Chapter 8

Traffic Channel Allocation

Outline

- Introduction
- Static Allocation versus Dynamic allocation
- Fixed Channel Allocation (FCA)
- Dynamic Channel Allocation (DCA)
- Hybrid Channel Allocation (HCA)
- Allocation in Specialized System Structure
- System Modeling

Introduction

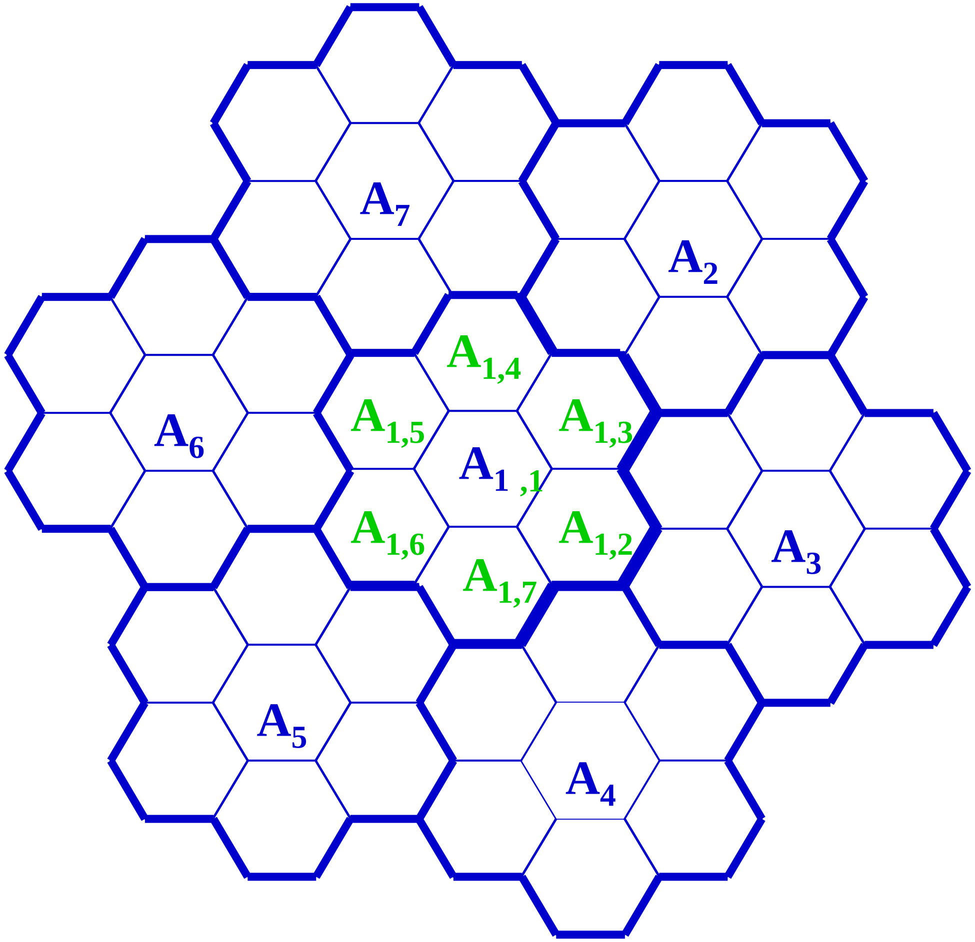
- **What is channel allocation?**
- **A given radio spectrum is to be divided into a set of disjointed channels that can be used simultaneously while minimizing interference in adjacent channel by allocating channels appropriately (especially for traffic channels)**
- **S_{total} channels equally partitioned among N cells and each cell with S channels as**

$$S = S_{total}/N, \text{ e.g., } 140/7=20$$

  - ✓ **$A_{1,1}$: Channels 1-20, $A_{1,2}$: Channels 21-40**
  - ✓ **$A_{1,3}$: Channels 41-60, $A_{1,4}$: Channels 61-80**
  - ✓ **$A_{1,5}$: Channels 81-100, $A_{1,6}$: Channels 101-120**
  - ✓ **$A_{1,7}$: Channels 120-140**

Introduction

- **Channel allocation schemes can be divided in general into Static versus Dynamic**
  - **Fixed Channel Allocation (FCA);**
  - **Dynamic Channel Allocation (DCA);**
  - **Hybrid Channel Allocation (HCA).**



Fixed Channel Allocation (FCA)

- **In FCA, a set of channels is permanently allocated to each cell**
- **Number of available channels *S* is divided into sets, the minimum number of channel sets *N* required is related to the frequency reuse distance *D* as follows:**

