EEE4121F-A
Mobile and Wireless Networks

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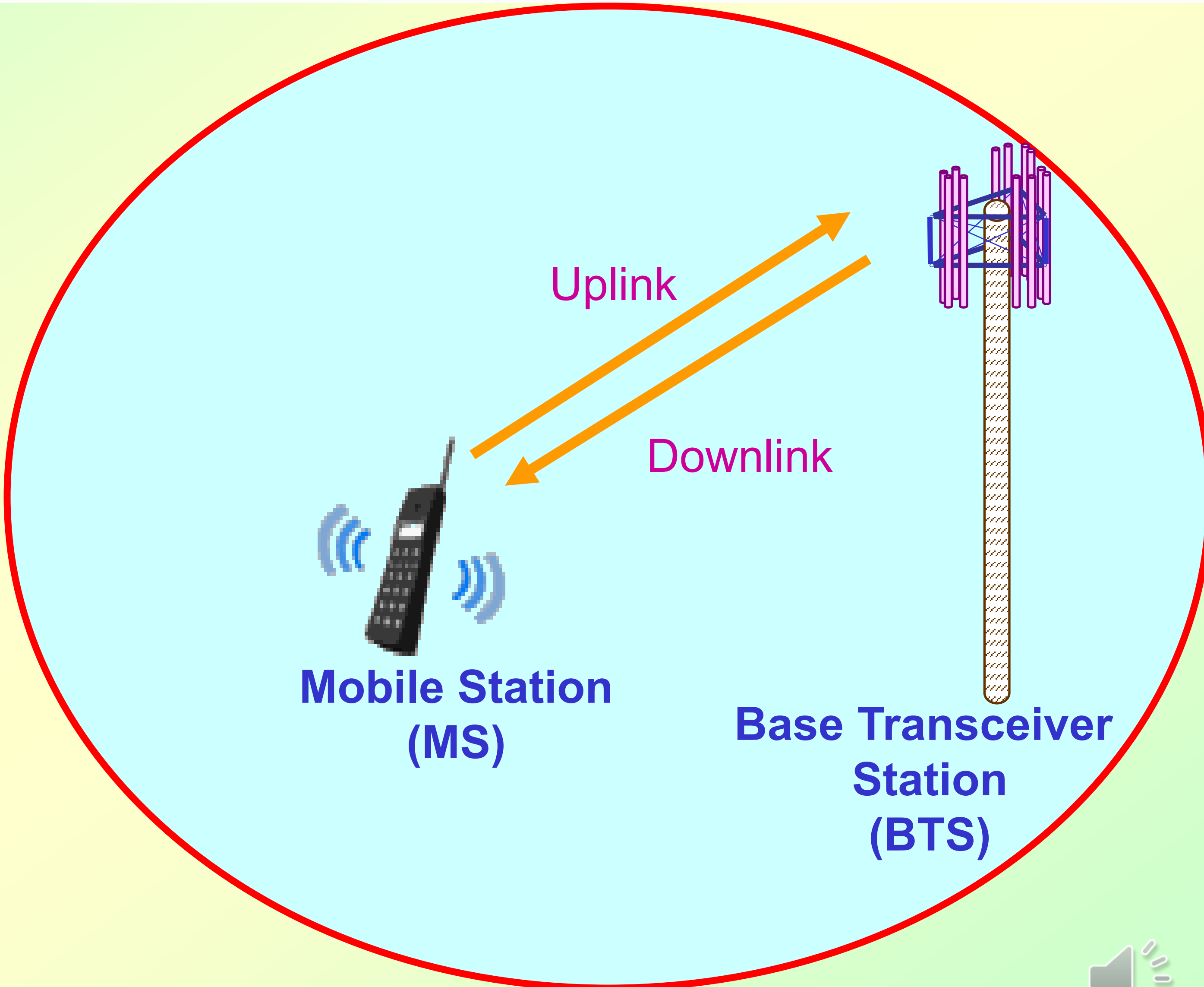
Radio Resource Management in Wireless Networks

