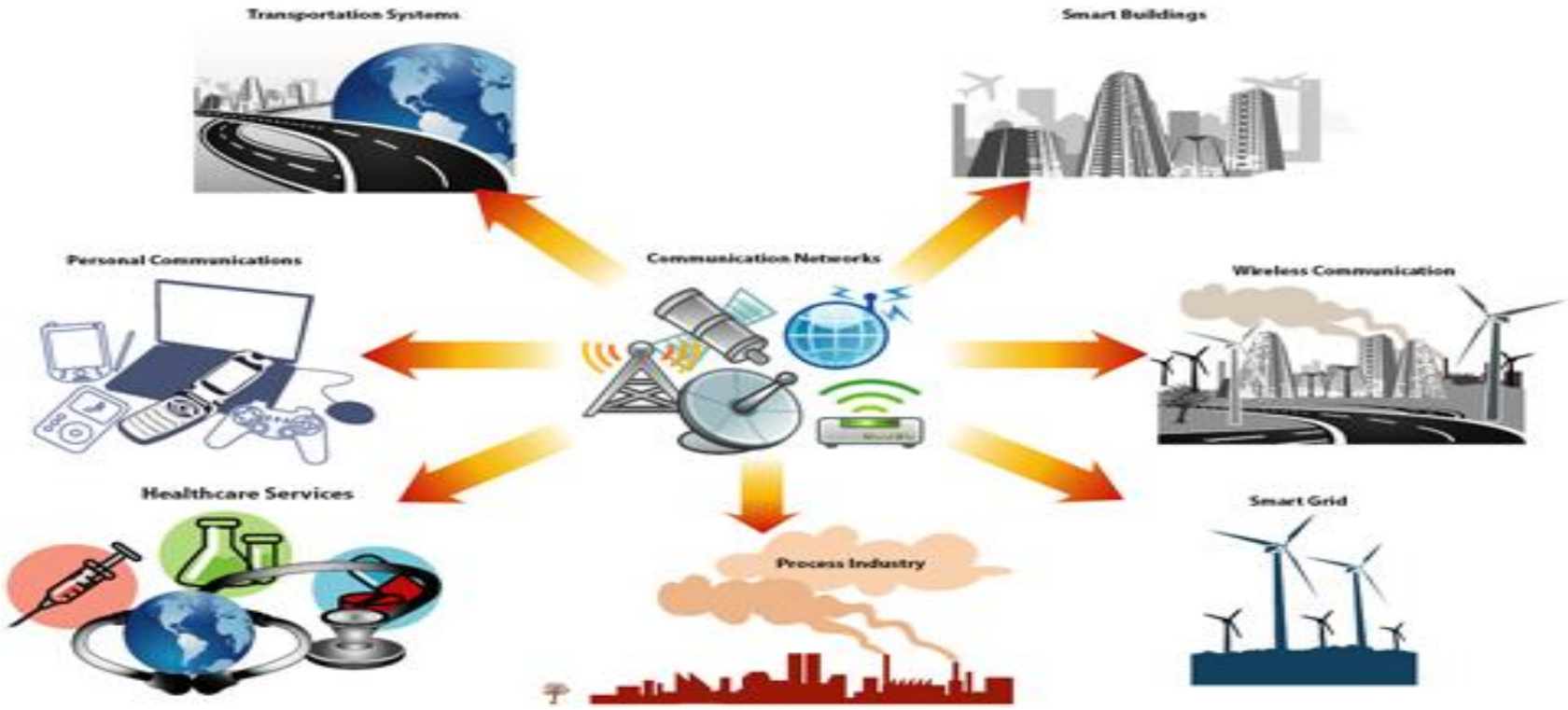
GSM



By

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Radio link features in GSM systems

Introduction

The GSM system uses a number of interference reducing mechanisms. These include

1) Adaptive Power Control (APC)
2) Discontinuous Transmission (DTX)
3) Slow Frequency Hopping (SFH).

The purpose of power control is to adjust the power of the radio transmitter and adapt to the needs of an actual radio link between the BTS and the MS. If the received power and quality are high enough, the transmitted power is reduced stepwise to a minimum necessary value.