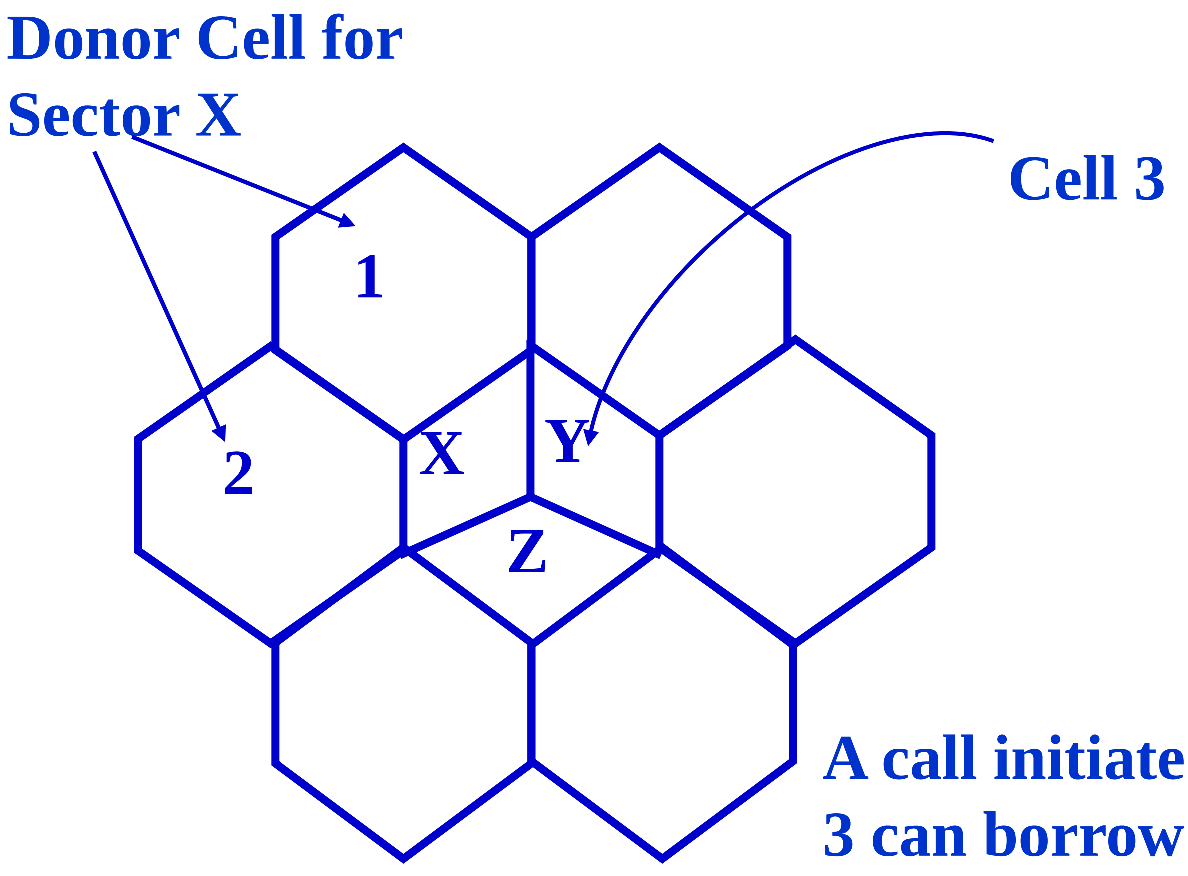
$$N = D^2 / 3R^2 \quad or \quad \sqrt{N} = \frac{D}{\sqrt{3}R}$$

- **If a cell of cluster A_1 borrows channel, there should not be interference with cells A_2, A_3, A_4, A_5, A_6, and A_7**

Simple Borrowing Schemes

- **In SB schemes, cell (*acceptor cell*) that has used all its nominal channels can borrow free channels from its neighboring cell (*donor cell*) to accommodate new calls.**
- **Borrowing can be done from an adjacent cell which has largest number of free channels (*borrowing from the richest*)**
- **Select the first free channel found for borrowing using a search algorithm (*borrow first available scheme*)**
- **Return the borrowed channel when channel becomes free in the cell (*basic algorithm with reassignment*)**
- **To be available for borrowing, the channel must not interfere with existing calls, as shown in the next figure**