Radio Resource Management

Resource allocation



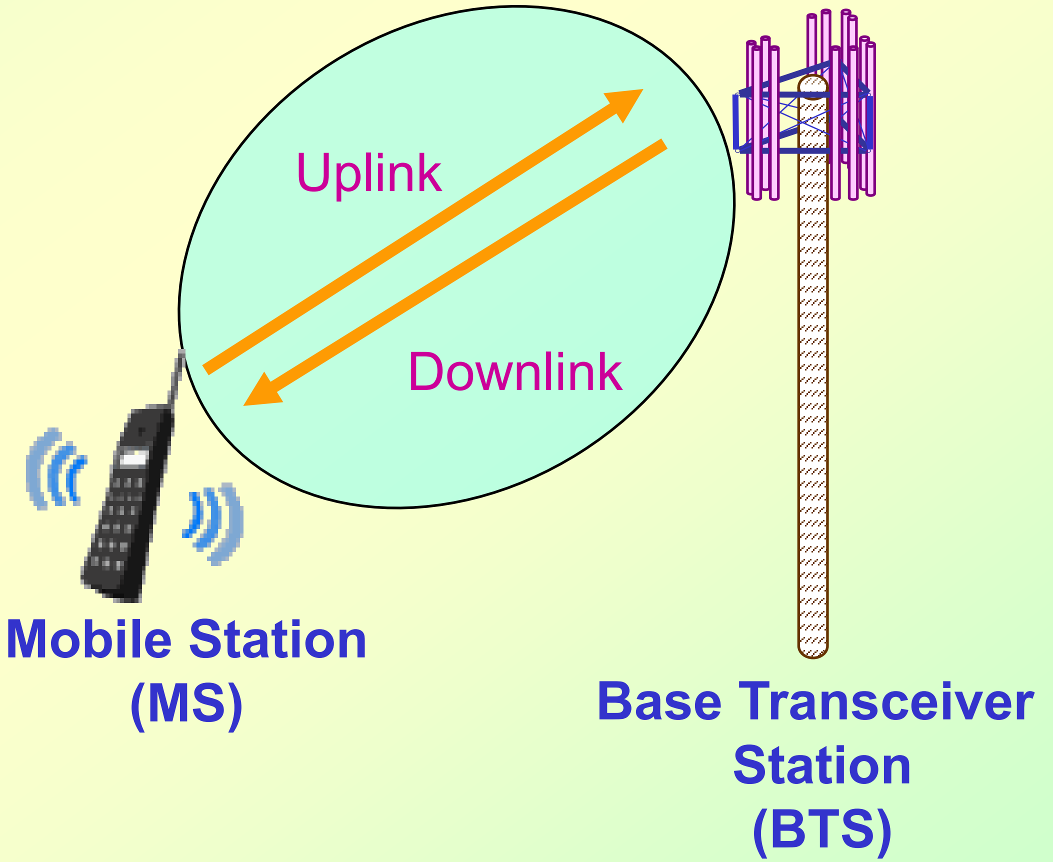
Radio Resource Management

Resources: Frequency, Time, Power, Space
Problem: Interference, and slow processing speed
Solution: Channelize

♦ Wireless communication systems use electric and magnetic waves to transmit signals through the air.

♦ When subscribers share the same frequency, they will create interference.

♦ The level of interference depends on what technique is used to separate the users in the network.



When heaven smiles at you it does not matter who frowns.

Bandwidth Management Schemes

Bandwidth allocation strategies for wireless networks can be classified into four groups

(1) complete sharing

(2) complete partitioning

(3) Handoff call prioritization

(4) Service class prioritization

Complete Sharing

- ♦Complete sharing scheme is a first come first serve scheme and it is the simplest bandwidth allocation policy

- ♦It is a non-prioritization scheme in which new and handoff calls are treated the same way

- ♦ An incoming call is accepted if there is enough radio resource to accommodate it

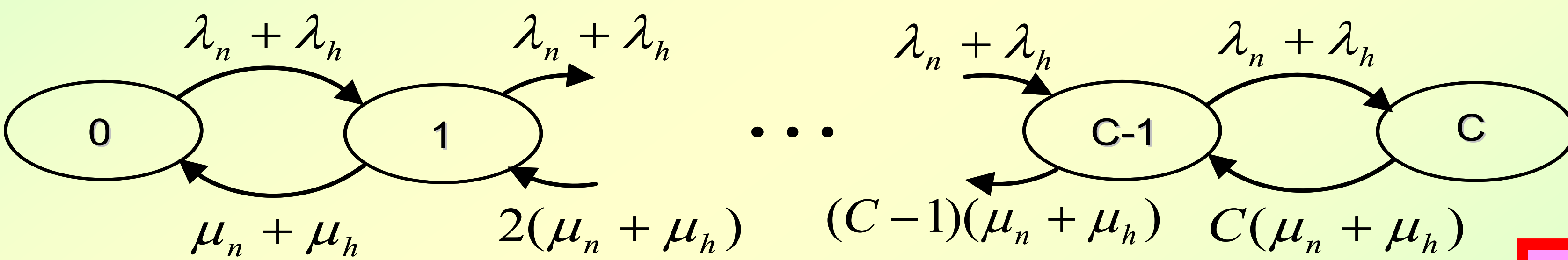
- ♦ When the network gets to its maximum capacity, a new call will be blocked while a handoff call will be dropped

- ♦Two advantages of complete sharing CAC scheme are implementation simplicity and good radio resource utilization

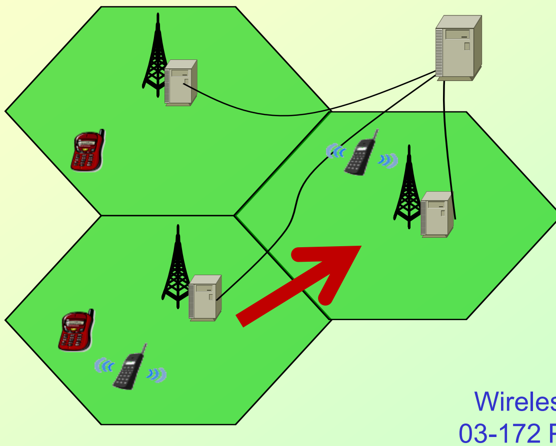
- ♦The disadvantage is high handoff call dropping probability, and consequently, poor QoS performance

Complete Sharing

- A bandwidth allocation strategies can be represented using a Markov chain.
- A Markov chain is a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event.
- It consists of a set of states, S and transition probabilities
- The state transition diagram of a complete sharing system in a single cell is shown below where C is the available resource.