Radio link measurements

- In GSM the MS uses the BS identity code (BSIC) fig to distinguish between neighboring BSs.
- The **signal level values (RXLEV)** and **signal quality level values (RXQUAL)** used in GSM are listed in table
- Intercell handover from the serving cell to a neighbor cell occurs when RXLEV and/or RXQUAL is low on the serving cell to a neighbor cell.
- Intracell handover from one channel/time slot in the same cell occurs when RXLEV is high but RXQUAL is low.

- The MS monitors the signal strength of neighbor BSs and maintains a list of six strongest Nonserving BSs.
- A new BS is selected from the list if,

a) The path loss criterion for the serving BS is not met for 5 seconds
b) The signaling link with the serving BS fails
c) The serving BS becomes barred
d) Nonserving cell access signal is greater than that of serving BS for 5 seconds .

Radio link features

Dynamic Power control:

- The GSM network is designed so that the MS is instructed to use only the minimum power level necessary to achieve effective communication with the BTS.
- GSM defines eight power classes for the BTS transmitter to cover all five classes of MSs (0.8W to 20W).

- The MS measures the receive power level of serving BS, the quality of receive signal, the receive power level and ID codes for up to six neighbor BSs.
- The BS measures the receive power level and signal quality of each MS, the distance to the MS and transmit power of MS and BS.
- Signal power level is determined by averaging the incoming signal level over a specified period of time.
- The receive power level in dBm is mapped to a value between 0 and 63.

- The BER is mapped to 8 levels of where 0 is the best quality . Once the BS determines the minimum required transmit power, it sends this information to the MS.
- In the BS, transmit power control may be employed, but it is optional.
- For the BTS, the power output is nominally controlled in 2-dB steps to provide better channel interference performance.

- Both MS and BTS power control is performed in a 2-dB steps , down form the level of power class to a minimum of +13dBm.
- The power output level of MS is controlled in a monotonic sequence of 15 steps of 2 dB on the command through SACCH from the BTS.
- Power levels are sent to MSs via a 5-bit transmit power (TXPWR) field in the downlink SACCH message block.
- The MS sends confirmation to the BTS via MS_TXPWR_CONF field in the uplink SACCH message.

- The use of minimum transmitting power to access the network helps to increase the battery life of mobile set and reduce interference.
- By carefully controlling the ramp-up of the transmitter as well as the power level, the spectral interference with other GSM equipment can be minimized.

Discontinuous Transmission (DTX)

- A more practical method that is directly applicable to the capacity assessment procedure is to relate the DTX activity factor v of the transmitter to the occupancy;
- Ex, v= 0.4, P_{occup}=0.8, then the effective channel occupancy $P_{active=}$0.32.
- P_{occup} is used to calculate the interference.
- The improvement in the overall S/I ratio of the system allows the use of a smaller reuse distance and therefore, increases the spectrum efficiency.

- Another advantage of DTX is the reduction in the power consumption of mobile phone; this is especially important for the handheld unit.
- The drawback of DTX is introduction of clipping to the speech due to imperfect operation of the voice activity detector(VAD) which can sometimes fail to detect the exact times of start and end of the speech bursts.
- Another disadvantage of DTX is the noise contrast between the active and silent periods.

- Discontinuous transmission is a GSM feature in which speech is transmitted only when there is speech available to transmit.
- This helps to reduce RF interference in MSs.
- GSM transmission will cease 4 speech block periods(20ms each)(fig 6.3) after speech activity has stopped.
- However, the mobile will periodically send a signal called a silence indicator(SID) every 480ms top provide comfort noise level information to the BS so that the person on the far end can hear some low-level noise.

SFH

- SFH is used in GSM to improve performance in the multipath fading environment and to reduce the required S/I ratio.
- Fades occur when there is a loss in signal power due to variations in terrain such as valleys or hills or due to objects such as buildings or even large metal objects such as aircraft interfering with the signal path, causing the original signal to be attenuated or cancelled out.