Simple Channel Borrowing Schemes

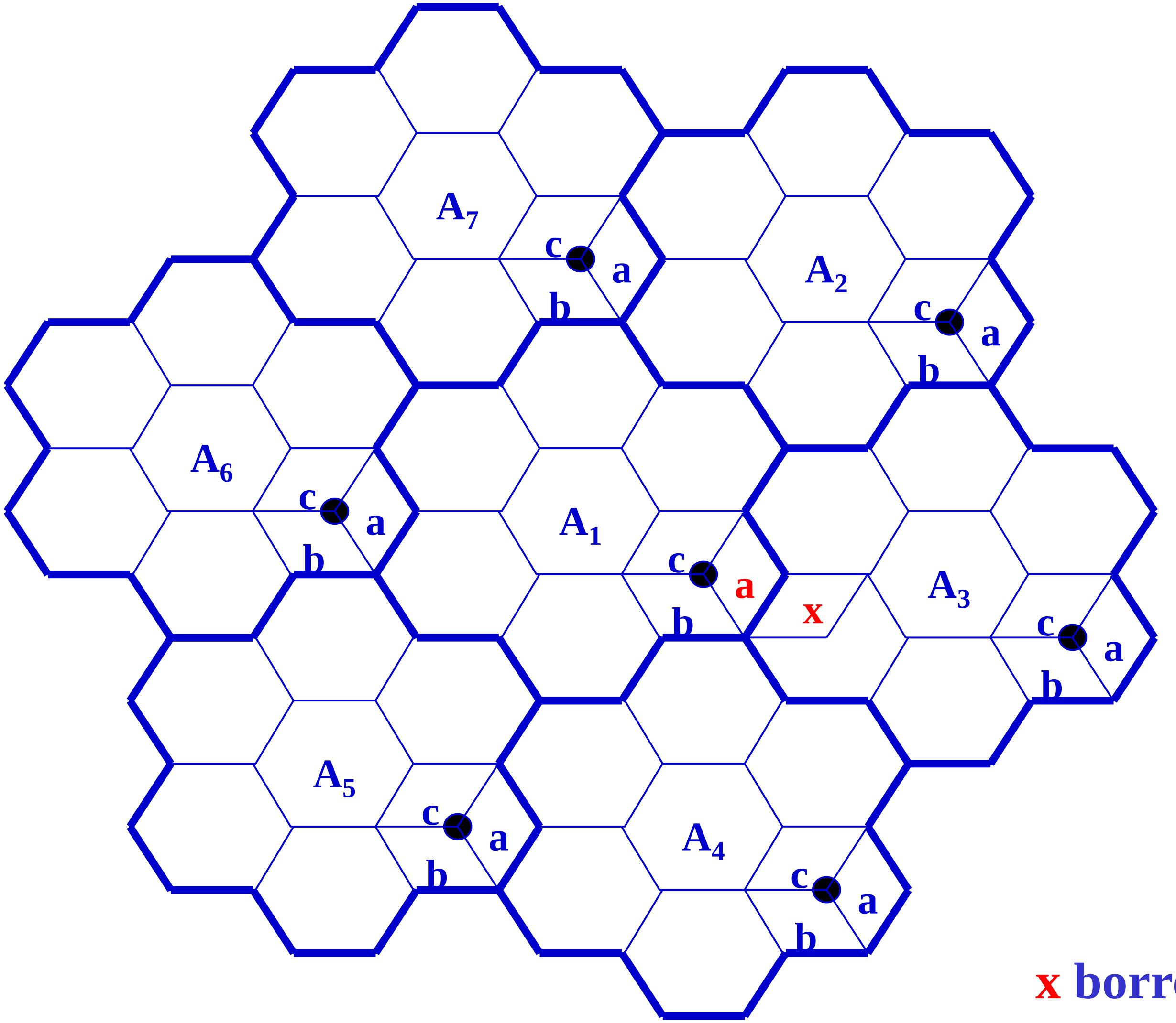


A call initiated in the sector X of cell 3 can borrow a channel from adjacent cells 1 or 2

Complex Borrowing Scheme

- **Partition the traffic channels into two groups, one group assigned to each cell permanently and the second group to be borrowed by neighboring cells**
- **The ratio between the two groups is determined a priori**

Complex Channel Borrowing using Sectored Cell-based Wireless System



x borrows some channels from a

Simple Channel Borrowing Schemes

Scheme	Description
Simple Borrowing (SB)	A nominal channel set is assigned to a cell, as in the FCA case. After all nominal channels are used, an available channel from a neighboring cell is borrowed
Borrow from the Richest (SBR)	Channels that are candidates for borrowing are available channels nominally assigned to one of the adjacent cells of the acceptor cell. If more than one adjacent cell has channels available for borrowing, a channel is borrowed from the cell with the greatest number of channels available for borrowing
Basic Algorithm (BA)	This is an improved version of the SBR strategy which takes channel blocking into account when selecting a candidate channel for borrowing. This scheme tried to minimize the future call blocking probability in the cell that is most affected by the channel borrowing
Basic Algorithm with Reassignment	This scheme provides for the transfer of a call from a borrowed channel to a nominal channel whenever a nominal channel becomes available
Borrow First Available	Instead of trying to optimize when borrowing, this algorithm selects the first candidate channel it finds

Dynamic Channel Allocation (DCA)

- In DCA schemes, all channels are kept in a central pool and are assigned dynamically to new calls as they arrive in the system
- After each call is completed, the channel is returned to the central pool. Select the most appropriate channel for any call based simply on current allocation and current traffic, with the aim of minimizing the interference
- DCA scheme can overcome the problem of FCA scheme. However, variations in DCA schemes center around the different cost functions used for selecting one of the candidate channels for assignment

Dynamic Channel Allocation (DCA)

- **DCA schemes can be centralized or distributed**
- **The centralized DCA scheme involves a single controller selecting a channel for each cell**
- **The distributed DCA scheme involves a number of controllers scattered across the network (MSCs)**
- **Centralized DCA schemes can theoretically provide the best performance. However, the enormous amount of computation and communication among BSs leads to excessive system latencies and render centralized DCA schemes impractical. Nevertheless, centralized DCA schemes often provide a useful benchmark to compare practical decentralized DCA schemes**

Centralized DCA

- For a new call, a free channel from the central pool is selected that would maximize the number of members in its co-channel set
- Minimize the mean square of distance between cells using the same channel

Centralized DCA Schemes

Scheme	Description
First Available (FA)	Among the DCA schemes the simplest one is the FA strategy. In FA, the first available channel within the reuse distance encountered during a channel search is assigned to the call. The FA strategy minimizes the system computational time
Mean Square (MSQ)	The MSQ scheme selects the available channel that minimizes the mean square of the distance among the cells using the same channel
Selection with Maximum Usage on the Reuse Ring (RING)	A candidate channel is selected which is in use in the most cells in the co-channel set. If more than one channel has this maximum usage, an arbitrary selection among such channel is made to serve the call. If none is available, then the selection is made based on the FA scheme

Distributed DCA Schemes

- Based on one of the three parameters:
  - Co-channel distance

    - co-channel cells in the neighborhood not using the channel

    - sometimes adjacent channel interference taken into account
  - Signal strength measurement

    - expected CCIR (Co-channel Interference Ratio) above threshold
  - SNR (Signal-to-Noise Ratio)

Comparison between FCA and DCA

FCA	DCA
▪ Performs better under heavy traffic	▪ Performs better under light/moderate traffic
▪ Low flexibility in channel assignment	▪ Flexible channel allocation
▪ Maximum channel reusability	▪ Not always maximum channel reusability
▪ Sensitive to time and spatial changes	▪ Insensitive to time and spatial changes
▪ Unstable grade of service per cell in an interference cell group	▪ Stable grade of service per cell in an interference cell group
▪ High forced call termination probability	▪ Low to moderate forced call termination probability
▪ Suitable for large cell environment	▪ Suitable in microcellular environment
▪ Low flexibility	▪ High flexibility

Comparison between FCA and DCA

FCA	DCA
■ Radio equipment covers all channels assigned to the cell ■ Independent channel control ■ Low computational effort ■ Low call set up delay ■ Low implementation complexity ■ Complex, labor intensive frequency planning ■ Low signaling load ■ Centralized control	■ Radio equipment covers the temporary channel assigned to the cell ■ Fully centralized to fully distributed control dependent on the scheme ■ High computational effort ■ Moderate to high call set up delay ■ Moderate to high implementation complexity ■ No frequency planning ■ Moderate to high signaling load ■ Centralized, distributed control depending on the scheme

Other Channel Allocation Schemes

- **Based on different criterion being used as a potential way of optimizing the performance, many other channel allocation schemes have been suggested**
  - **Hybrid Channel Allocation (HCA)**
  - **Flexible Channel Allocation (FCA)**