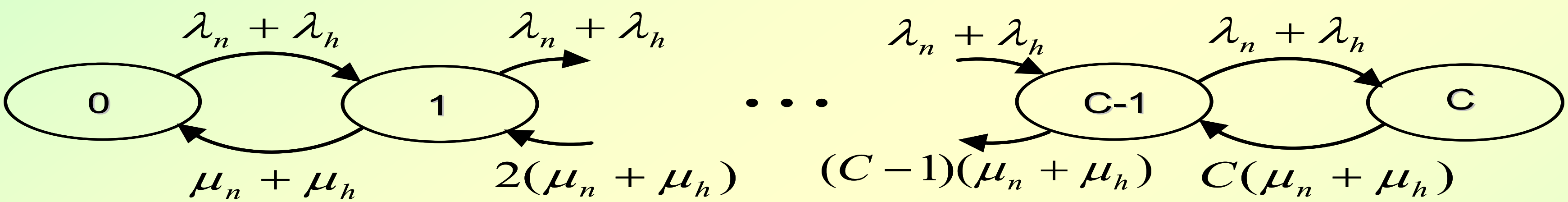
$\lambda_n, \lambda_h, \mu_n$ *and* μ_h represent new call arrival rate, handoff call arrival rate, new call departure rate, and handoff call departure rate respectively

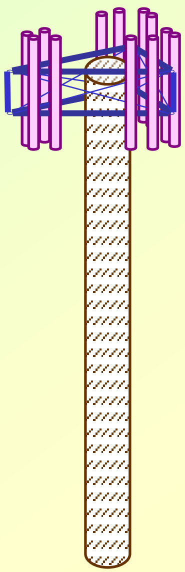


Resource allocation

Example of a GSM Network

In complete sharing, new and handoff calls are treated equally





Base Station

- *In the above diagram, a single cell of the GSM network has 8 time slots for new and handoff calls, and can operated in 9 possible states (0,1,2,3,4,5,6,7,8).*
- *The network will be in one of the 9 states at any point in time*
- *When the network is in state 0, there is no call (new or handoff in the cell)*
- *When the network is in state 8, it is operating at the maximum capacity.*

Complete Partitioning

- In the complete partitioning CAC scheme, entire available bandwidth is partitioned into pools.

- Each pool is dedicated to a particular type of calls (new or handoff calls) and/or particular traffic class of calls

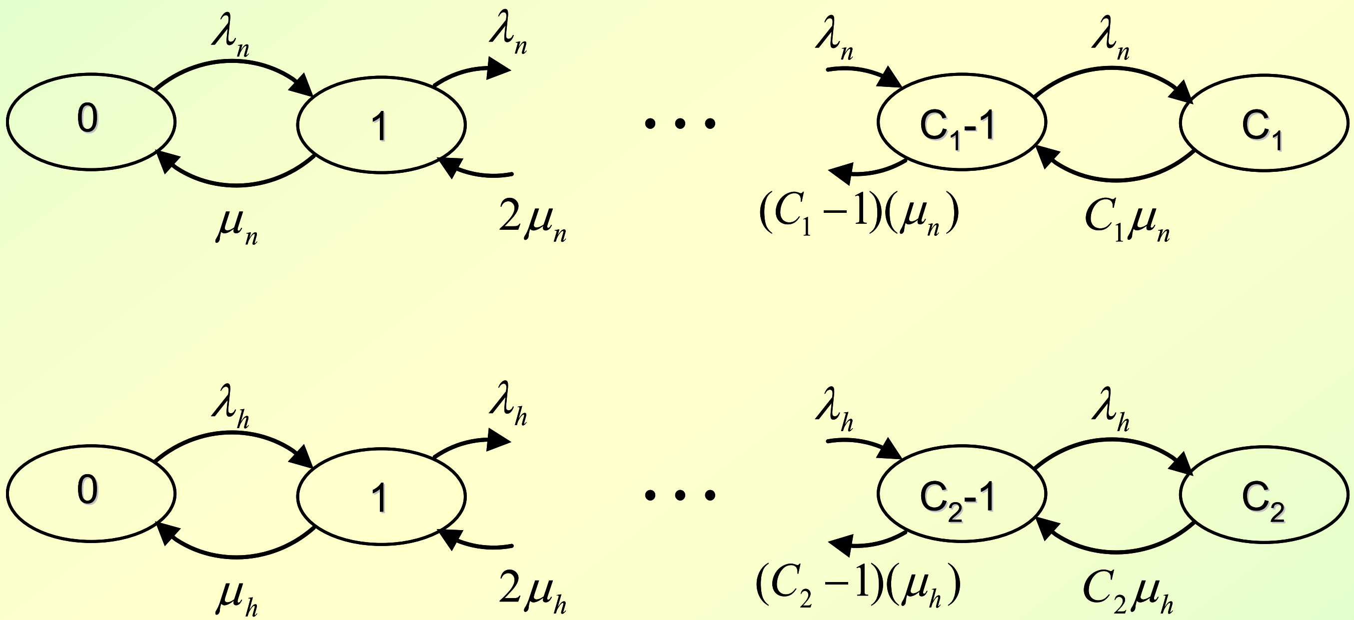
Resource 1 **(e.g. for new calls)**	**Resource 2** **(e.g. for handoff calls)**