- When the mobile passes through areas of fade and poor reception, there is less chance of losing the radio link in these areas by invoking SFH .
- FH provides frequency diversity to overcome Rayleigh fading due to multipath propagation.
- FH allows the maintenance of the radio link by shifting onto another frequency before the link is totally lost.

- FH also provides interference diversity. At any time, the amount of interference on various channels in a given cell varies from channel to channel.
- FH reduces the S/I ratio required for good communications.
- For a non-hopping radio link, the minimum required S/I ratio is about 12 dB, where as FH reduces the requirement to 9 dB.
- With the reduced S/I requirement, the system capacity will be improved.

- The difference between the MS and BTS in frequency hopping mode is that in the MS only three out of eight time slots are available to receive, transmit and monitor, where as BTS uses all eight time slots, since it is capable of supporting eight MSs in one frame.
- The SCH is used for synchronization with the system as the MS initially seeks service or gets ready to move to another cell.
- The FCCH is used to allow the MS to accurately tune to a BS. The BCCH is used to provide general information one per-BTS basis required by the MS for registration into the system.

- Two different implementation schemes of SFH are used in BSs. These are RF hopping and base band hopping.
- The RF hopping needs transceivers, as in the MS, except that two or three synthesizers are often required to allow one synthesizer to tuned while the others are being used.
- The tuning time for each individual synthesizer is a minimum of one time slot.
- The main disadvantage of RF hopping is that a hybrid combiner must be used since there need to be non-frequency selective signal combining.

- The base band hopping is suitable when a large number of transceivers are used in one BTS.
- It uses a fixed frequency transceivers and multiplexes a number of base band processing systems to use the appropriate transmitter for the defined hopping sequence.
- Base band hopping avoids the wideband combiner because the resulting frequency of each transceiver is fixed, so as selective combiner can be used.
- Base band hopping requires one transceiver to be allocated for one frequency.
- This implementation is only cost effective in large systems that already have a number of transceiver at the BTS.

- Hybrid hopping is a combination of two implementation schemes.
- For the receive path, RF hopping is used because the need for wideband filters over the GSM frequency range does not present a problem for the selectivity of the BTS.
- Base band hopping is used for transmit path to reduce the output losses.
- Two parameters- mobile allocation index offset(MAIO) and hopping sequence number(HSN) are used to describe them.

Future enhancements to reduce interference in GSM

- The demand for spectrum to serve mobile users has rapidly increased.
- There are two main approaches that can be used in GSM:

a) Channel borrowing

b) Advanced technology

In **channel borrowing** there are three types

1) Dynamic Channel Allocation(DCA)
2) Hybrid Channel Assignment(HCA)
3) Channel Borrowing without Locking(CBWL)

In **advanced antenna technology** we use Smart or intelligent antennas.

Channel borrowing

- In DCA, a central pool of all channels is used. A channel is borrowed from the pool by a BS for use on a call.
- When the call is completed the channel is returned to the pool. The basic DCA has a self organizing channel assignment algorithm based on dynamic real-time measurements of interference levels.
- These measurements are usually performed at the MS in order to reduce the computational load and the complexity of the system.

- In a call setup phase, the BS assignment is done on strongest signal from neighboring BSs.
- The channel assignment is Based on interference consideration. The interference level of the idle channels is measured and by means of signal level from the preferred BS, the resulting S/I ratio is estimated.
- If the S/I ratio exceeds the selected threshold value, the channel is considered a suitable channel.

- Different DCA algorithms differ in the selection of the preferred channel among the suitable channels.
- If the suitable channel set is found empty, the system looks for a new BS, received with a sufficient signal level and searches for a good quality channel.
- If no suitable channel is found, the call is blocked.

- During the call, the system monitors the quality of channel under use by measuring BER.
- If the quality threshold is exceeded, a handover request is initiated.
- A suitable channel is searched for among the channels of the current BS that show a better quality.

