Performance Analysis of Cellular Networks

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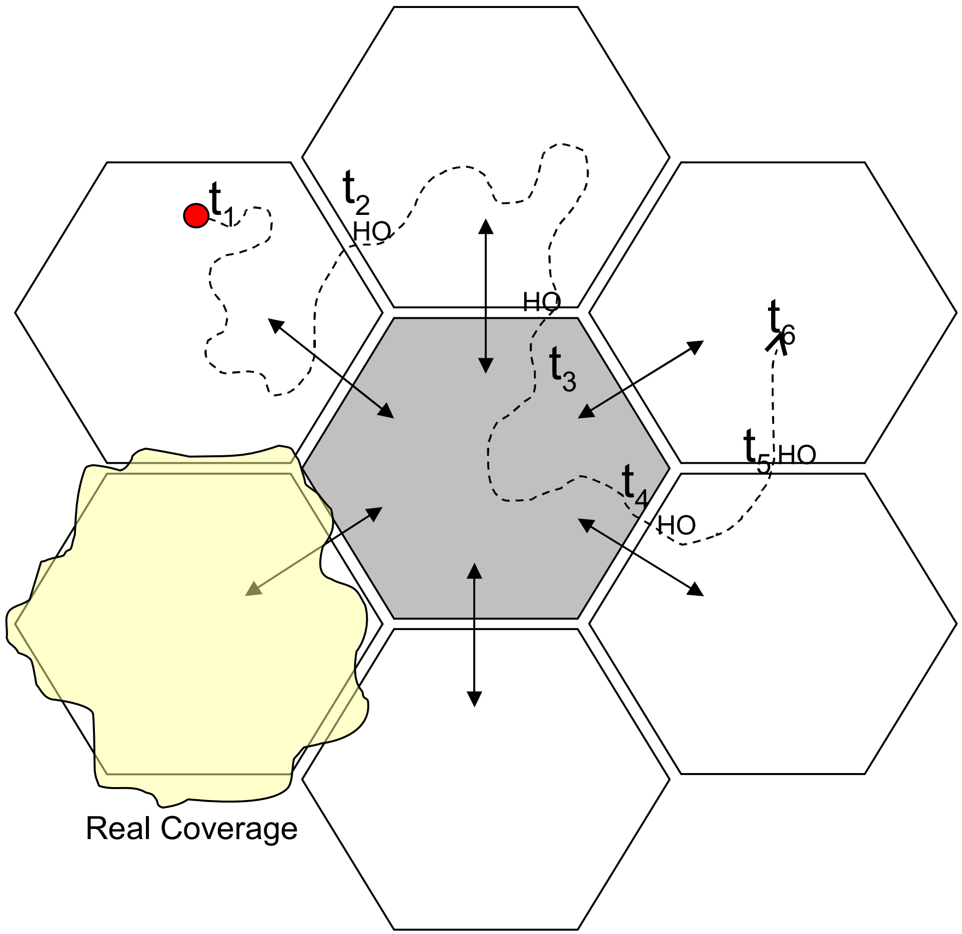


Scenario

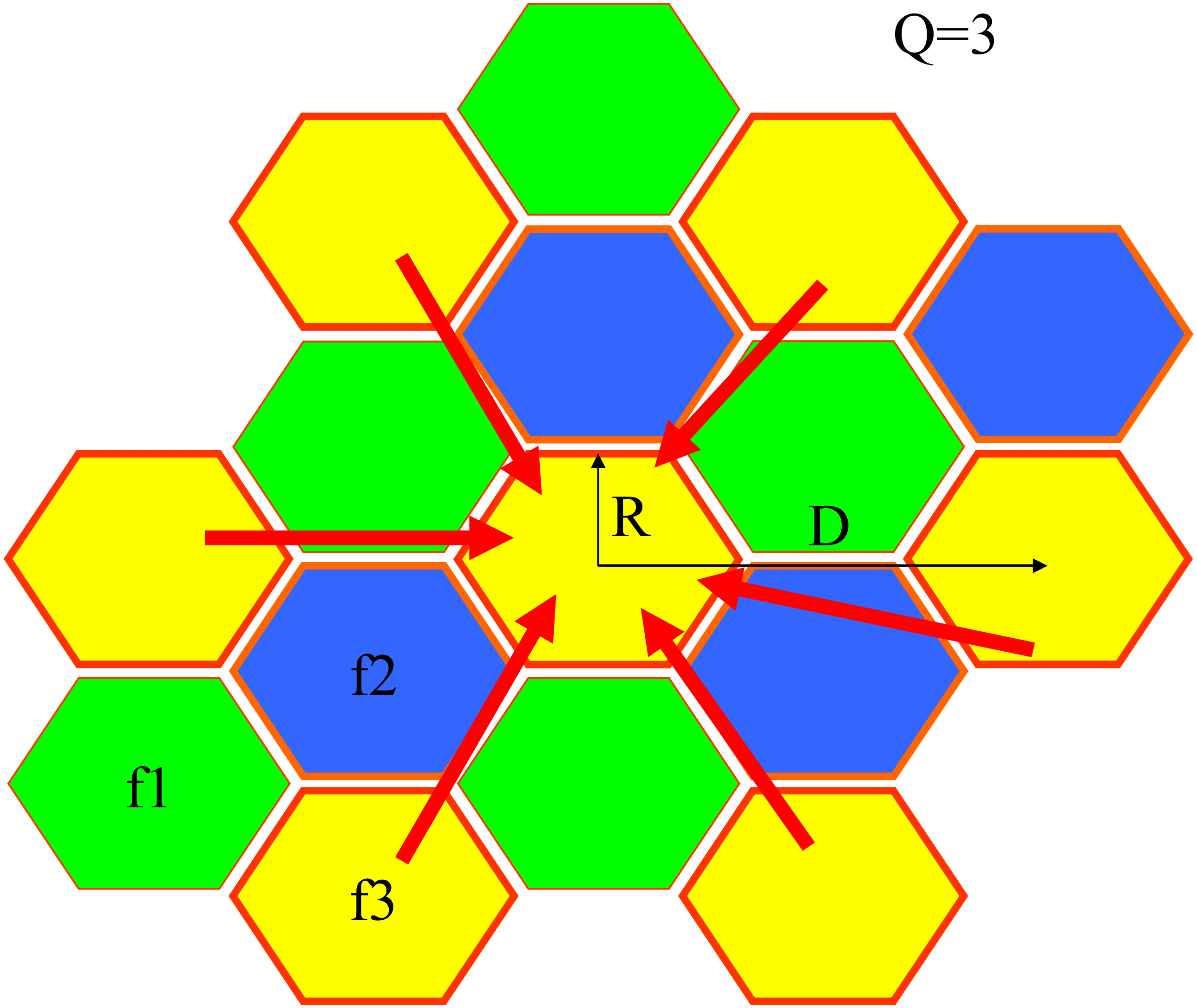
- Two type of cells:
  - A: low mobility
  - B: high mobility