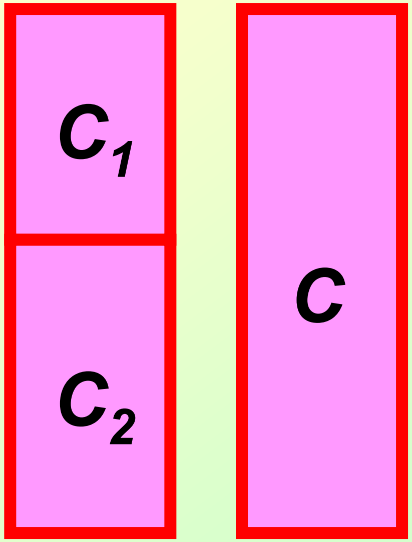
Resource a **(e.g. for voice calls)**	**Resource b** **(e.g. for video calls)**	**Resource c** **(e.g. for data calls)**

Complete Partitioning

State transition diagrams of a system where the available resource (C)) is partitioned into two (C1 and C2)

C1 is used for new calls whereas C2 is used for handoff calls





Handoff Call Prioritization Scheme

- Due to users' mobility within the coverage of wireless networks, an accepted call that has not been completed in the current cell has to be transferred to another cell
- The call may not be able to get a channel in the new cell to continue its service due to limited radio resources in wireless networks. Eventually, it may be dropped
- However, wireless network subscribers are more intolerant to dropping a handoff call than blocking a new call
- Therefore, in order to ensure that handoff call dropping probability is kept below a certain level, handoff calls are usually admitted with a higher priority compared with new calls

Handoff Call Prioritization

- Guard Channel
- Fractional Guard Channel
- Queuing Priority Scheme
- QoS Degradation Scheme
- Threshold-Base Scheme

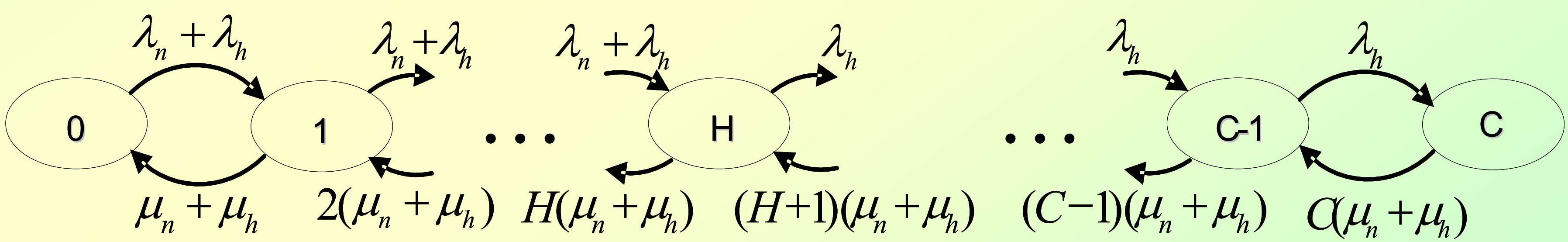
Guard Channel

♦In this scheme, some channels (referred to as guard channels) are specifically reserved in each cell to take care of handoff calls

♦ For example, if the total number of available channels in a single cell is **C** and the threshold for accepting new calls is **H**, the number of guard channels is **C – H**

♦ A new call is accepted if the total number of channels used by ongoing calls is less than the threshold H, whereas a handoff call is always accepted if there is an available channel.

♦According to this channel reservation, the threshold must be chosen such that the handoff call dropping probability is as low as possible, while the system can admit as many incoming new calls as possible.



