Heuristics for QoS Provisioning in Wireless Data Networks

Samrat Ganguly

Dragos Niculescu

Brett Vickers

Outline

- motivation and goals
- existing approaches
- call admission
  - cell based
  - region based
  - dynamic region based
    - region formation
    - convolution
- simulation scenarios
  - transient state
  - stable state

Motivation

- conflicting goals in network resource provisioning
  - users want strong guarantees
  - network aims for high utilization
- mobility =¿ impossible to provide strong guarantees

Goals

Devise a call admission scheme which

- provides QoS for data calls for multiple service classes
- improves service quality through careful provisioning of network resources
- improves utilization of the network and increase the number of allowed callers
- account for changing mobility patterns
- simplifies configuration of network parameters
- reduced state maintenance requirements

Call Admission - Comparison With Voice Networks

- voice networks
  - a single class of calls
  - new calls may be blocked
  - handoff calls may be dropped
- data networks
  - calls are never dropped
  - connections share bandwidth
  - in the worst case, there may be high overload
  - there may be multiple classes of traffic

Other Proposed Approaches (For Data Networks)

- basic approach:
  - uses guard channels [1]
  - a fraction of cell's bandwidth is reserved for handoff calls
- aggregate state based provisioning approach
  - region based call admission [2]
  - distributed call admission [3]
- bandwidth reservation approach
  - shadow cluster [4]
  - prediction based [5]
  - mobility specs [6]
  - MRSVP [7]

Overview Of Dynamic Region Based Scheme

two step decision:

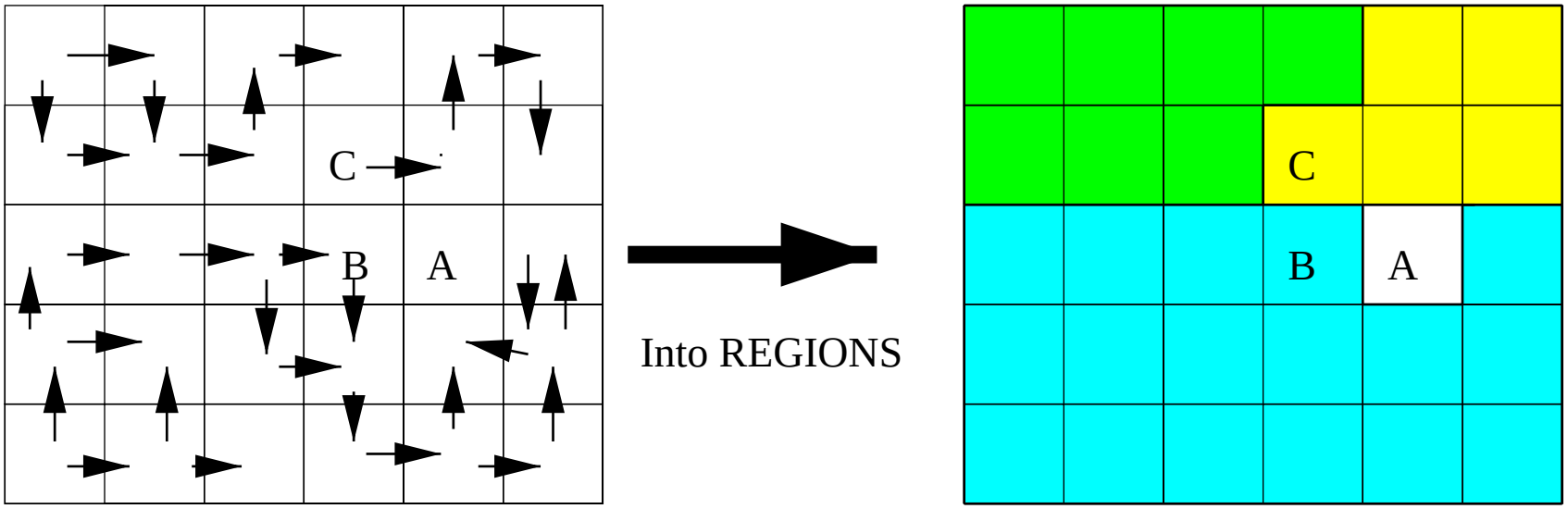
1. **REACTIVE: dynamic region formation**
   - the map is partitioned into disjoint, exhaustive region