Assumptions

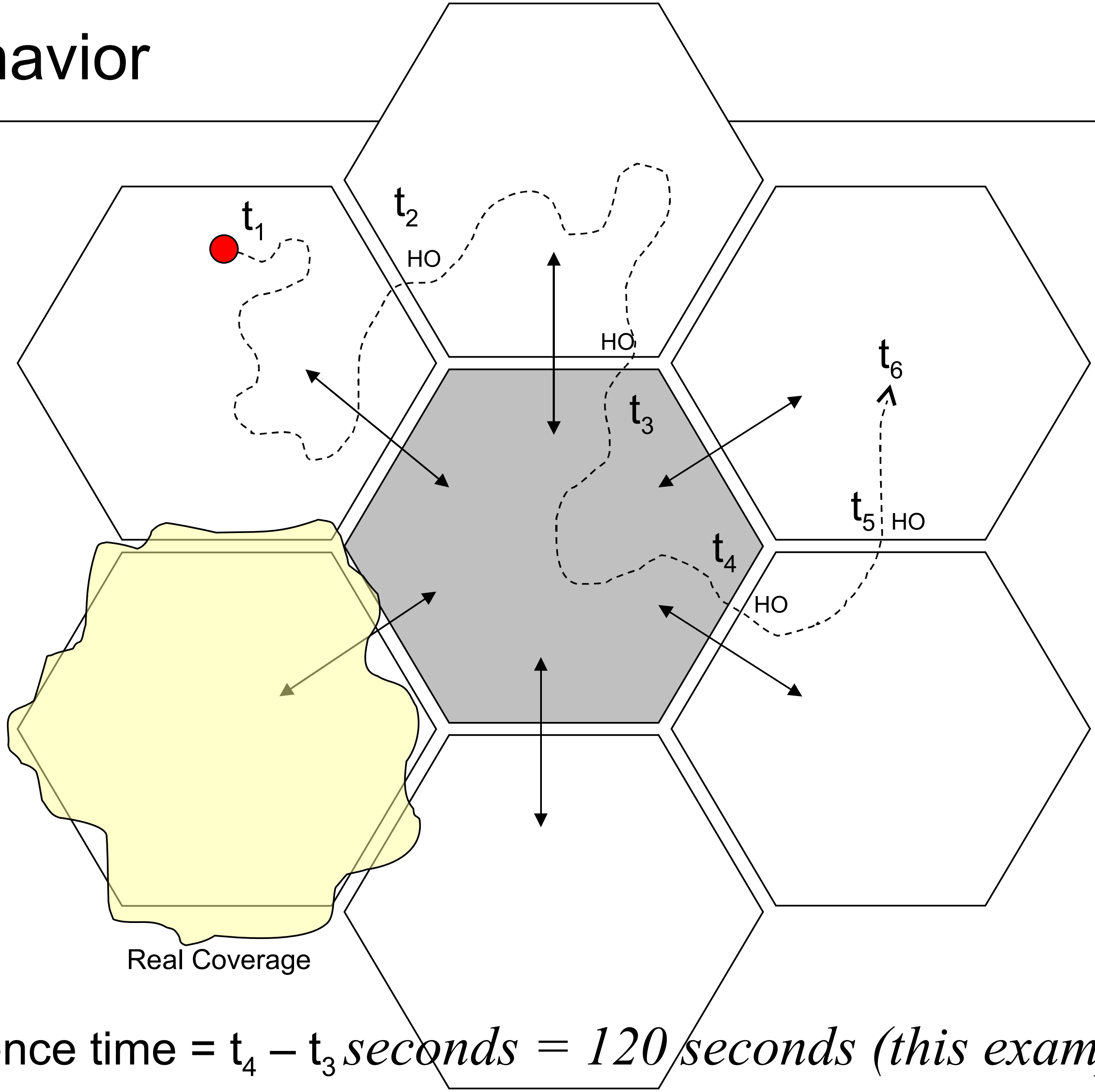
- Homogeneous hab. Density:
  - Low: 1000 hab / Km^2
  - High: 5000 hab / Km^2
- Each uses makes an average of 3 calls / day
- Hexagonal Cells of radius: R= 300 m
  - Area Hex: 2,6·R^2 (0.234 Km^2)
- The mobile operator has only 3 carriers
  - Each carrier has 8 channels.

Frequency planning

- Using more channels, a better Q is obtained.
  - C/I ↑



User behavior



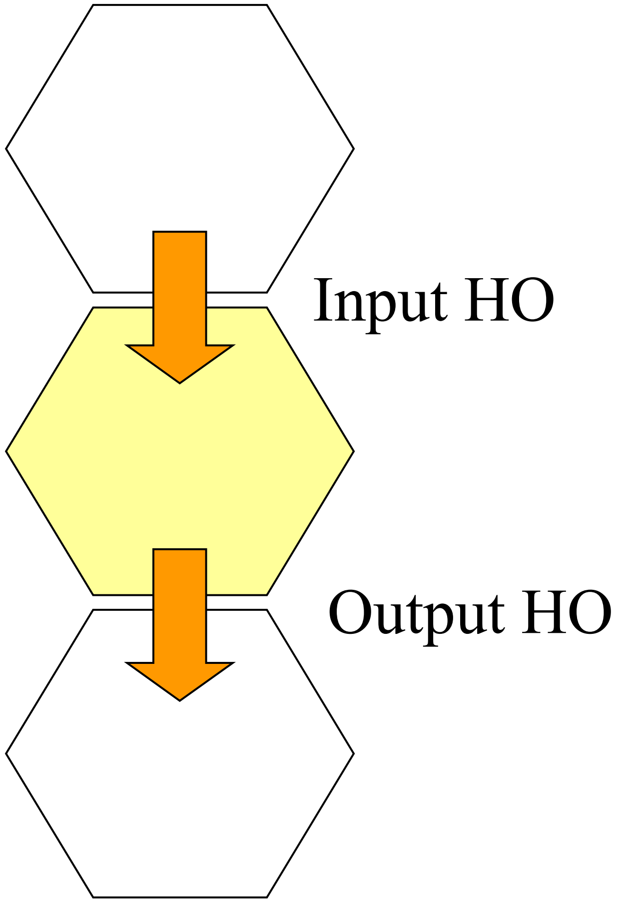
Cell residence time = $t_4 - t_3$ *seconds = 120 seconds (this example)*