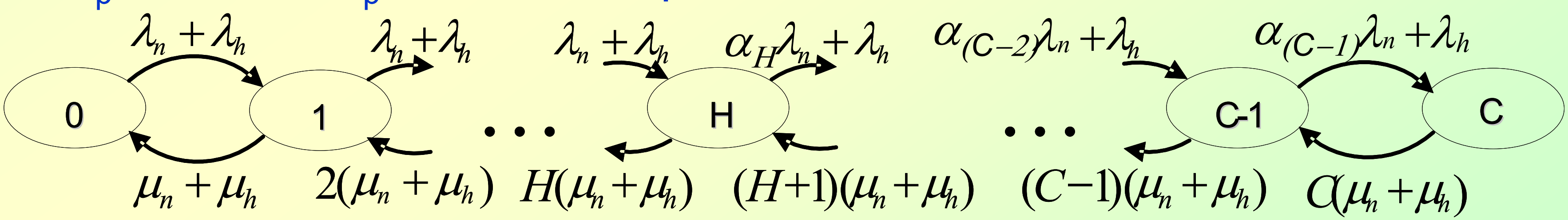
State transition diagram for guard bandwidth scheme

Fractional Guard Channel

- ♦In fractional guard channel scheme, handoff calls are prioritized over new calls by accepting an incoming new call with a certain probability that depends on the number of busy channels

- ♦ In other words, when the number of busy channels becomes larger, the acceptance probability for a new call becomes smaller, and vice versa

- ♦This approach helps to reduce the handoff call dropping probability.
- ♦The policy has a threshold, H for limiting the acceptance of new calls. A handoff is accepted as long as there is a channel available. Before the wireless system gets to threshold, H, new calls are accepted with a probability of 1. After threshold, H, a new call is accepted with a probability of α_p where $0 \leq \alpha_p \leq 1$, and H < p < C.



State transition diagram for guard bandwidth scheme

Queuing Priority Scheme

- ♦ Queuing priority scheme accepts calls (new and handoff) whenever there are free channels
- ♦ When all the channels are occupied, handoff calls are queued while new calls are blocked
- ♦ Alternatively, all incoming calls are queued with certain rearrangement in the queue
- ♦ When radio resource becomes available, one or some of the calls in the handoff queue are served until there is no more resource
- ♦ The remaining calls are queued until resource becomes available again. However, a call is only queued for a certain period of time. If radio resource is not available within this period, the call will be dropped.
- ♦ The main disadvantage of queuing priority scheme is that is needs a lot of buffers to deal with real-time multimedia traffic

QoS Degradation Scheme

- ♦ QoS degradation can either be bandwidth degradation or delay degradation

- ♦ In bandwidth degradation method, calls are categorized as adaptive (degradable) and non-adaptive (non-degradable) calls and degradable calls have flexible QoS requirements (e.g., minimum and maximum data rates)

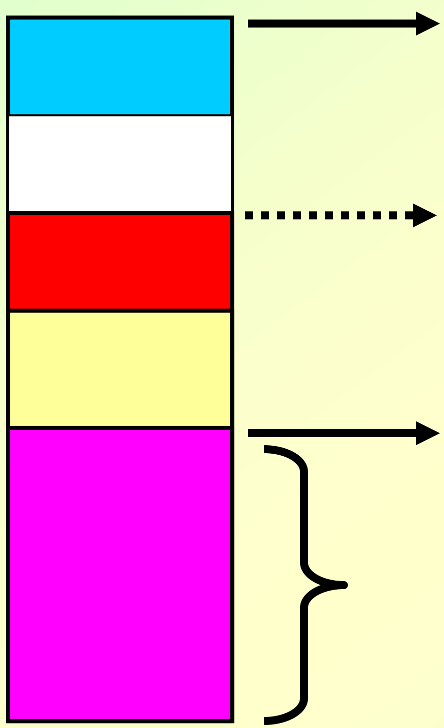
- ♦ For most multimedia applications, e.g., voice over IP or video conferencing, service can be degraded temporarily if it is still within the pre-defined range

- ♦ Bandwidth degradation reduces handoff call dropping by reducing the bandwidth of the ongoing adaptive calls during network congestion

- ♦ When a handoff call arrives and there is network congestion, the system is able to free some radio resource to admit the handoff calls by degrading some of the ongoing adaptive calls.

Degradable Calls

For adaptive class-i calls



♦ **When the system is underutilized**

All arriving new and handoff class-i calls are admitted the highest bandwidth level (i.e. $b_{i,max}$) for the calls

This approach improves system utilization

♦ **When the system is being fully utilized**

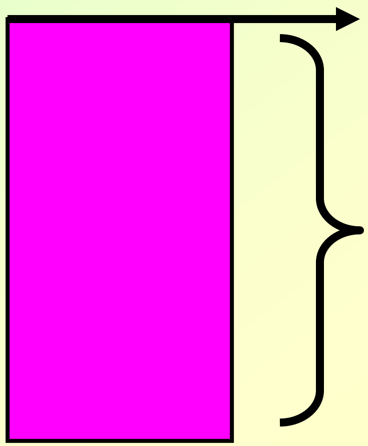
Bandwidth adaptation unit degrades some ongoing call(s) to free just enough bandwidth to accommodate the incoming call.

This approach improves connection-level QoS

When heaven smiles at you it does not matter who frowns.