2. **PROACTIVE: convolution based admission**
   - query each cell in the region

Step1: Dynamic Region Formation

- **region**: a group of cells affecting each other due to user mobility

- the entire region is queried to admit a call in any cell of the region



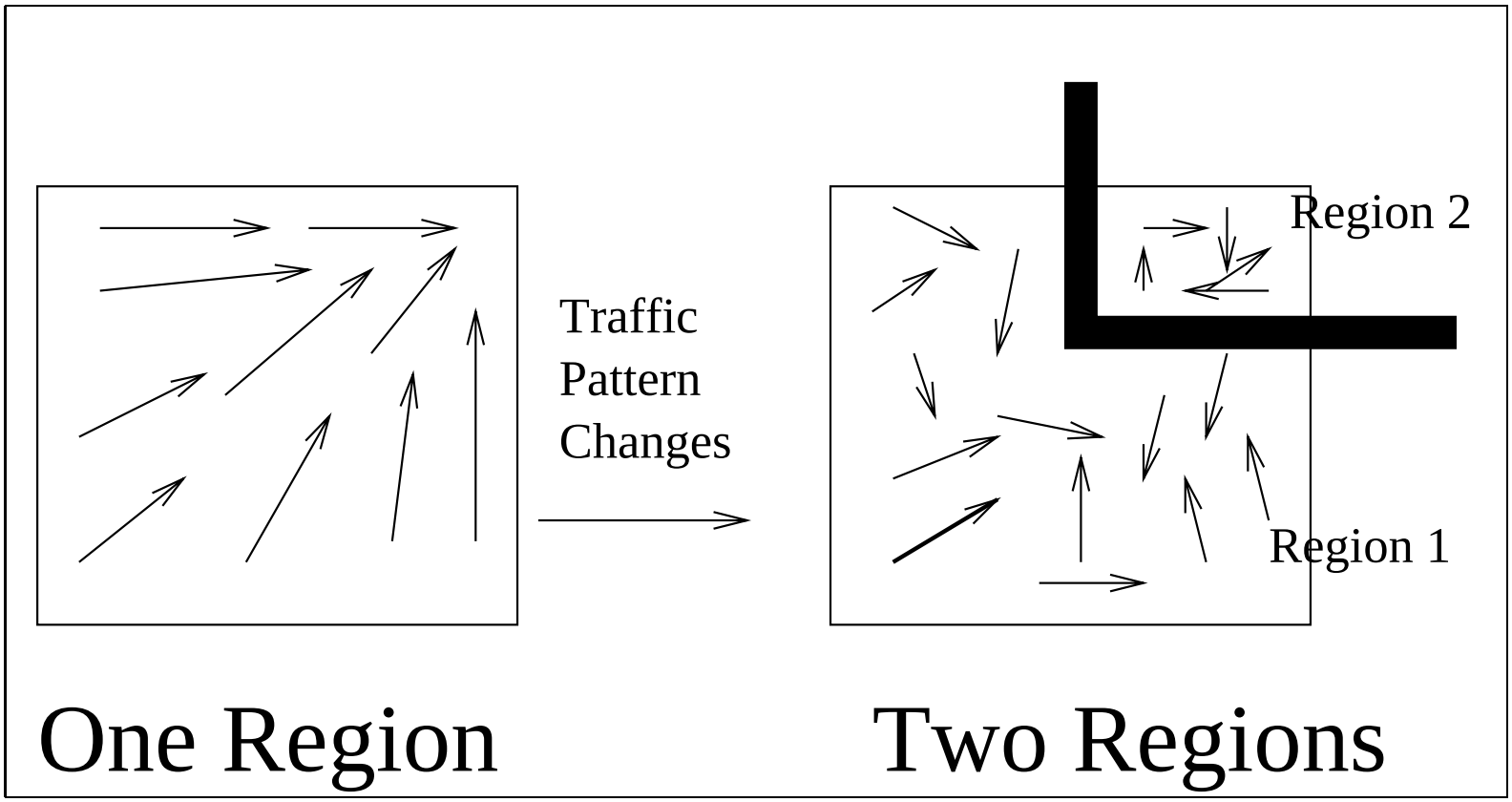
Traffic Pattern

Region Subdivision

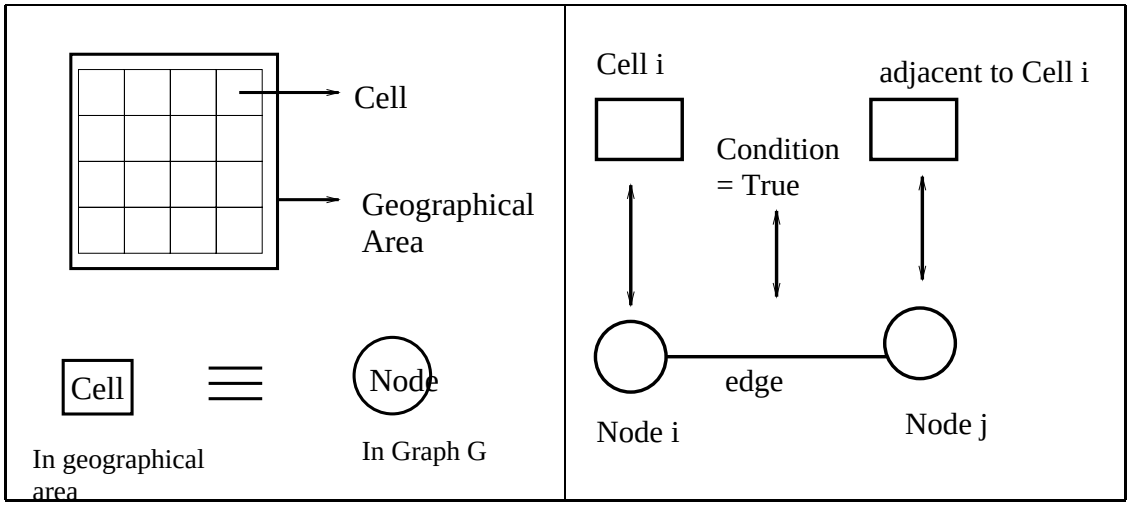
Dynamic Region Formation

- Reactive $\Longrightarrow$ changing traffic pattern drives formation of regions