Traffic parameters

- Hab. / cell
  - Hab. Density: 1000 hab / Km^2; 5000 hab / Km^2
  - Cell area: 0.234 Km^2
    - → 234 hab / cell, 1170 hab / cell
  - → Number of calls / day (average):
    - → 234·3 = 702 calls / day → λ=0.008125 calls / second
    - → 1170·3 = 3510 calls / day → λ=0.040625 calls / second
- → Call duration:
  - → [Assumption] The same for hand-off and new calls
    - → Cell residence time (X=120 seconds)
- Offered load (traffic) per cell:
  - Low traffic: A= 0.008125 · 120 = 0.975 Erlangs
  - High traffic: A= 0.040626 · 120 = 4.875 Erlangs

Handoff rate

- Input HO = Output HO
- Probability of HO
  - α = 0 (no mobility)
  - α = 0.1 – 0.3 (low mobility)
  - α = 0.7 – 0.9 (high mobility)
- HO rate:
  - $\lambda_{ho} = \alpha \cdot \lambda$



Low traffic, Low mobility Cell: $\alpha = 0.2$

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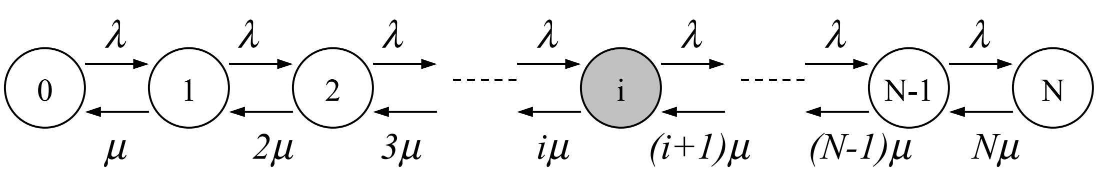
- All channel are used by new and HO calls.
- C=8 channels / carrier.
- λ=0.008125 calls / second (Poisson arrivals)
- $\lambda_{ho} = \alpha \cdot \lambda = 0.0016250$
- X= 120 seconds → μ=1/X=0.0083333 sec. /call

- Model of the cell:



Low traffic, Low mobility Cell: $\alpha = 0.2$

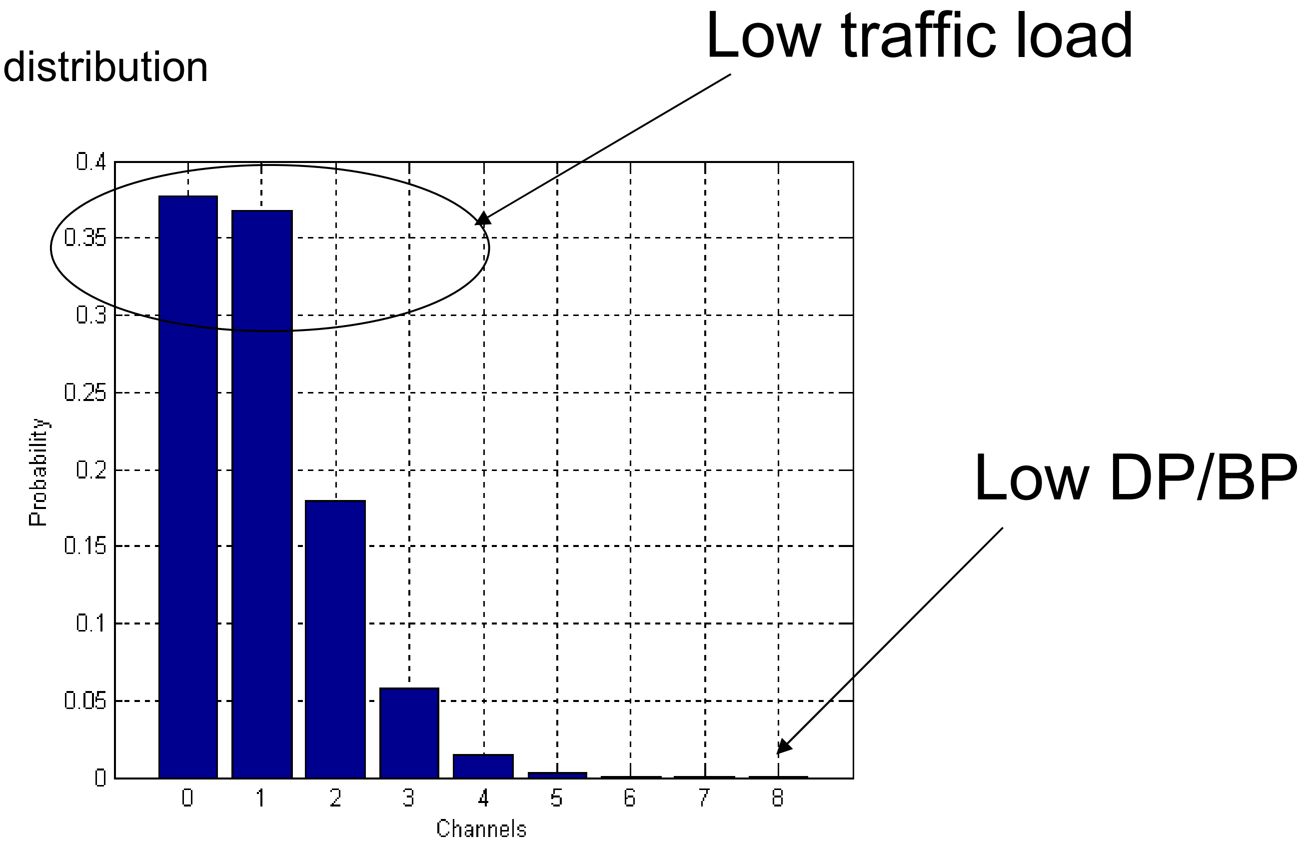
- Solving the Model
  1) Markov Chain (ok) – Birth and death model.
  2) Equilibrium /Balance equations.
  3) Performance metrics:
     1) Blocking / Dropping Probability: P(C) (state C)
     2) System Empty: P(0) (state 0)
     3) Average number of calls in the system
        - $E[N]=P(0)\cdot 0+P(1)\cdot 1+\ldots+P(C)\cdot C$
     4) ...