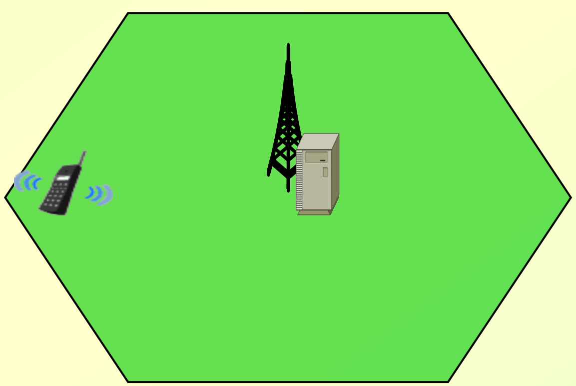
Non- Degradable Calls

For non-adaptive class-i calls



$b_{i,min} = b_{i,max}$

For non-degradable calls, resource allocated must be maintained during the entire duration of the call.



Service Class Prioritization

- In wireless systems which support multiple service classes
- The limited bandwidth has to be shared among the multiple traffic classes
- Complete sharing scheme allows the network radio resource to be shared among the various service classes without preference for any class
- However, it is often necessary to provide preferential treatment among users of different service classes while still utilizing the system resources efficiently
- Preferential treatments are given to certain classes of calls for the following reasons:
  - (1) some calls (such as voice call) have stringent QoS requirements and therefore require preferential treatment.
  - (2) Some subscribers in a particular service class are willing to pay more for better QoS.
- Service class prioritization scheme is more complicated than complete sharing and complete partitioning schemes

Bandwidth Management Scheme

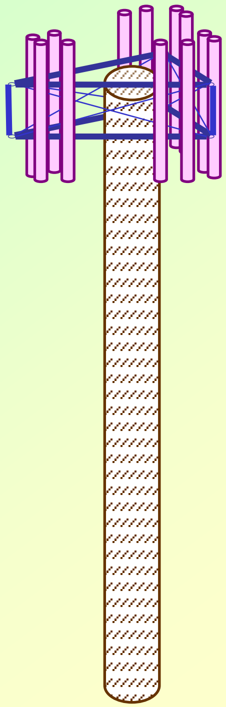
Bandwidth Allocation Strategy	Main Idea	Advantage	Disadvantage
Complete Sharing	An incoming call is accepted, regardless of the class/ type, as long as there is enough radio resource to accommodate it.	Implementation simplicity and high radio Resource utilization	High handoff call Dropping probability. No differential treatment for calls with stringent QoS requirements
Complete Partitioning	Available bandwidth is partitioned into pools and each pool is dedicated to a particular type of calls. An incoming call can only be admitted into a particular pool.	Implementation simplicity	Poor radio resource utilization

Bandwidth Management Scheme

Bandwidth Allocation Strategy	Main Idea	Advantage	Disadvantage
Handoff Call Prioritization	Handoff calls are given more access to radio resources than new calls. New calls may be blocked whereas handoff calls are still being admitted.	Low handoff call dropping probability	High new call blocking probability
Service-Class Prioritization	Certain classes of calls are given preferential treatment over some other classes of calls. For example, class-1 calls may be blocked whereas class-2 calls are still being admitted.	Differential treatments of calls based on QoS requirements	Implementation complexity

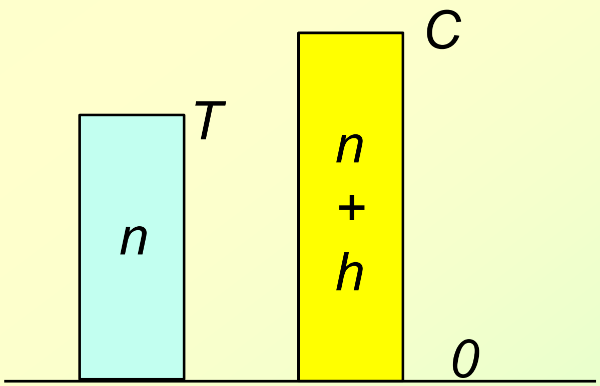
When heaven smiles at you it does not matter who frowns.

Example of a GSM Network

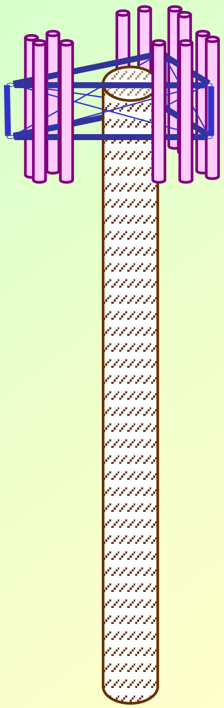


Base Station

A cell of a GSM network has 8 timeslots for supporting new and handoff calls. Assuming that all states of the cell are equally probable, calculate the blocking probability for new calls and dropping probabilities for handoff calls if the cell uses a threshold-based bandwidth reservation scheme, with threshold, T=6 **(i.e. a maximum of 6 new calls can be admitted into the network)**