- Example:



Dynamic Region Formation Algorithm



- Initially there is no edge between any nodes
- all pairs of adjacent cells are considered
- when the test condition holds, add an edge between two nodes
- regions consist of cells which are simply connected in the associated graph

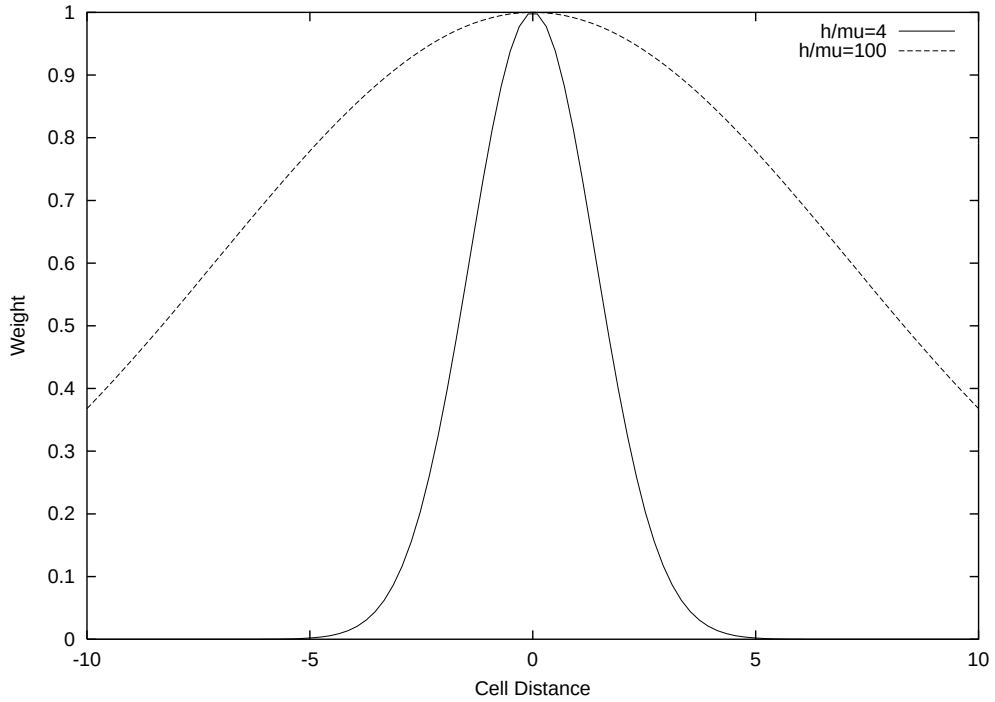
Dynamic Region Formation Algorithm

```
CONDITION(Cell i, Cell j)

{

return (bias(i-> j) == TRUE) OR

       (weight(i->j) == TRUE)

}
```

