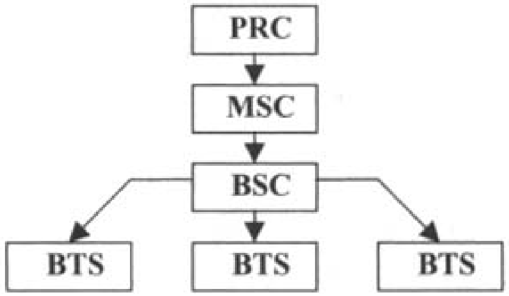
- Usually networks are designed using mixed technologies (SDH and PDH). In mixed networks that do not have proper synchronization planning.
- The internal clock of these equipments is not very accurate, so external synchronization is needed

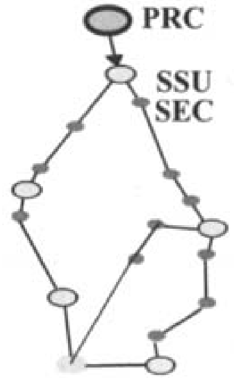
There are three clock levels recognized by the ITU-T G.803:

- PRC (primary reference clock, operator)
- Slave clock (synchronization supply unit or SSU known as refresher clocks also)
- SEC (SDH equipment clock).

Implementation of the Synchronization

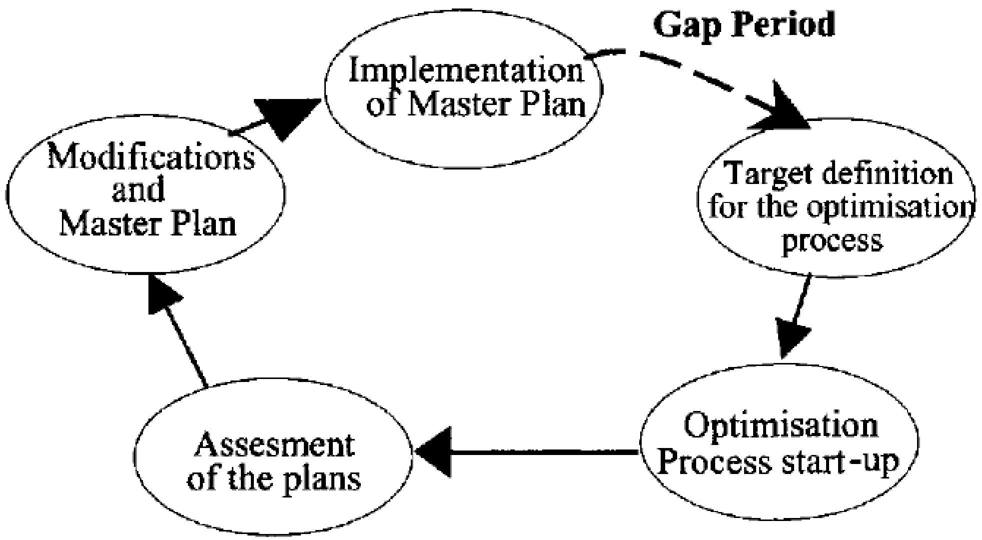
- MCB: 0 - signal is based on the master clock
- MCB: 1 - signal is based on some other clock (e.g. internal)
- LCB: 0 - synchronize slave from master, no possibility of timing loop
- LCB: 1 - do not synchronize slave from master (e.g. there may be possibility of a timing loop).



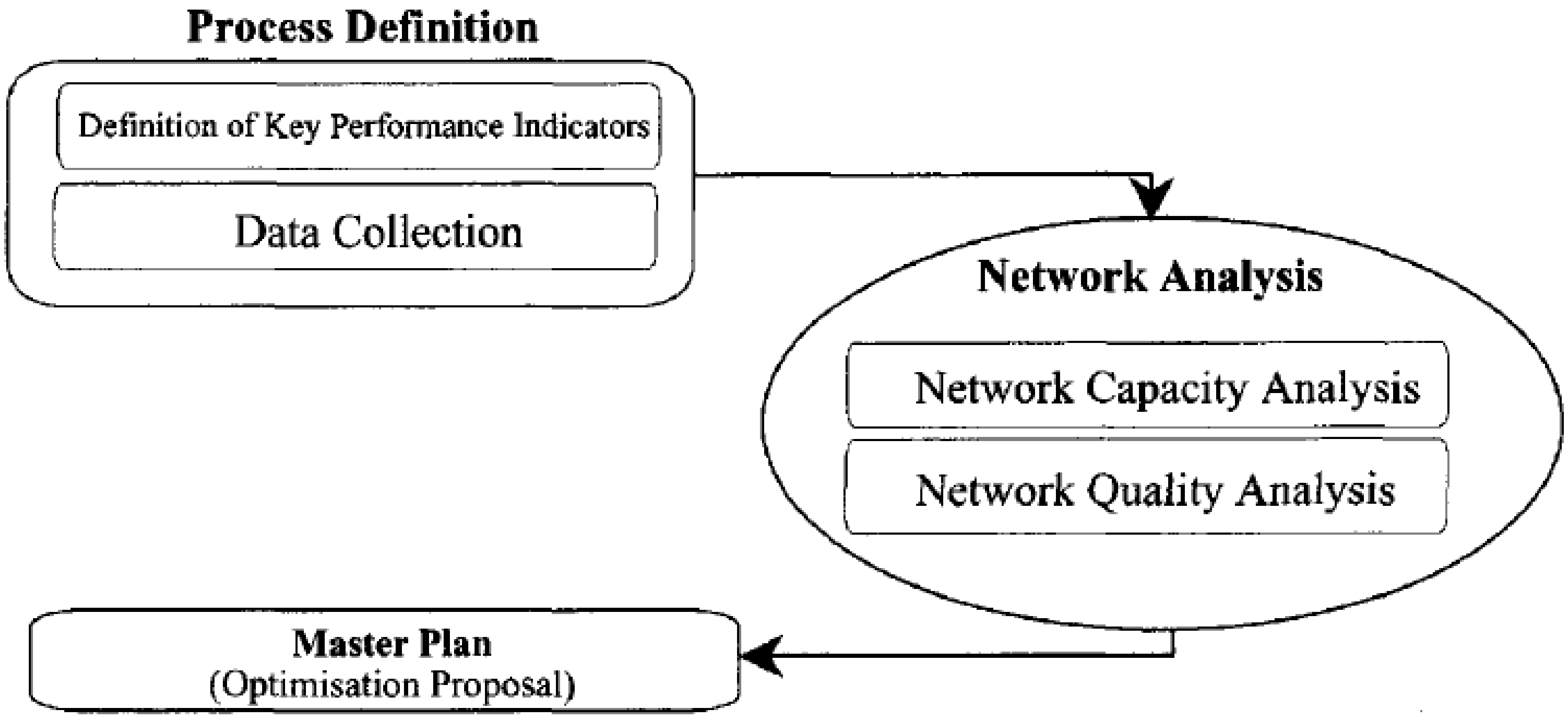


TRANSMISSION NETWORK OPTIMISATION

- The process starts with the making of plans based on the data available and the targets to be achieved. These plans are then assessed and optimized, to achieve a balance between costs, quality and the time frame for the process.
- This master plan is then implemented.
- Unlike in the radio network, where optimization is an ongoing process, there is a gap period before the next optimization cycle can begin in the transmission network.



Cellular transmission network optimisation cycle



Cellular transmission network optimisation process