Hybrid Channel Allocation (HCA)

- HCA schemes are the combination of both FCA and DCA techniques
- In HCA schemes, the total number of channels available for service is divided into fixed and dynamic sets
  - The fixed set contains a number of nominal channels that are assigned to cells as in the FCA schemes and, in all cases, are to be preferred for use in their respective cells
  - The dynamic set is shared by all users in the system to increase flexibility

Example: When a call requires service from a cell and all of its nominal channels are busy, a channel from the dynamic set is assigned to the call

Hybrid Channel Allocation (HCA)

- **Request for a channel from the dynamic set is initiated only when the cell has exhausted using all its channels from the fixed set**
- **Optimal ratio: ratio of number of fixed and dynamic channels**
  - ✓ **3:1 (fixed to dynamic), provides better service than fixed scheme for traffic load up to 50% (105 versus 35 channels)**
  - ✓ **Beyond 50% traffic load fixed scheme perform better**
  - ✓ **For dynamic, with traffic load of 15% to 40%, better results are found with HCA**

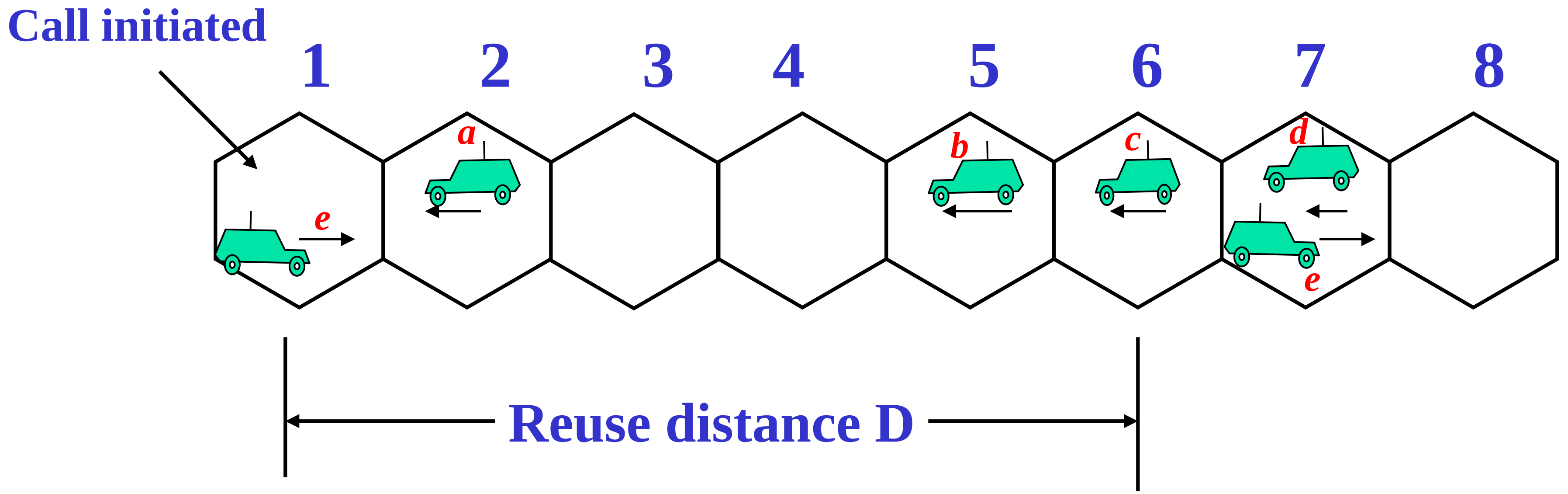
Flexible Channel Allocation (FCA)

- **Similar to hybrid scheme with channels divided into fixed and flexible (emergency) sets**
- **Fixed sets used to handle lighter loads**
- **Variations in traffic (peaks in time and space) are needed to schedule emergency channels**
- **Two types: Scheduled and Predictive**
- ***Scheduled*: Prior estimate is done about traffic change**
- ***Predictive*: Traffic intensity and blocking probability is monitored in each cell all the time**

Allocation in Specialized System Structure

- Channel Allocation in One-Dimensional Systems
- Reuse Partitioning-Based Channel Allocation
- Overlapped Cells-Based Channel Allocation

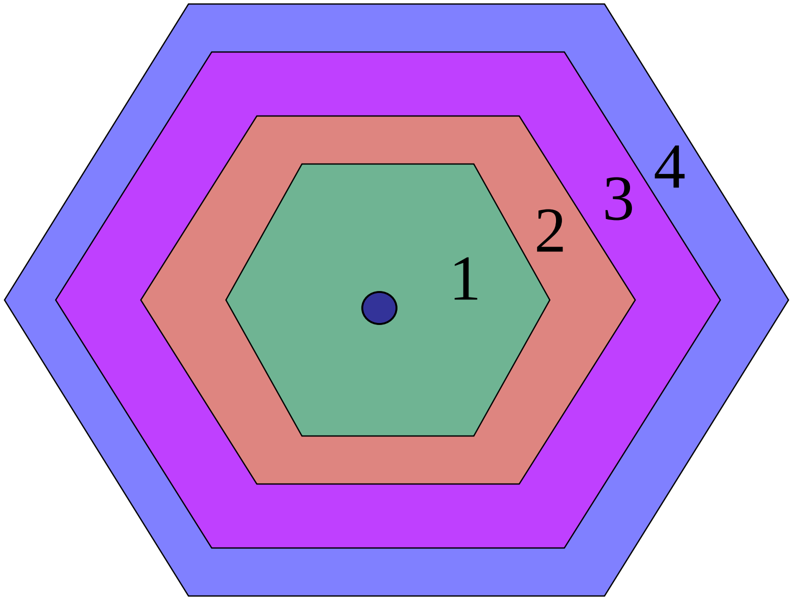
Channel Allocation in One-dimensional Systems