bias (i-> j) ratio of traffic i->j to total outgoing traffic from i > Threshold

weight (i->j) exponential function of d, h, $and\, \mu$.

Weight Function

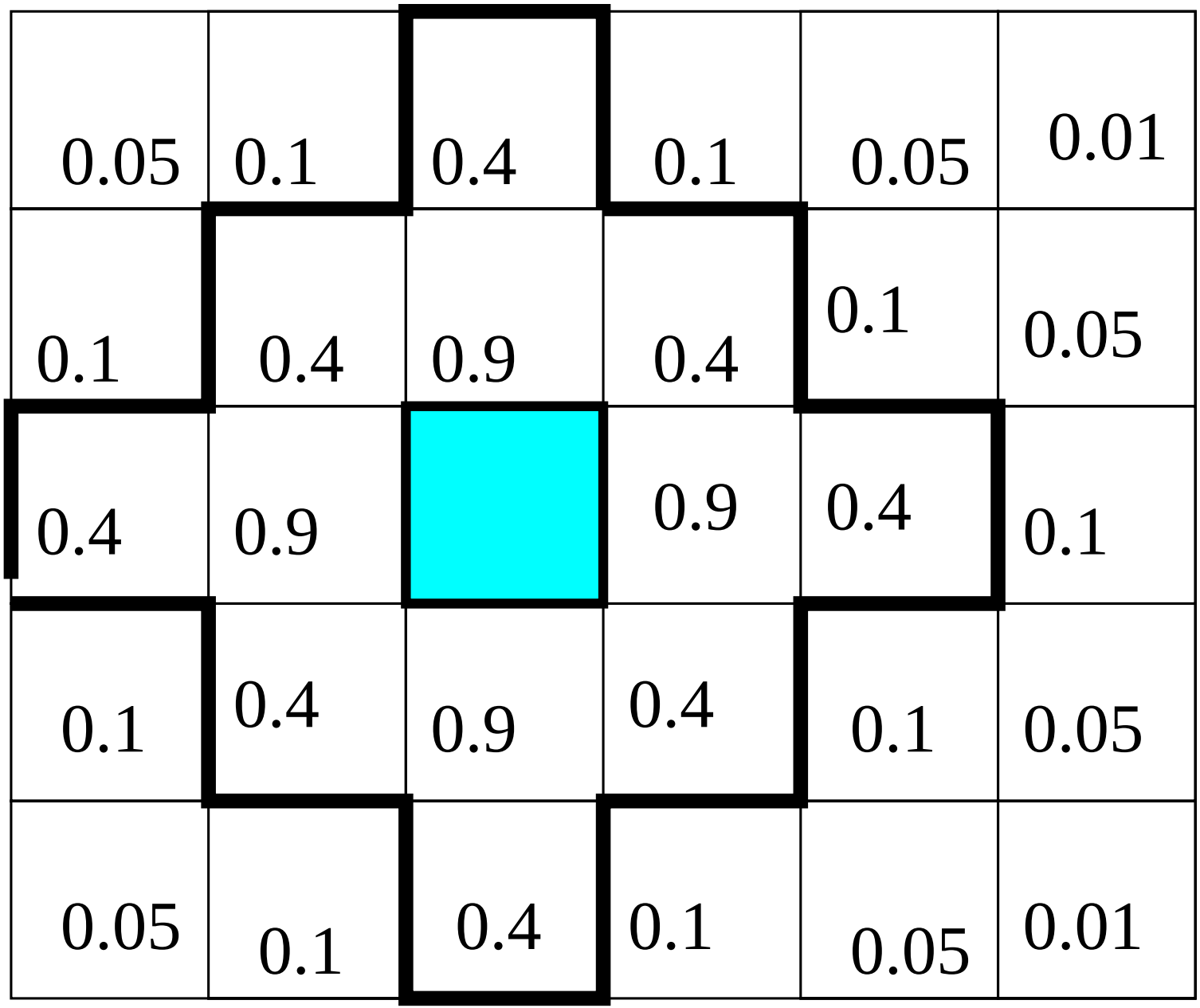


$$weight(i \rightarrow j) = (e^{-\frac{d^2}{S\frac{h}{\mu}}} > threshold)$$