- Grade of Service
  - $GoS = BP + 10 \cdot DP$ (BP: blocking prob, DP: drop. Prob)

- Note: If we are interested only in the blocking probability: Erlang-B tables
  - http://www.sis.pitt.edu/~dtipper/2720/erlang-table.pdf

Low traffic, Low mobility Cell: α = 0.2

- Steady – state distribution



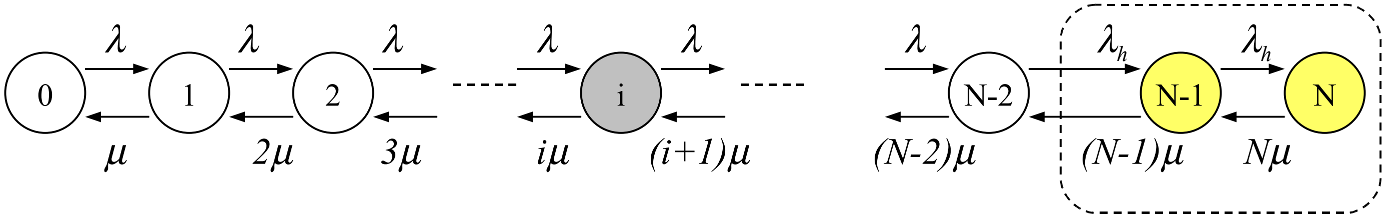
- Arrival distribution = Steady-state distribution (PASTA)

Low traffic, Low mobility Cell: $\alpha = 0.2$

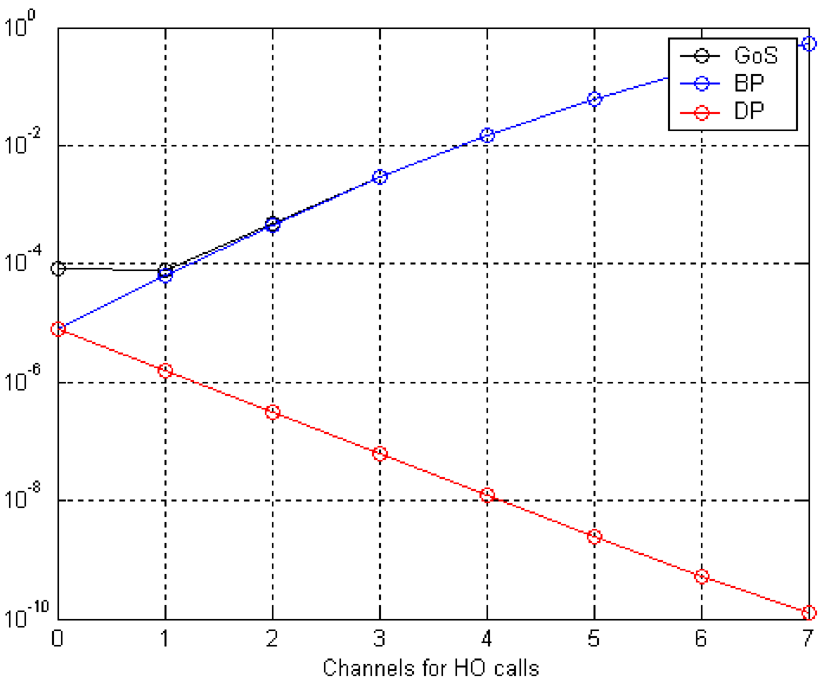
- All channel are used by new and HO calls.
- C=8 channels / carrier.
- λ=0.008125 calls / second.
- $\lambda_{ho} = \alpha \cdot \lambda = 0.0016250$
- X= 120 seconds → μ=1/X=0.0083333 sec. /call

- Blocking Probability = 7.6398e-006
- Dropping Probability = 7.6398e-006
- GoS=8.4037e-005

Guard Channels



- Using guard channels for HO calls
- Goal: min (GoS)



High traffic, Low mobility Cell: $\alpha = 0.2$

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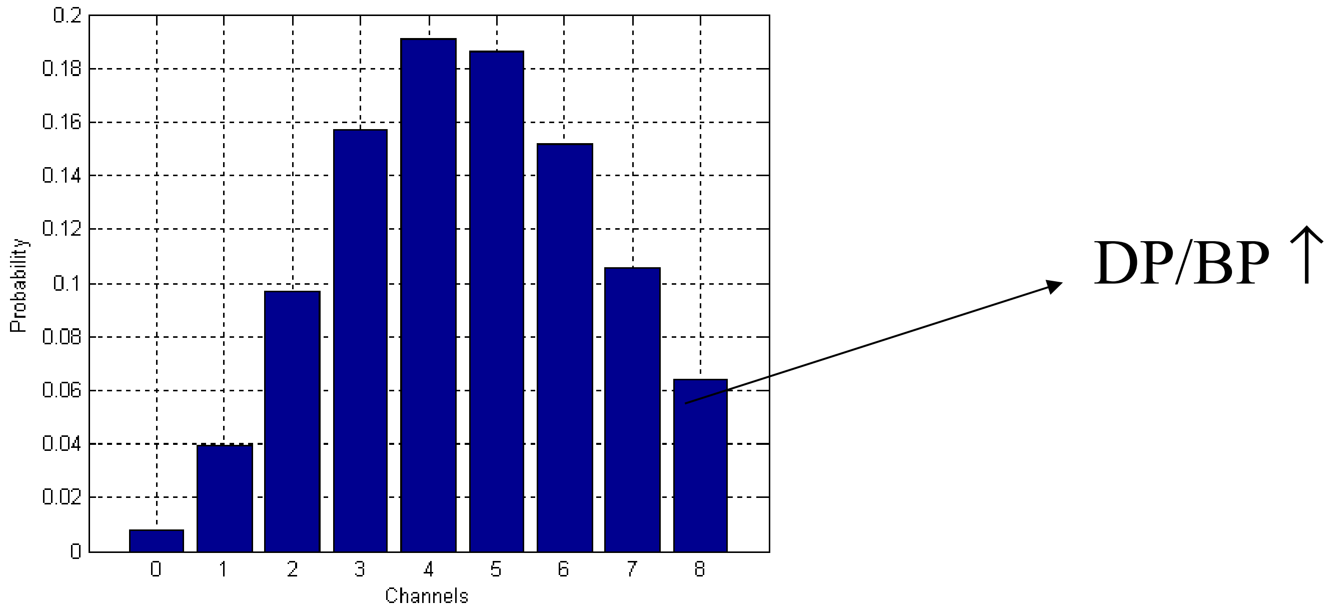
- λ= 0.040625 calls / second.
- $\lambda_{ho}=\alpha \cdot \lambda$ = 0.00812 calls / second