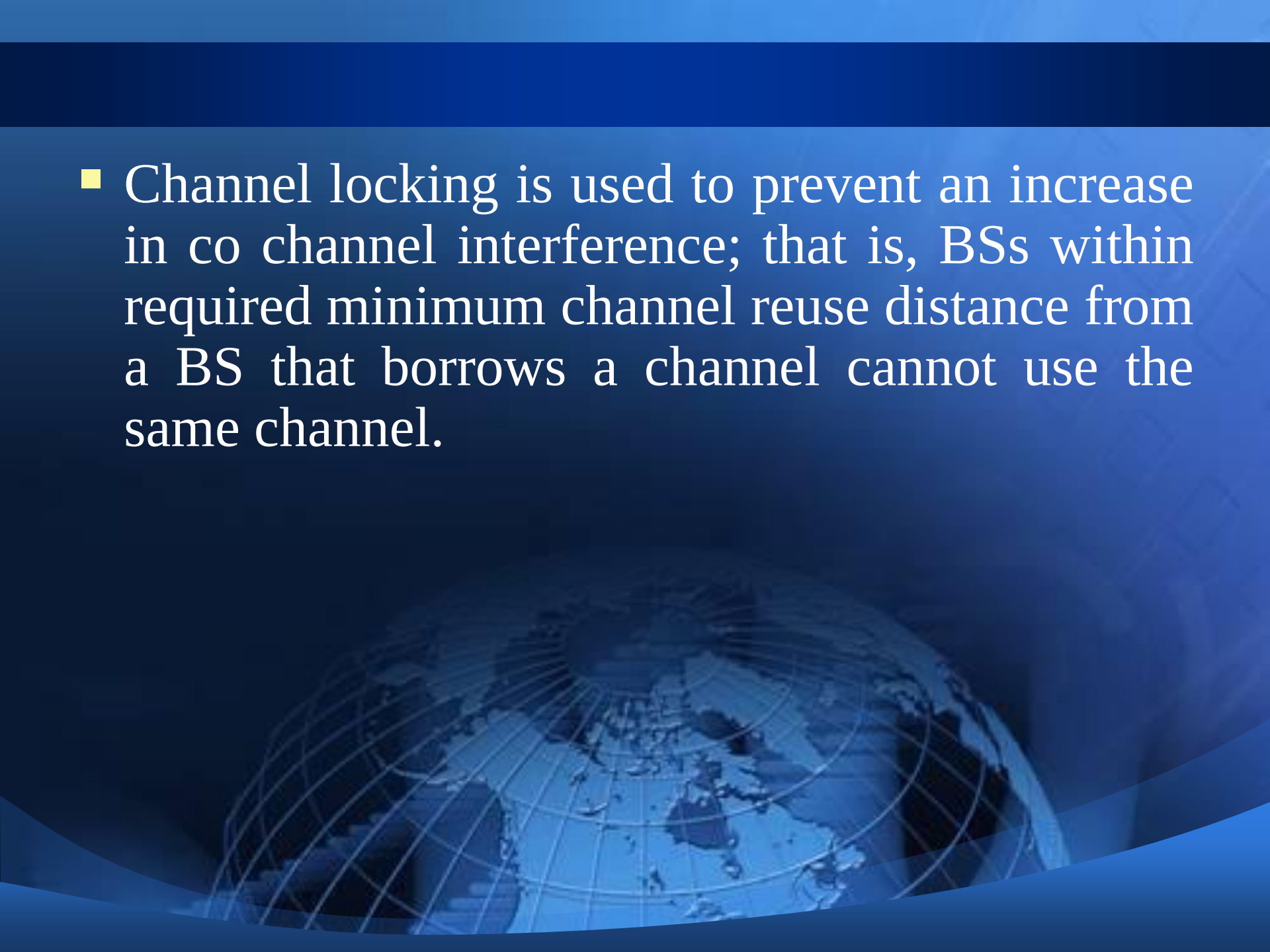
Hybrid Channel Assignment(HCA)

- In HCA, some channels are permanently assigned to each BS as in FCA(Fixed Channel Assignment) and others are kept in a central pool for borrowing as in DCA.
- Channel locking is used to prevent an increase in co channel interference; that is BSs within the required minimum channel reuse distance of the borrowing BS.
- Another disadvantage is the difficulty in maintaining co channel reuse distance at the minimum required value everywhere in the system. Because of this difficulty, DCA and HCA generally perform less satisfactorily than FCA under high loads.