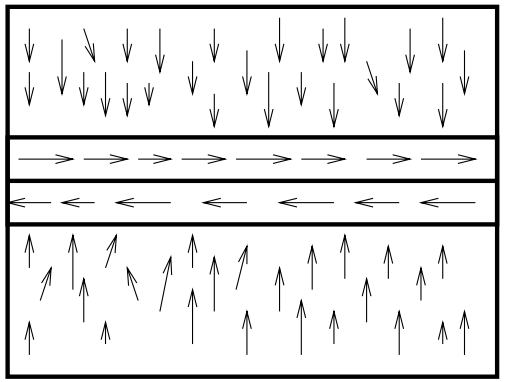
d = hop distance from overloaded cell along direction i->j

h = handoff rate

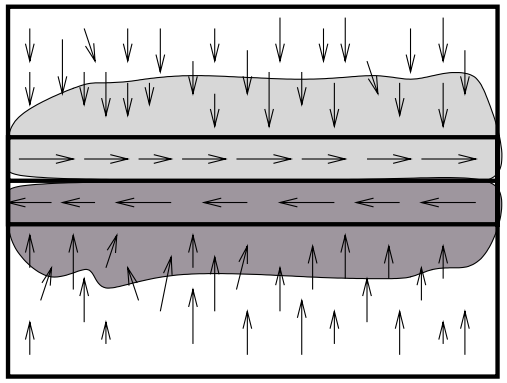
μ = departure rate


0.05
0.1
0.4
0.1
0.05
0.01
0.1
0.4
0.9
0.4
0.1
0.05
0.4
0.9
0.9
0.4
0.1
0.1
0.4
0.9
0.4
0.1
0.05
0.05
0.1
0.4
0.1
0.05
0.01