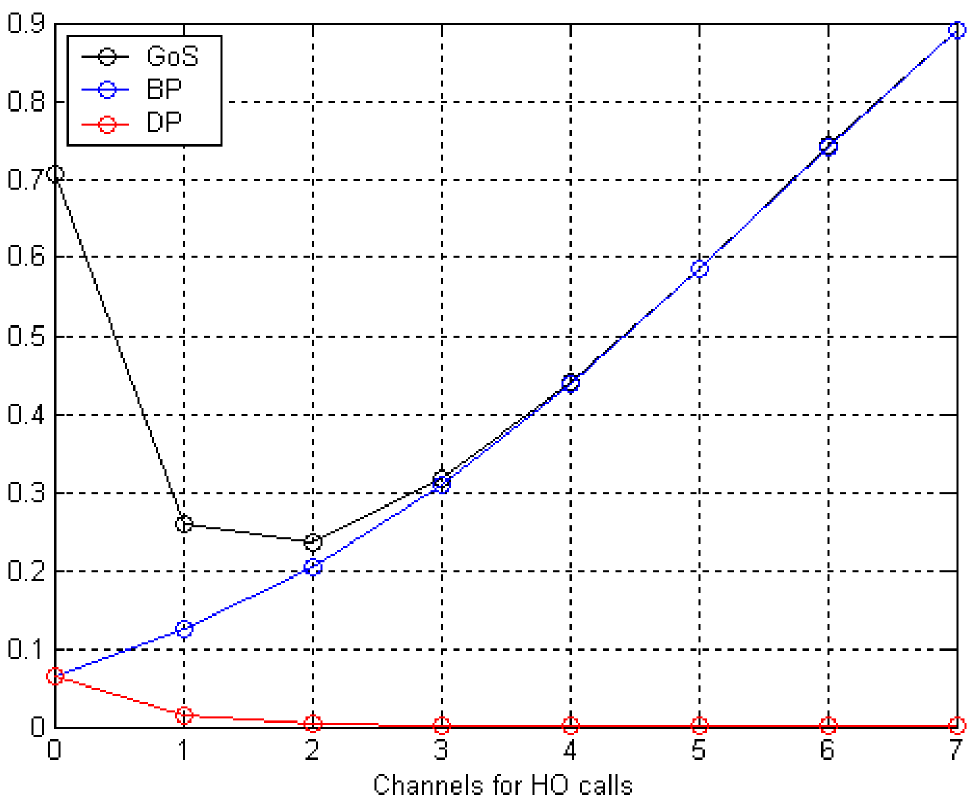
Without guard channels



Blocking / Dropping Probabilities
New: 6.4280e-002
HO: 6.4280e-002
Grade of Service 7.0708e-001

High traffic, Low mobility Cell: $\alpha = 0.2$

- Using guard channels for HO calls
- Goal: min (GoS)



High traffic, High mobility Cell: $\alpha = 0.7$

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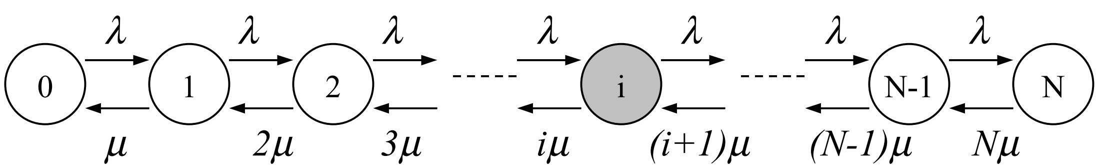
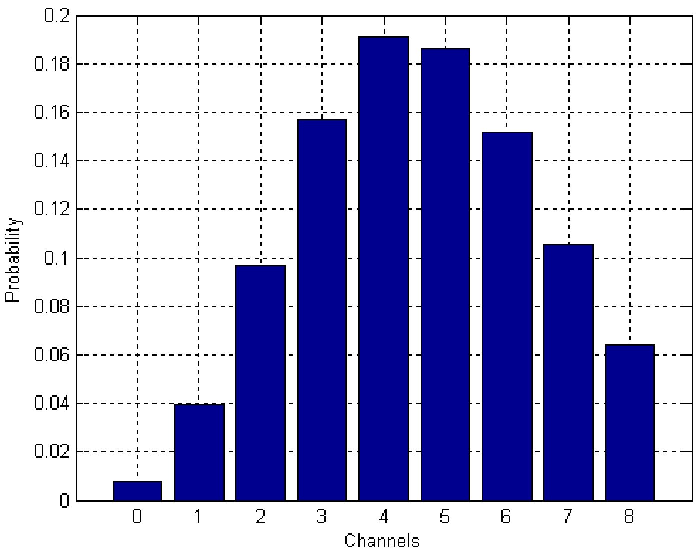
- All channel are used by new and HO calls.
- C=8 channels / carrier.
- λ= 0.040625 calls / second.
- $\lambda_{ho}=\alpha\cdot\lambda$ = 0.028437 calls / second.
- X= 120 seconds → μ=1/X=0.0083333 sec. /call