If a new call is initiated in cell 1, with the current location of channels *a, b, c, d, e* as shown. It is better to assign channel *e* to mobile in cell 1. Assuming that as cell 1 moves to cell 2, MS in cell 7 moves to cell 8

Reuse Partitioning based Channel Allocation

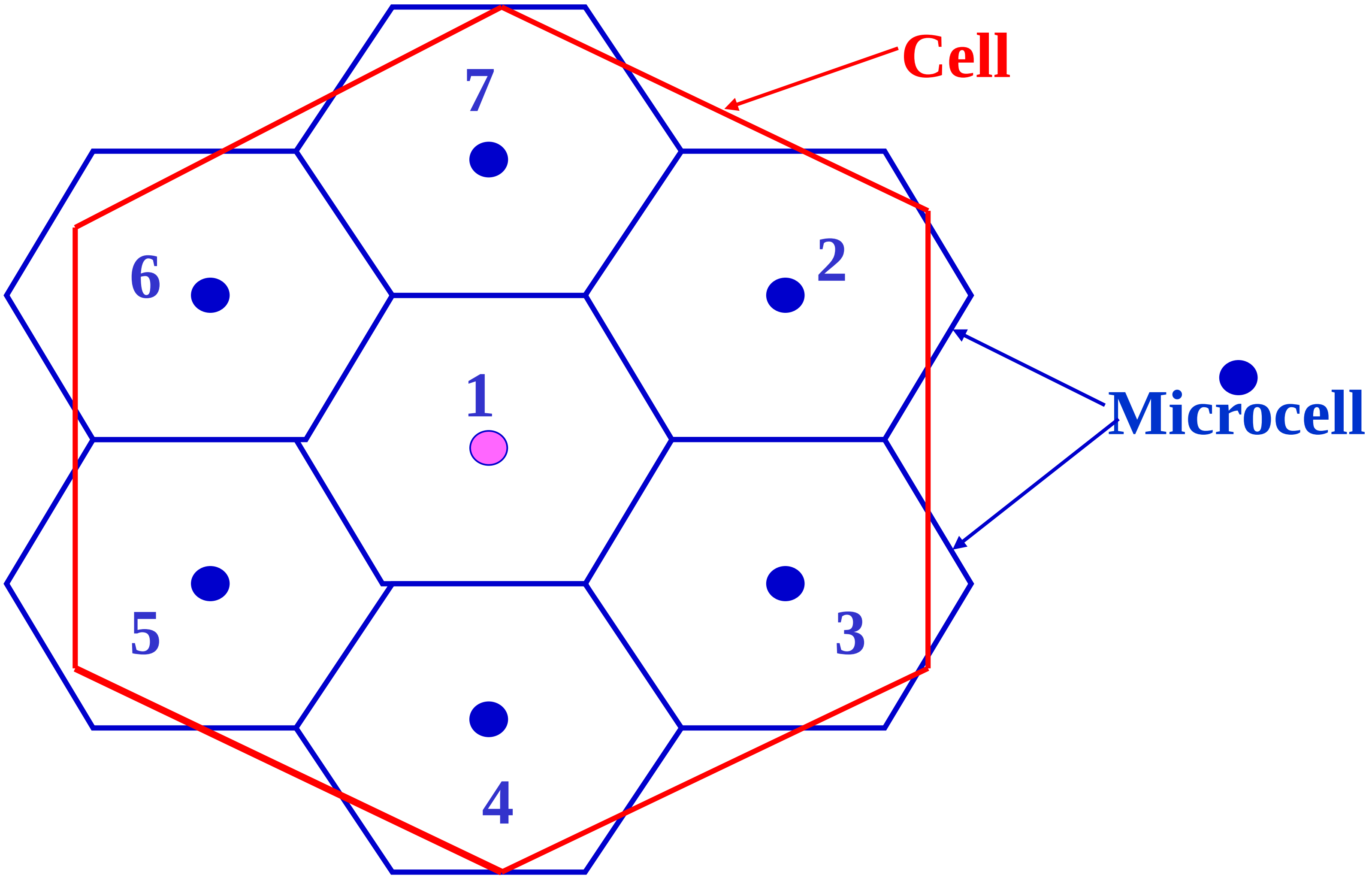
- Each cell is divided into concentric zones.
- Inner zone being closer to BS would require lesser power to attain a desired channel which has a lower value of reuse distance
- Mobile subscribers with the best SIR are assigned a set of channels with the smallest reuse distance.