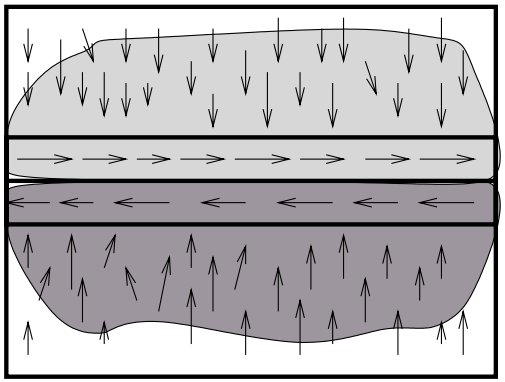
Dynamic Region Formation - Examples



Highway



Low Mobility



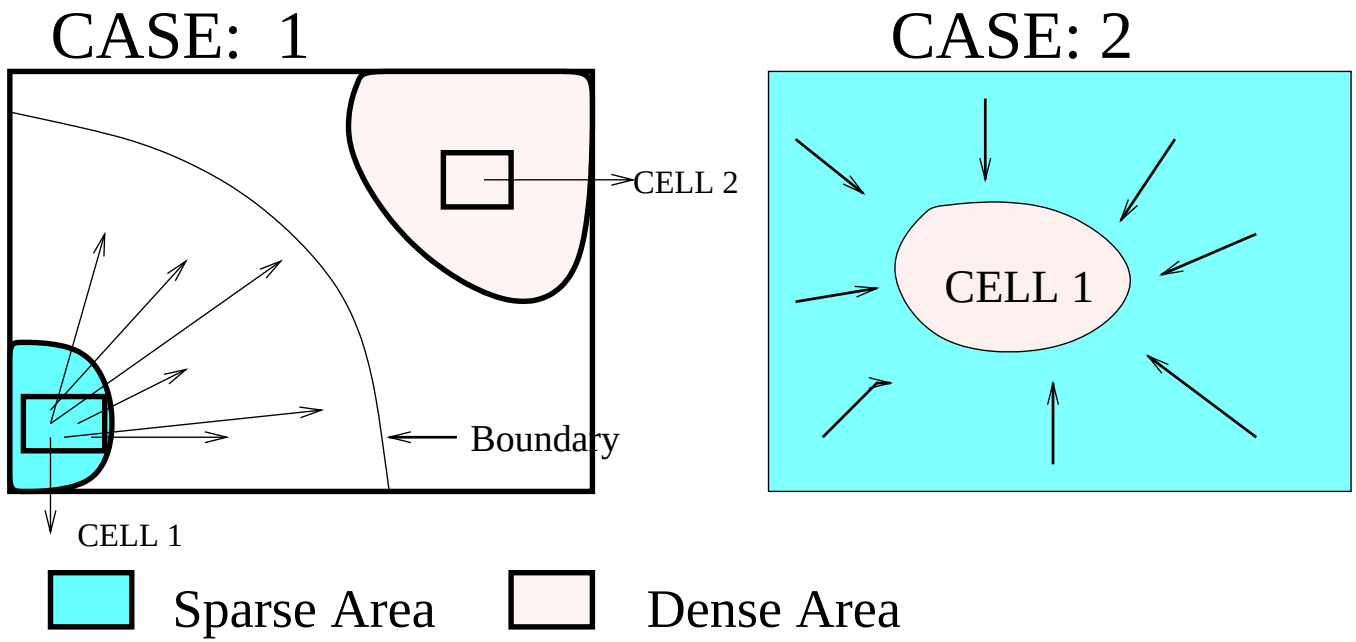
High Mobility

Region 1

Region 2

Step2: Convolution Based Call Admission

- what are the problems with region based admission?



- Case 1: users from cell 1 do not reach cell 2
  - if cell 2 is overloaded, cell 1 will admit less calls
- Case 2: region-based scheme will admit calls in cell 1 even if it is overloaded

Convolution Based Call Admission

- convolution based decision
  - near cells weigh more then faraway ones
  - with high mobility, even faraway cells count
  - a call is accepted in cell i if Normalised Convoluted Population is less than threshold where

$$\frac{\sum_{cell\, j \in region(i)} n_j \cdot weight(d_{ij}, h, \mu)}{\sum_{cell\, j \in region(i)} B_{ij}.weight(d_{ij}, h, \mu)} < \alpha$$

  - n_j - population in cell j
  - B_j - capacity of cell j
  - d_{ij} - distance between cells i and j