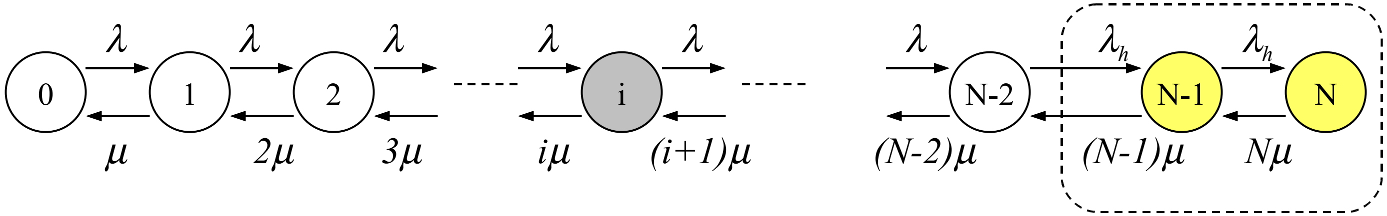


High traffic, High mobility Cell: α = 0.7

- Blocking / Dropping Probabilities: New | HO
  - New: 6.4280e-002
  - HO: 6.4280e-002
- Grade of Service
  - 7.0708e-001

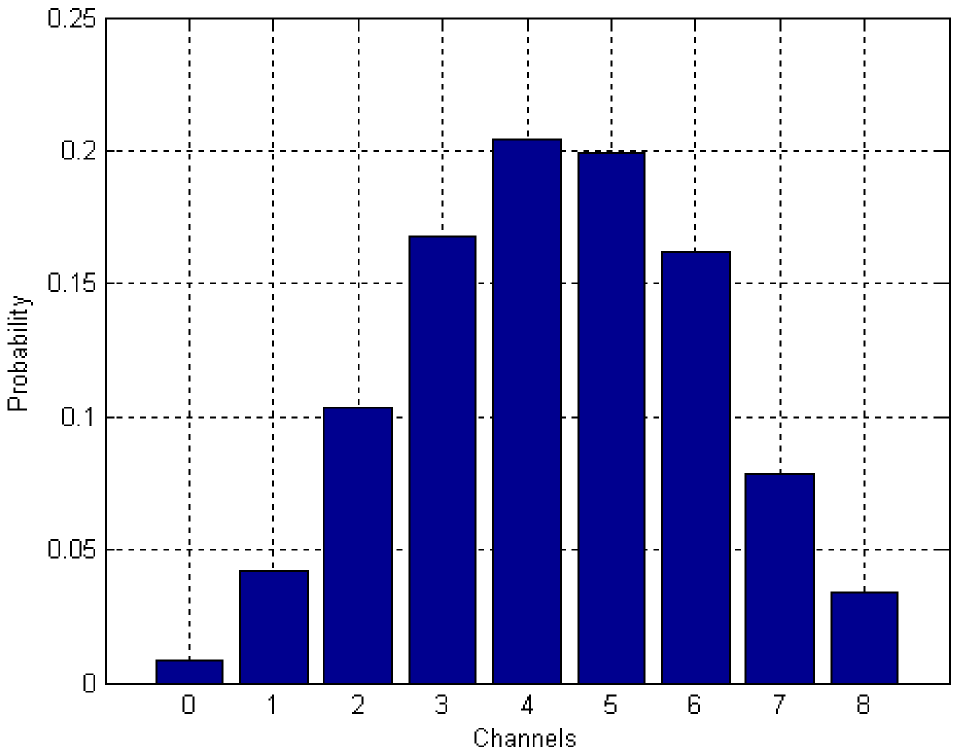


- The use guard channels for HO calls can improve the GoS (and thus, the overall system performance)