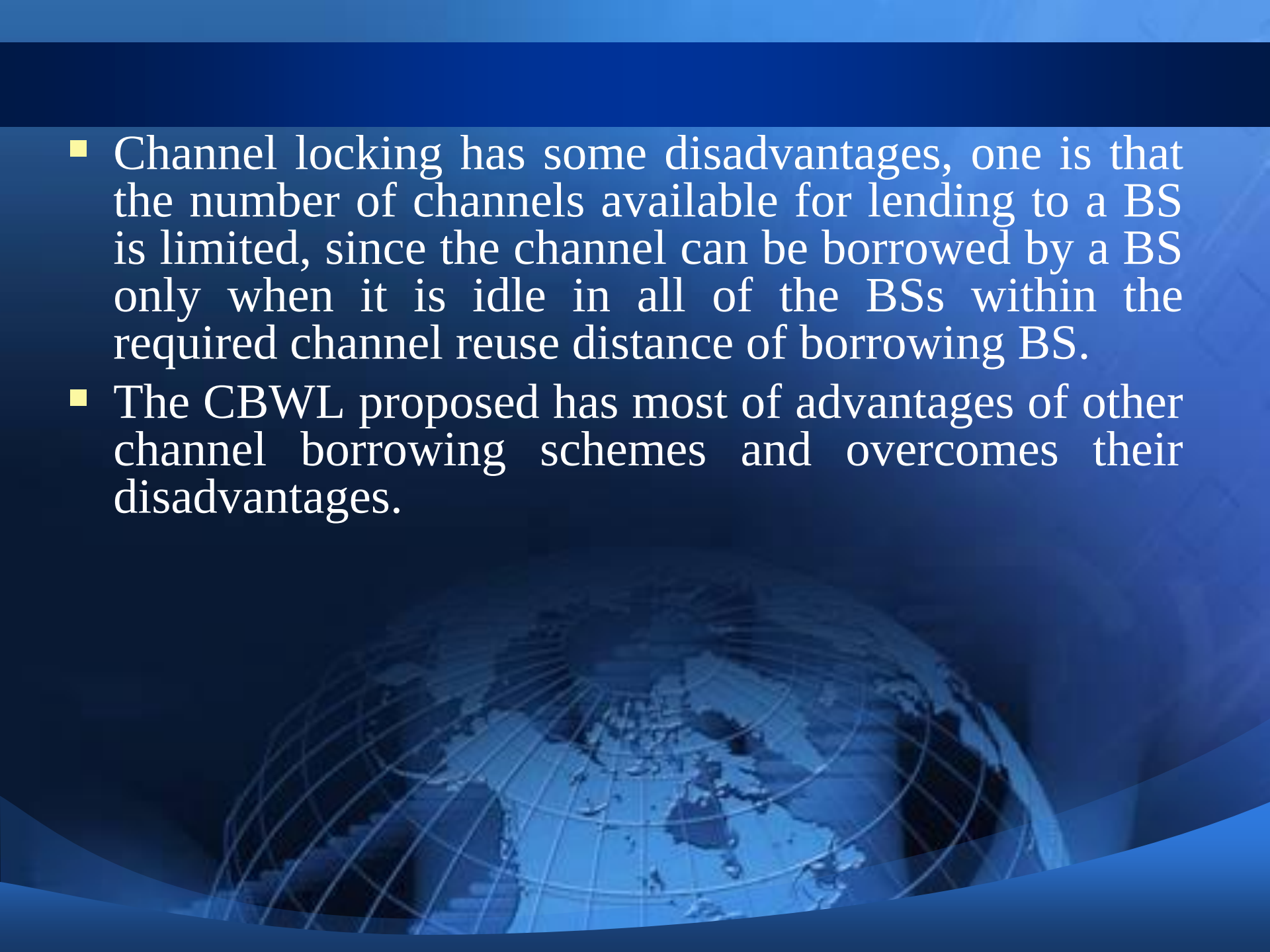
Channel Borrowing Without Locking(CBWL)

- In CBWL, each BS is allocated channels as in FCA.
- If all channels of the BS are occupied and a new call arrives, channel borrowing is used.
- A channel can be borrowed only from an adjacent BS.
- The borrowed channel cannot be used by the original lending BS but can still be used

- Channel locking is used to prevent an increase in co channel interference; that is, BSs within required minimum channel reuse distance from a BS that borrows a channel cannot use the same channel.