Example of a GSM Network



- *Given: b=1, C=8, H=6, where b is the bandwidth required for a new or handoff call.*
- *The current state of the heterogeneous system is represented as follows:*

$$\Omega = (n, h)$$

- *The non-negative integer n and h denote the number of ongoing new calls and ongoing handoff calls in the cell of the GSM network, respectively.*
- *The state S of all admissible states is given as:*

$$S = \{\Omega = (n, h): \ ((n + h) * b \leq C) \ \wedge \ (n * b \leq T) \ \}$$

- *The blocking states for new calls are s $\subset$ S for which (b+ (n+h)*b > C) or (b+ n*b > T)*

- *The dropping states for handoff calls are s $\subset$ S for which (b+ (n+h)*b > C)*

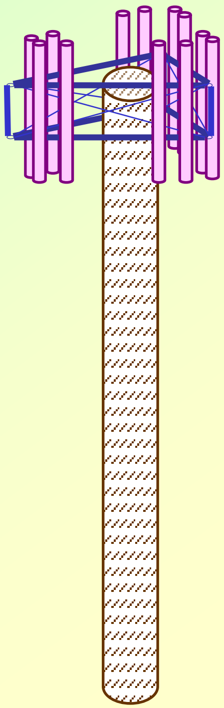
Example of a GSM Network

$$S = \{\Omega = (\mathrm{n},\mathrm{h}):\ ((n+h)*\mathrm{b} \le \mathrm{C})\ \wedge\ (n*b \le T)\ \}$$

Admissible states for [n, h]

[00], [01], [02], [03], [04], [05], [06], [07], [08]
[10], [11], [12], [13], [14], [15], [16], [17]
[20], [21], [22], [23], [24], [25], [26]
[30], [31], [32], [33], [34], [35]
[40], [41], [42], [43], [44]
[50], [51], [52], [53]
[60], [61], [62]

42



Base Station

Blocking states for [n, h] *(b+ (n+h)*b > C) or (b+ (n)*b > T)*

[00], [01], [02], [03], [04], [05], [06], [07], [08]
[10], [11], [12], [13], [14], [15], [16], [17]
[20], [21], [22], [23], [24], [25], [26]
[30], [31], [32], [33], [34], [35]
[40], [41], [42], [43], [44]
[50], [51], [52], [53]
[60], [61], [62]

9

Blocking probability (P_b) = (no of blocking states)/(no of admissible states)

$$P_b = 9/42 = 0.2143$$

Example of a GSM Network

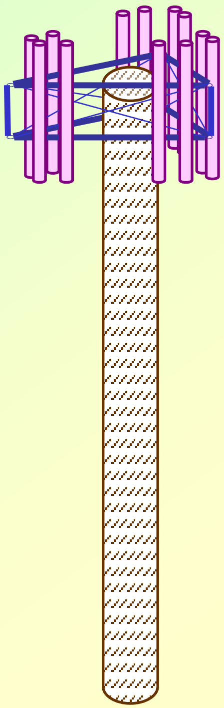
Dropping states for [n, h] → *(b+ (n+h)*b > C)*

[00], [01], [02], [03], [04], [05], [06], [07], [08]
[10], [11], [12], [13], [14], [15], [16], [17]
[20], [21], [22], [23], [24], [25], [26]
[30], [31], [32], [33], [34], [35]
[40], [41], [42], [43], [44]
[50], [51], [52], [53]
[60], [61], [62]

→ **7**

Dropping probability (P_d) = (no of dropping states)/(no of admissible states)