High traffic, High mobility Cell: $\alpha = 0.7$

- 2 channels reserved for HO calls
- BP=0.27449
- DP=0.03366
- GoS=0.61

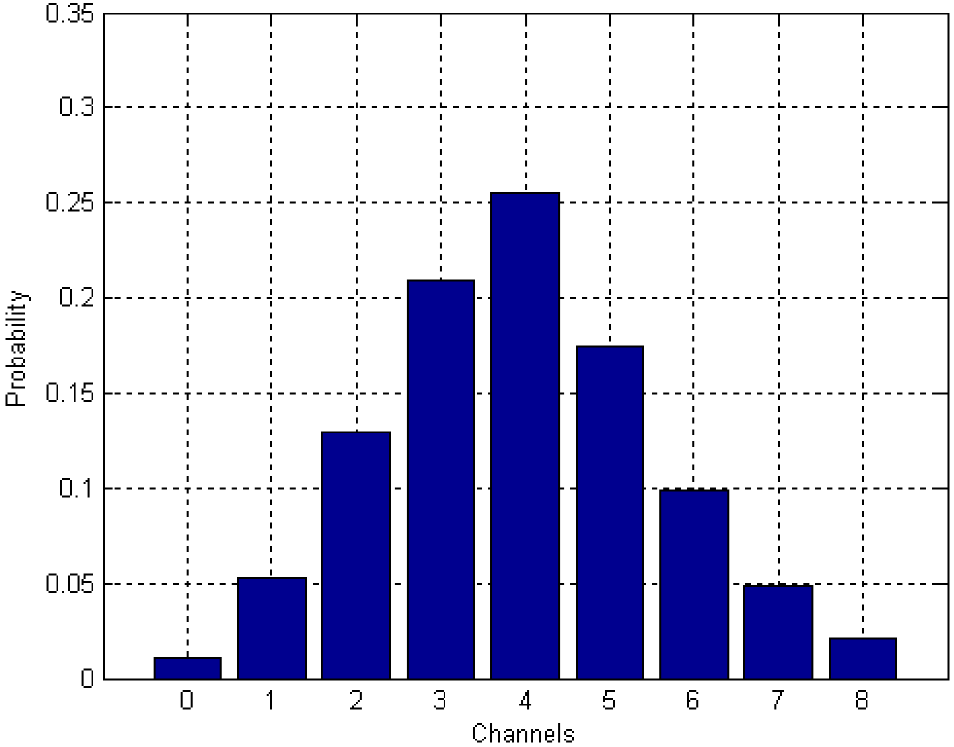


$$BP=P(6)+P(7)+P(8)$$
$$DP=P(8)$$

High traffic, High mobility Cell: $\alpha = 0.7$

- 4 channels reserved for HO calls
- BP=0.5977
- DP=0.02061
- GoS=0.80

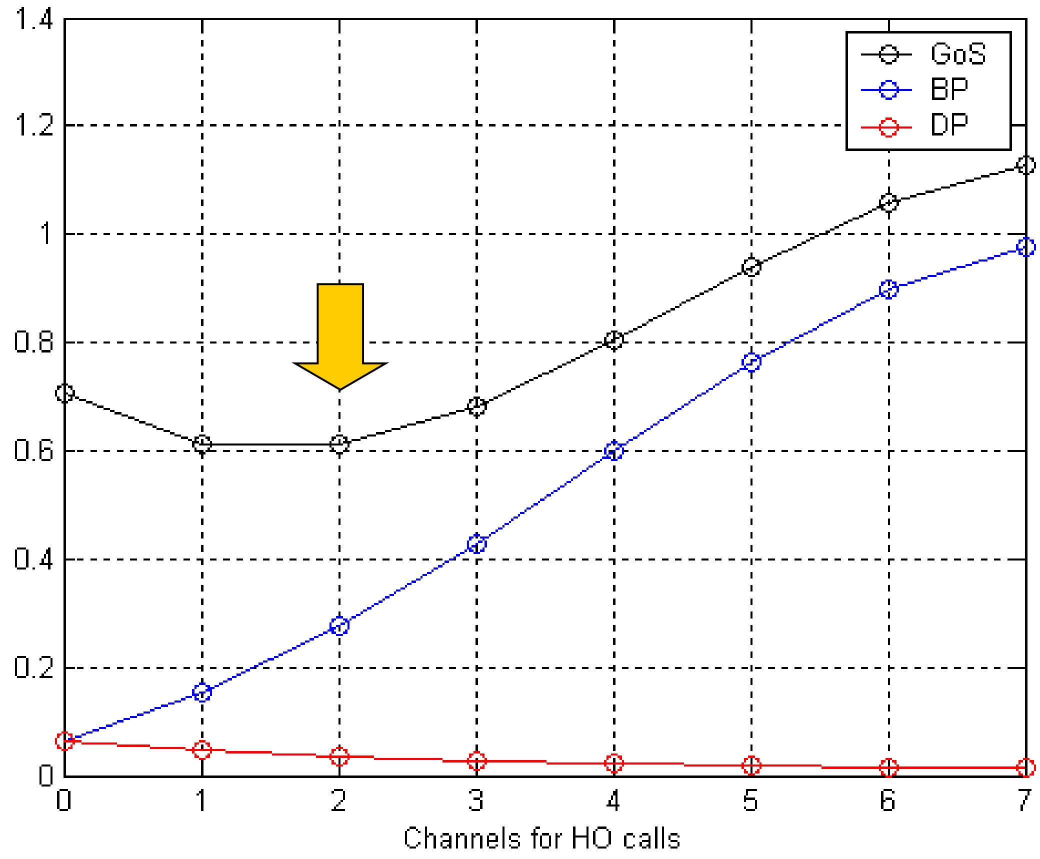
  It’s better to have only 2 guard channels than 4.



Exercise: and 3 or 1 guard channels...

Will be better than 2 or not?

Exercise solution

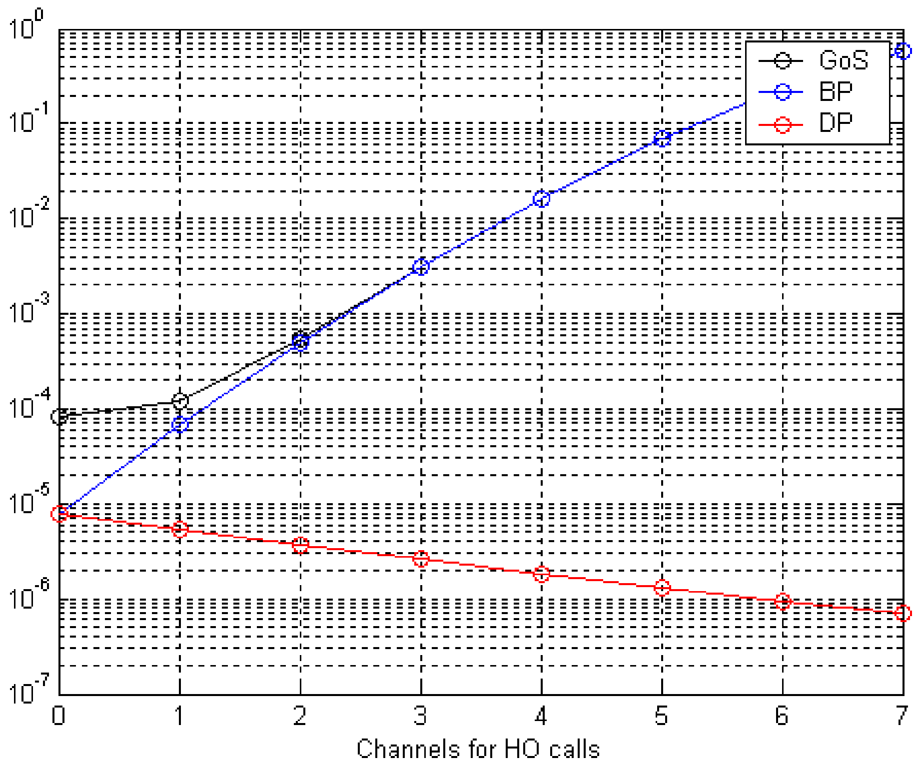


Optimum number of guard channels?

Interesting results....