- Channel locking has some disadvantages, one is that the number of channels available for lending to a BS is limited, since the channel can be borrowed by a BS only when it is idle in all of the BSs within the required channel reuse distance of borrowing BS.
- The CBWL proposed has most of advantages of other channel borrowing schemes and overcomes their disadvantages.



- The borrowed channel cannot be used by the original lending BS but can still be used in any nearby co channel BSs. Thus, there is no channel locking.
- To prevent the increase of co channel interference, borrowed channels are used with reduced transmitted power. Therefore, they can be accessed only in part of borrowing cell.
- To determine whether a mobile is in the region that can be served by a borrowed channel, each BS transmits a signal with the same reduced power as that on a borrowed channel. The signal is called **borrowed channel sensing signal (BCSS).**
- If the BCSS is not above some suitable threshold at an MS, a borrowed channel cannot be used.

- CBWL offers **advantages** in comparison with DCA and HCA.
- In CBWL, only a fraction of the total channels of the system need to be accessible at each BS.
- The CBWL exhibits better performance in light as well as in heavy traffic loads.
- In CBWL, channel borrowing at a BS does not require global information about channel usage in the system, so the control and management tasks are simplified.
- In CBWL, a user can borrow channels from any of the adjacent BSs.

Smart antenna

- Another way to reduce interference is to use a smart or intelligent antenna.
- It refers to a group of core RF technologies that control directional antenna arrays by means of sophisticated digital signal processing (DSP) algorithms.
- A smart antenna evaluates signal conditions continuously of each signal that is transmitted or received.
- The smart antenna then uses this information to determine how to manipulate the incoming signals to maximize performance.

- The smart antenna constructs a composite signal from multiple antenna feeds by optimizing signal characteristics.
- The optimization is accomplished by assigning specific weight to each of the incoming signals.
- Smart antenna belongs to two basic classes:

1) Switched beam

2) Adaptive antenna

- A switched beam antenna combines signals according to a fixed number of beam patterns.
- One of the patterns will be considered a best fit for the signal on an individual channel at a given instance.
- The system logic may select another pattern as conditions change (i.e., the processor is said to switch between patterns as it tracks the signal).
- For such a system to operate, signal processing requires a powerful DSP engine, which must analyze the antenna signal across the entire frequency band occupied by the network, identify individual channels and then apply appropriate processing.

- The adaptive antenna essentially picks out the desired signal ,a field of interfering signals and thermal noise and self-regulates its performance to satisfy some preassigned criteria. Such criteria may include periodicity of switching and beam traversal.
- The adaptive array antenna effectively creates new spatial channels, forming areas of high signal gain while reducing the effect of other signal to a minimum.
- The adaptive array antenna increases the sensitivity in certain angular directions corresponding to interfering signals.

- The use of adaptive antenna would be considerably beneficial in the following areas:

a) **Coverage**: Adaptive beam forming can increase the cell coverage area substantially due to antenna gain and interference rejection.

In a noise-limited environment, the cell coverage area improved by a factor of $M^{1/\gamma}$, where M is the number of antenna elements in the array and γ is the propagation loss component.

b) **Capacity**: Transmission bit rate is increased due to improvement in the S/I ratio at the output of adaptive beam former.

In a noise limited environment, the minimum rate improvement in S/I ratio that can be achieved is 10logM dB

c) Signal quality: In a noise limited environment, the minimum receiver thresholds are reduced by 10logM dB on average.

In an interference limited environment, an additional improvement in tolerable S/I ratio at a single element is achieved due to interference rejection afforded against directional interferers.

The amount of improvement depends on the distribution of co channel users in the neighboring cells.

Thank You