$$P_d = 7/42$$
$$= 0.1667$$



Base Station

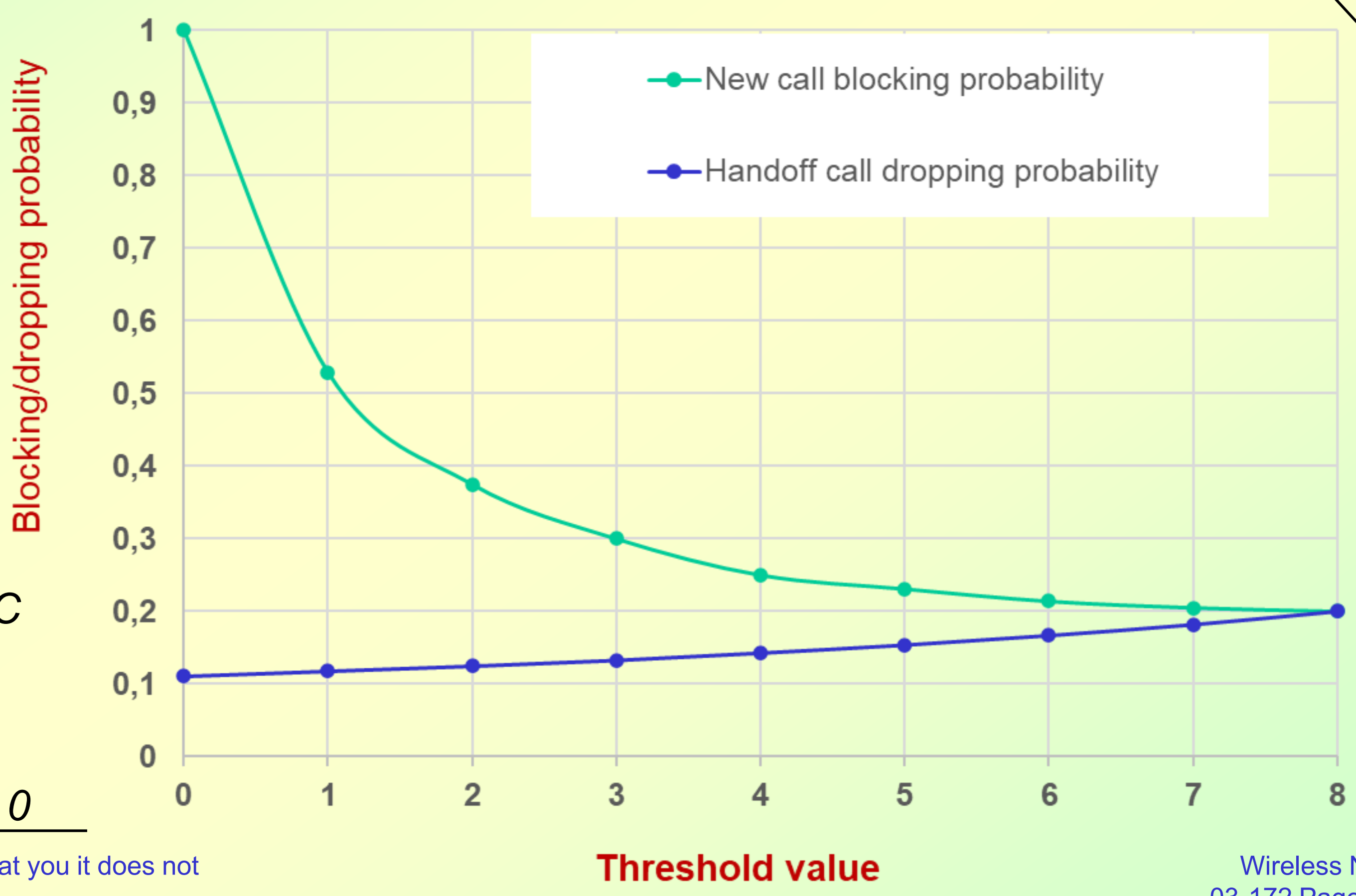
Sample Code in MATLAB

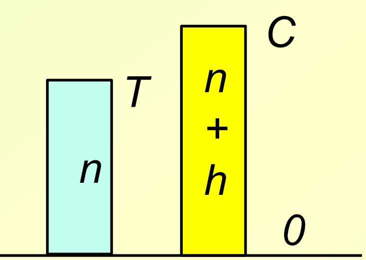
```
clc;
c1=8;
t1=6;
b1=1;
%n1=no of new calls;  %h1=no of handoff calls;
%s1=no of blocking states for n1; %s2= no of dropping states for h1;
%T=total no of admissible states;
s1=0;
s2=0;
T=0;
for n1=0:t1
    for h1=0:c1
if ((b1*(n1+h1)<=c1) & (b1*n1<=t1))
    T=T+1;
%blocking states for new calls
    if (b1+ (b1*(n1+h1)) > c1) | ((b1+ (b1*n1)) > t1)

        s1=s1+1;
    end
    %dropping states for handoff calls
    if b1+ (b1*(n1+h1)) > c1
        s2=s2+1;
    end
    states=[(n1),(h1)]
end
end
end
Block_new_calls =s1/T
Block_handoff_calls =s2/T
```

Handoff call prioritisation: effect of threshold (T) on P_b and P_d

T	0	1	2	3	4	5	6	7	8
P_b	1	0.529	0.375	0.3	0.257	0.231	0.214	0.205	0.2
P_d	0.111	0.118	0.125	0.133	0.143	0.154	0.167	0.182	0.2

= complete sharing scheme



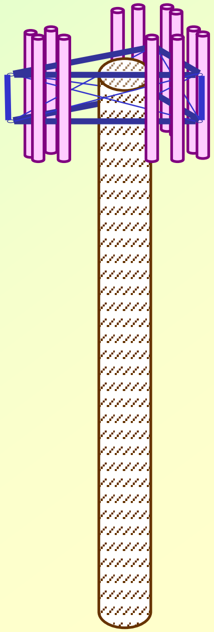


When heaven smiles at you it does not matter who frowns.

Assignment 1a

A cell of a GSM network has 24 timeslots for supporting new and handoff calls. Assuming that all states of the cell are equally probable, calculate the blocking probability for new calls and dropping probabilities for handoff calls if the cell uses a threshold-based bandwidth reservation scheme, with threshold values (T) shown below. Also show the effect of T over P_b and P_d

T	0	3	6	9	12	15	18	21	24
P_b									
P_d									



Base Station

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The greatest oak was once a little nut that held its ground.

Never quit!