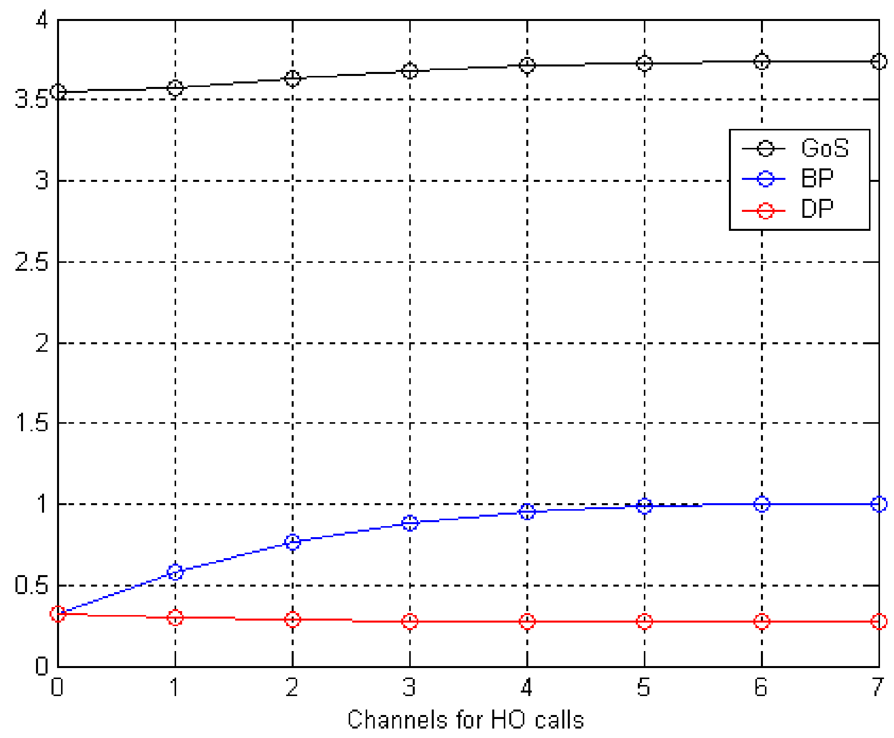
Low traffic, High mobility

- λ= 0.008125 calls / second
- α=0.7



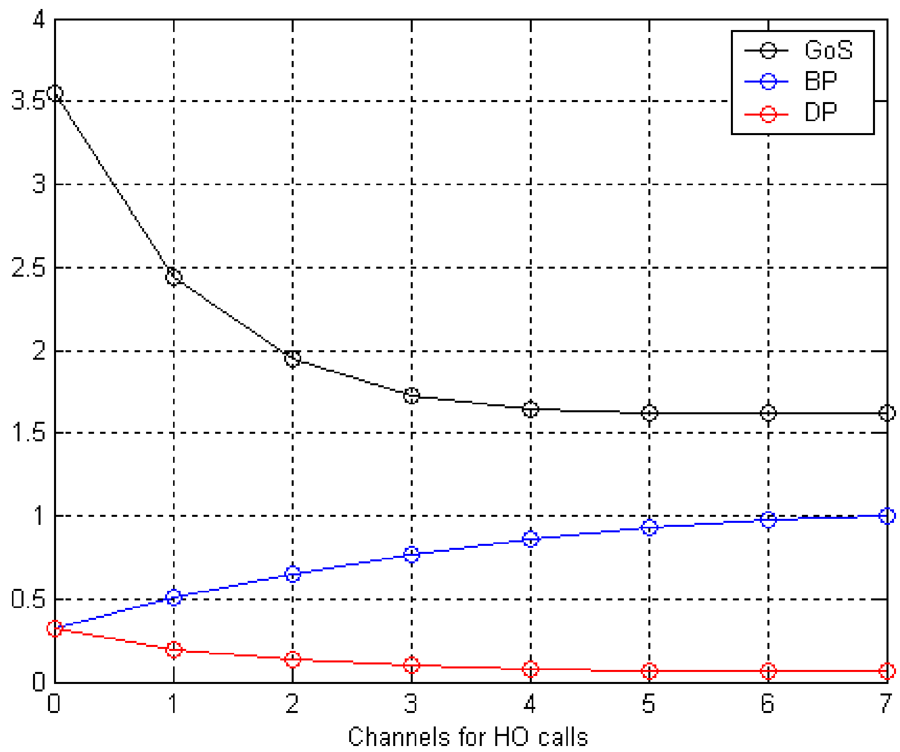
Very High Traffic, Very High Mobility

- λ= 0.080625 calls / second
- α=0.9



Very High Traffic, Medium Mobility

- λ= 0.080625 calls / second
- α=0.5



Conclusions

- We will need guard channels:
  - The system is high loaded.
  - The number of new calls is not negligible.

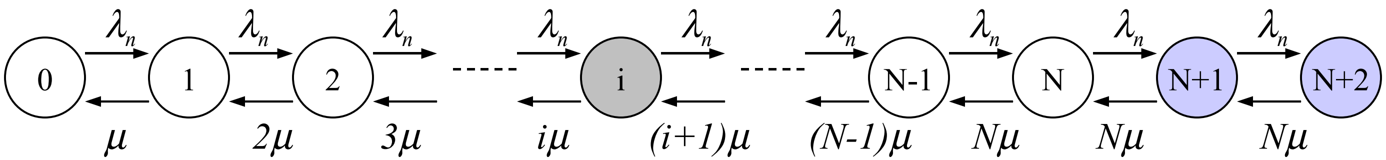
It is not related only with the mobility parameter.

Delaying new calls

Delaying new calls

- Queuing new calls until there are available resources in the system.
  - It has no sense for HO calls.

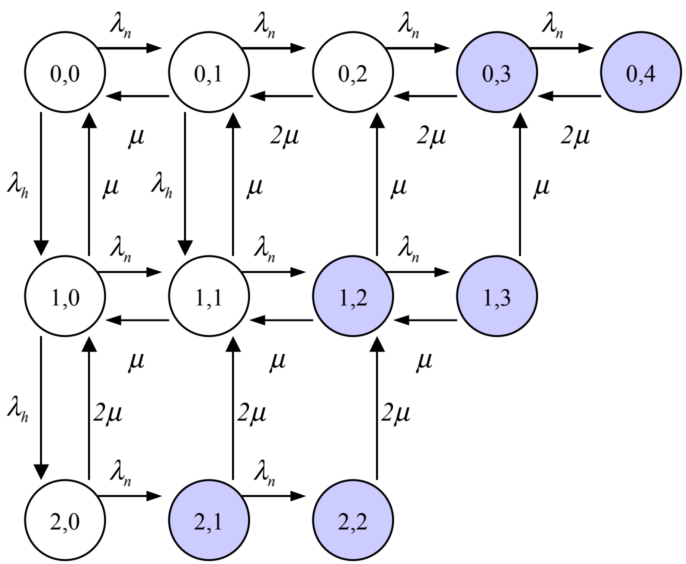
- Model of a system with only new calls:



Delaying new calls

C=2, Q=2 (only for new calls)

- Model of a system with new and HO calls



Problem

Problem

- 1 carrier / cell.
- Each carrier has 6 channels.
- λ= 0.08 calls / second
- X=120 seconds.
- α=0.4

- Number of guard channels that minimize the GoS?