Overlapped Cells-based Allocation

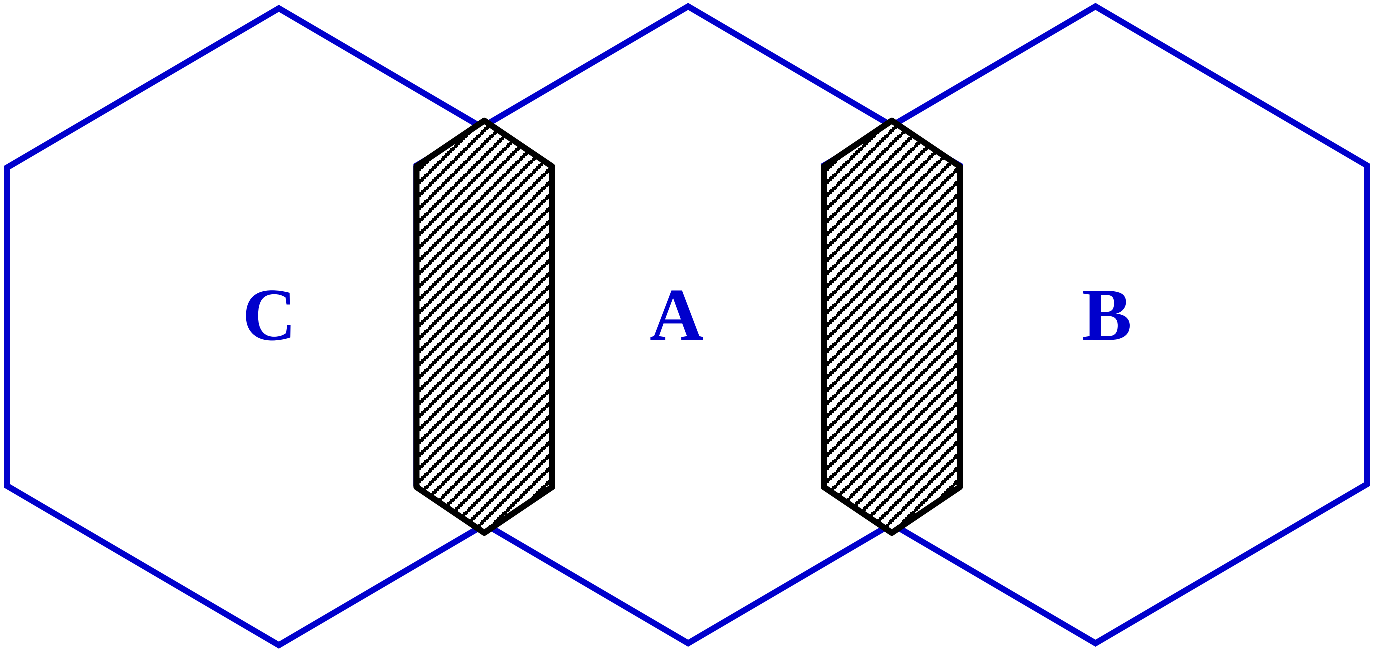
- Cell splitting into number of smaller cells (pico, micro cells), to handle increased traffic
- For fast moving MS, if channels are assigned from micro cell, number of handoffs will increase
- Therefore highly mobile MS are assigned channels from the cell
- MS with low mobility are assigned to micro- or pico-cells

Overlapped Cells-based Allocation



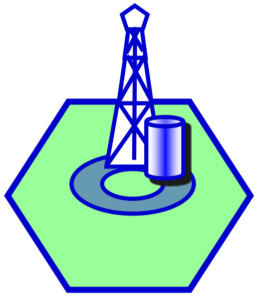
Use of Overlapped Cell Areas

- In the shared area Handoffs not necessary
- Directed retry: if MS in shared area does not find a free channel in cell A, it can take the free channel from cell B
- Directed handoff: Handoff a connected channel in the shaded area of cell A to cell B if a new call in cell A do not find a free channel

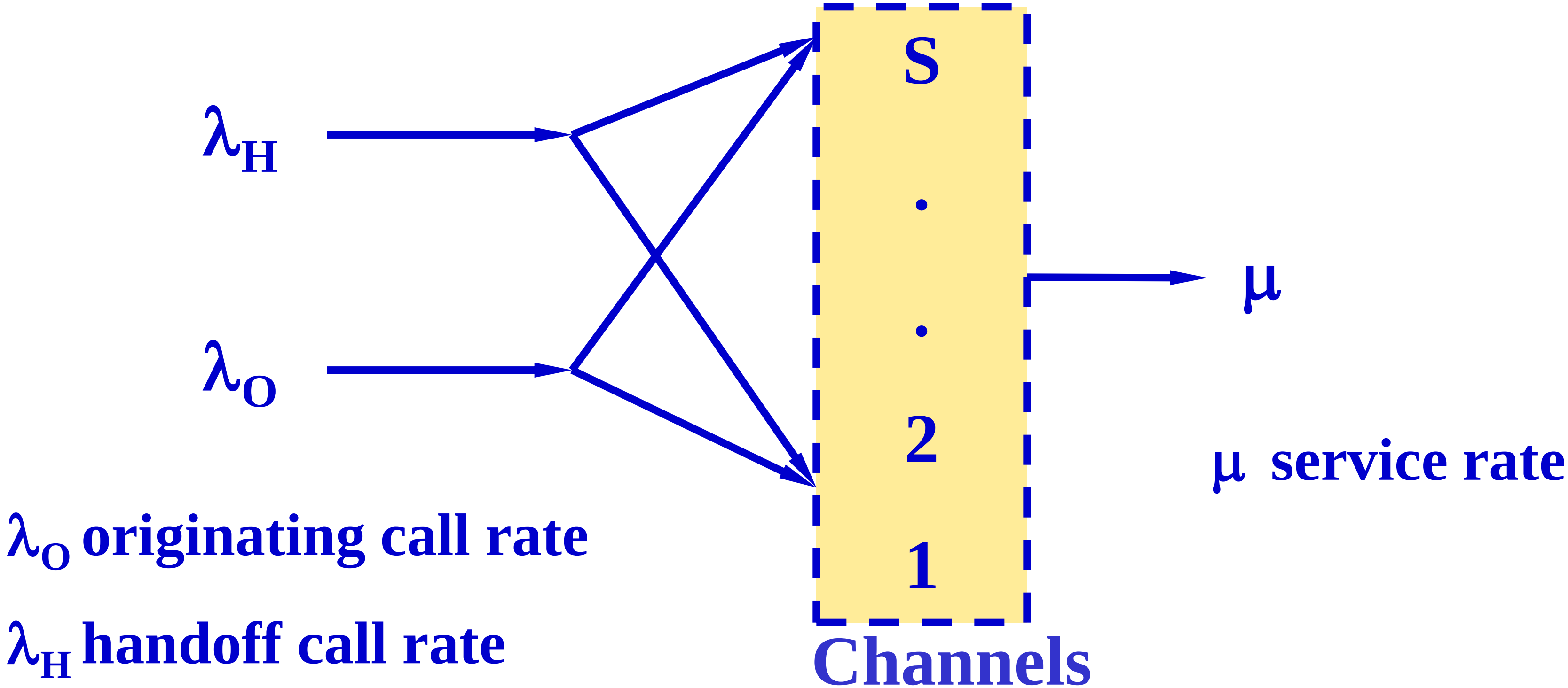


System Modeling

- The follows assumptions are made to obtain an approximate model of system
  - All MSs are assumed to be uniformly distributed through the cell
  - Each MS moves at a random speed and to an arbitrary random direction
- The arrival rate of originating call is given by λ_O
  - The arrival rate of handoff call is given by λ_H
  - The call service rate is given by μ



System Model



A generic system model for a cell with S channels

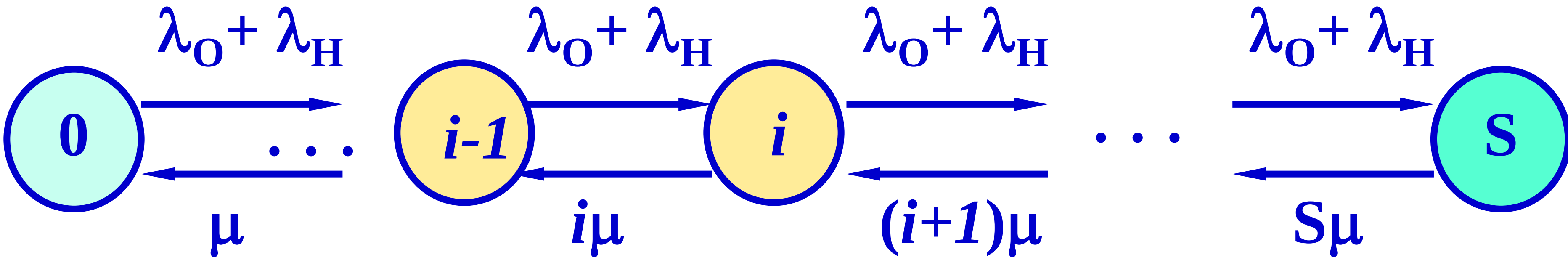
Analysis Model (cont'd)

The follows parameters are defined in the analysis model

- ***P(i)*:** the probability of "*i*" channels to be busy
- **λ_O :** the arrival rate of an originating call in the cell
- **λ_H :** the arrival rate of a handoff call from neighboring cells
- **B_O :** the blocking probability of originating calls
- **S :** the total number of channels allocated to a cell
- **μ:** the call service rate
- **μ_c :** the average call duration
- **$\mu_{c\text{-}dwell}$:** the outgoing rate of MSs

Basic Modeling

The states of a cell can be represented by (S+1) states Markov model. And a transition diagram of *M/M/S/S* model as shown below.



State transition diagram

$$i\mu P(i) = (\lambda_O + \lambda_H)P(i-1), \quad 0 \le i \le S$$

Basic Modeling (cont'd)

- **The state equilibrium equation for state *i* can be given as**

$$P(i) = \frac{\lambda_O + \lambda_H}{i\mu} P(i-1), \quad 0 \le i \le S$$

- **And the sum of all states must to be equal to one:**

$$\sum_{i=0}^{S} P(i) = 1$$

- **The steady-state probability *P(i)* is easily found as follows:**

$$P(i) = \frac{(\lambda_0 + \lambda_H)^i}{i!\,\mu^i} P(0), \quad 0 \le i \le S \quad \text{where}$$

$$P(0) = \left[\sum \frac{(\lambda_0 + \lambda_H)^i}{i!\,\mu^i} \right]^{-1}$$

Basic Modeling (cont'd)

- The blocking probability for an originating call when all S channels are busy, can be expressed by:

$$B_O = P(\mathrm{S}) = \frac{\dfrac{(\lambda_O + \lambda_H)^{\mathrm{S}}}{\mathrm{S}!\,\mu^{\mathrm{S}}}}{\sum_{i=0}^{\mathrm{S}} \dfrac{(\lambda_O + \lambda_H)^{i}}{i!\,\mu^{i}}}$$

- The blocking probability of a handoff request at this state is also the forced termination probability of a handoff call is:

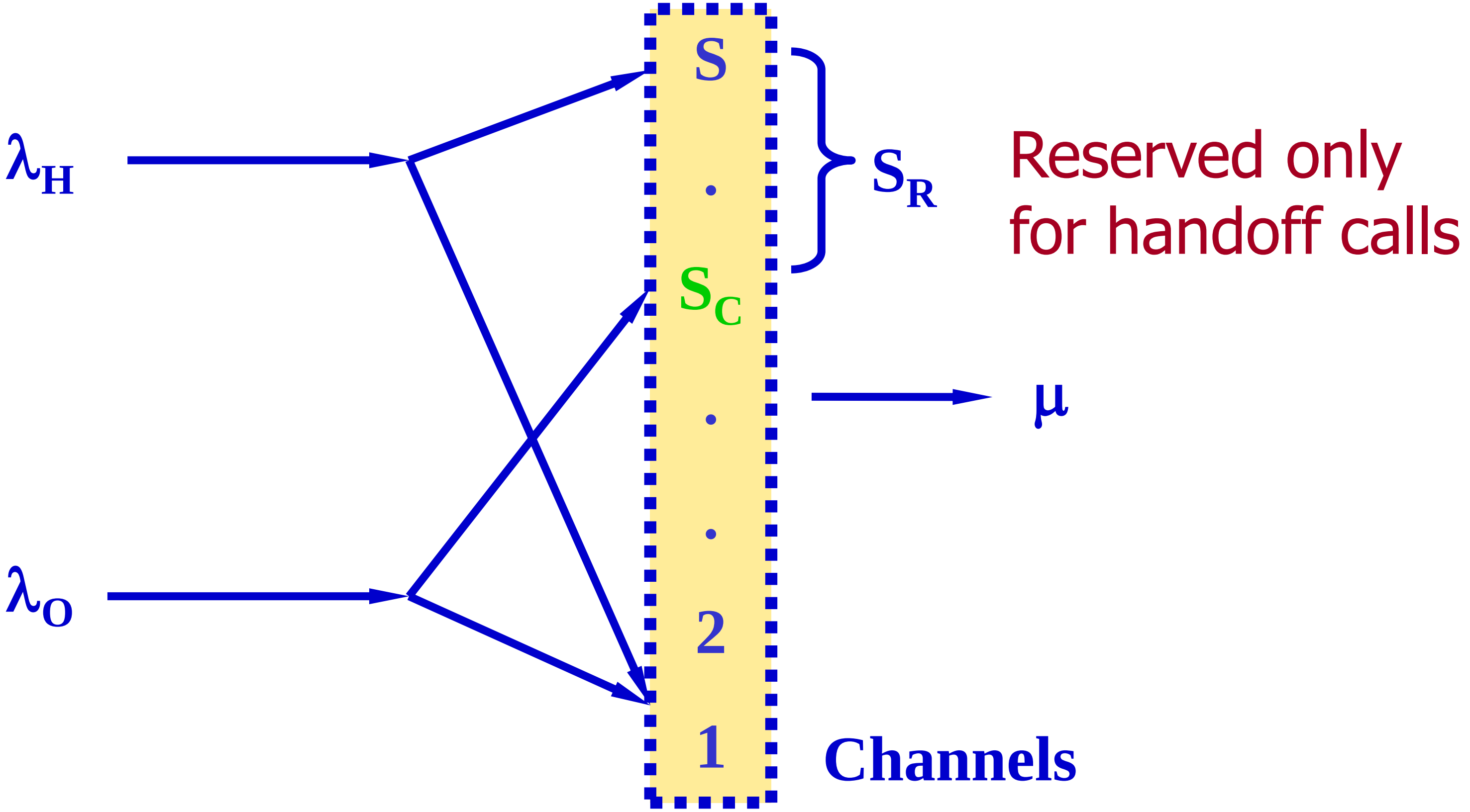
$$B_H = B_0$$

- This is **Erlang B** formula covered in Chapter 5

Modeling for Channel Reservation

- Why should we provide a higher priority to handoff calls?
- From users' view, the dropping of handoff calls is more serious and irritating than the blocking of originating calls
- How to provide a higher priority to handoff calls?
- One approach is reserve S_R channels exclusively for handoff calls among the S channels in a cell

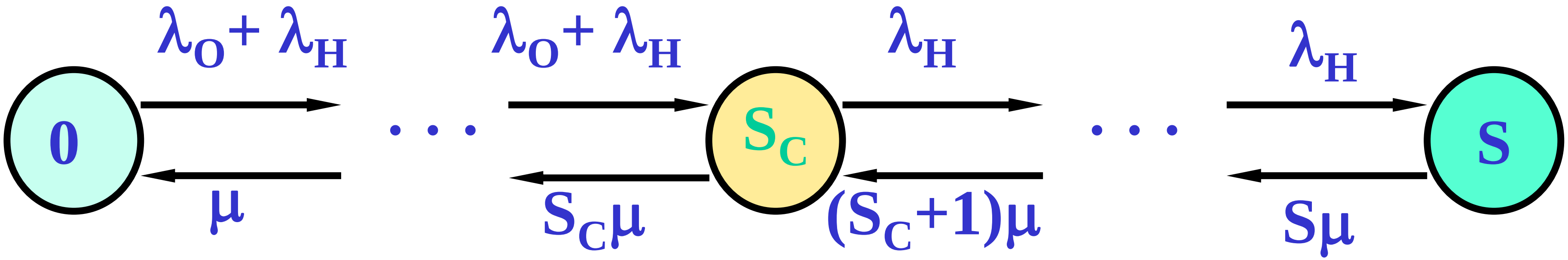
System Model with Reserved Channels



System model with reserved channels for handoff

(No blocking of originating calls till less than S_C channels are busy)

Analytical Model



State transition diagram

- The state balance equations can be obtained as

$$\begin{cases} i\mu P(i) = (\lambda_O + \lambda_H)P(i-1), & 0 \le i \le S_C \\ i\mu P(i) = \lambda_H P(i-1), & S_C < i \le S \end{cases}$$

and

$$\sum_{i=0}^{S} P(i) = 1.$$

Analytical Modeling (cont'd)

- **The steady-state probability *P(i)* can be obtained as:**

$$P(i)=\begin{cases}\dfrac{(\lambda_{\mathrm{O}}+\lambda_H)^i}{i!\,\mu^i}P(0), & 0\le i\le \mathrm{S_c}\\[2ex] \dfrac{(\lambda_{\mathrm{O}}+\lambda_H)^{\mathrm{S_c}}\,\lambda_H^{\,i-\mathrm{S_c}}}{i!\,\mu^i}P(0), & \mathrm{S_c}< i\le \mathrm{S}\end{cases}$$

- **Where**

$$P(0)=\left[\sum_{i=0}^{\mathrm{S_c}}\frac{(\lambda_0+\lambda_H)^i}{i!\,\mu^{\,i}}+\sum_{i=\mathrm{S_c}+1}^{\mathrm{S}}\frac{(\lambda_0+\lambda_H)^{\mathrm{S_c}}\,\lambda_H^{\,i-\mathrm{S_c}}}{i!\,\mu^{\,i}}\right]^{-1}$$

Analytical Model (Cont'd)

- **The blocking probability B_O for an originating call is given by (at least S_C channels busy):**

$$B_o = \sum_{i=S_C}^{S} P(i)$$

- **The blocking probability B_H for a handoff call is (all S channels busy) or forced termination probability of handoff call is:**

$$B_H = P(S) = \frac{(\lambda_O + \lambda_H)^{S_C} \lambda_H^{S-S_C}}{S!\,\mu^S} P(0)$$

Homework

- Exercise: 8.1, 8.4, 8.8, 8.15
- Quiz (Ch1. ~ Ch. 8): Nov. 11