Example

0.09	*0.5*	*0.09*
0.5	*1.0*	*0.5*
0.09	*0.5*	*0.09*

Weights

100	*50*	*50*
100	*20*	*40*
40	*30*	*20*

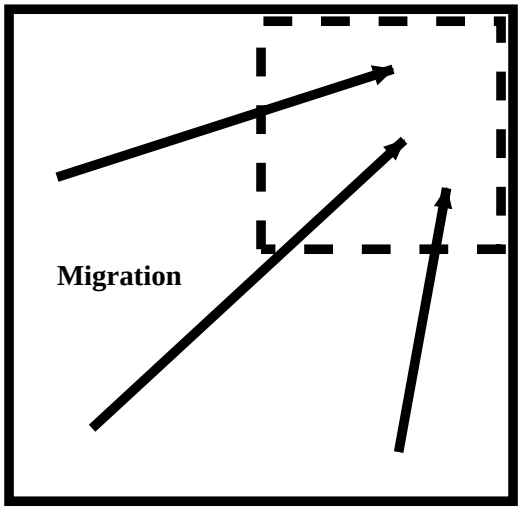
Population

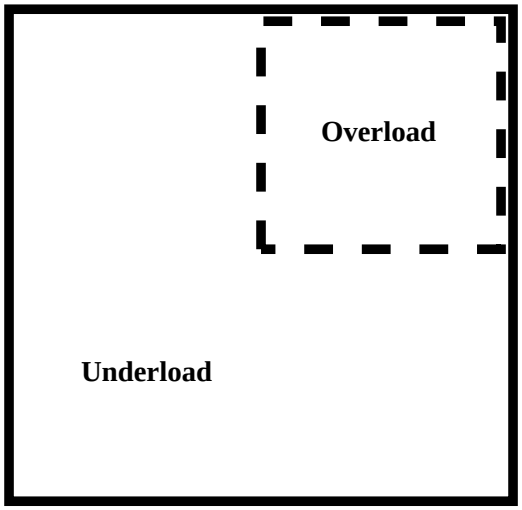
Convoluted Population = 1.0*20 + 0.5(100+30+40+50) + 0.09(40+20+50+100)
= 149

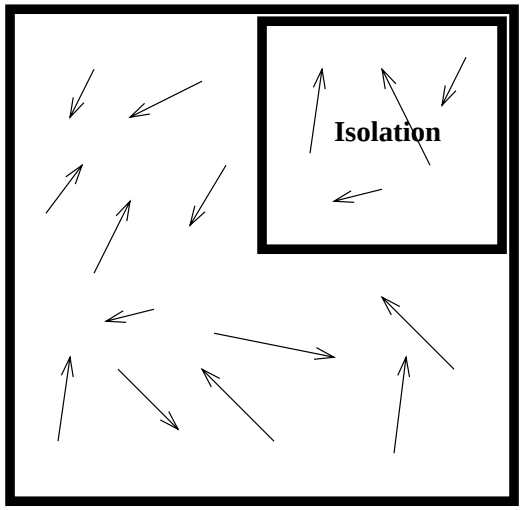
Simulation Scenarios

- rectangular wrapped-around map, rectangular cells
- there is no per mobile state
- state of the network is described by the number of mobiles in each cell
- cell occupancy - per cell parameters :
  - λ - new call rate (Poisson modelled process)
  - $1/\mu$ - mean call holding time (exponential)
  - h - handoff rate (exponential)
  - B - number of channels available in each cell
  - h/μ - the average number of handoffs a mobile makes
  - direction probabilities describe traffic patterns $\{d_N, d_S, d_E, d_W\}$

Simulation Scenarios - Transient State







- similar to the real-life event of a sports game

1. mobiles rush to a single area of the map (t=0..1000)

2. the migration stops and the corner becomes isolated (t=1000..2000)

Cell-Based and Region-Based Schemes

- cell-based decision:
  - $\frac{\#users\,in\,the\,cell}{capacity\,of\,the\,cell} < threshold$
  - oblivious to larger area traffic conditions
  - becomes uncontrolled with shifts in load
  - requires manual threshold assignment
- region based decision:
  - $\frac{\#users\,in\,the\,region}{capacity\,of\,the\,region} < threshold$
  - oblivious to traffic inside the region
  - requires manual region description
  - overall load is controlled

Distributed Call Admission

- admit a call if there is a low probability that in the near future:
  - the cell will be overloaded
  - any neighboring cell will be overloaded

- each cell has an admission region defined by the population around it

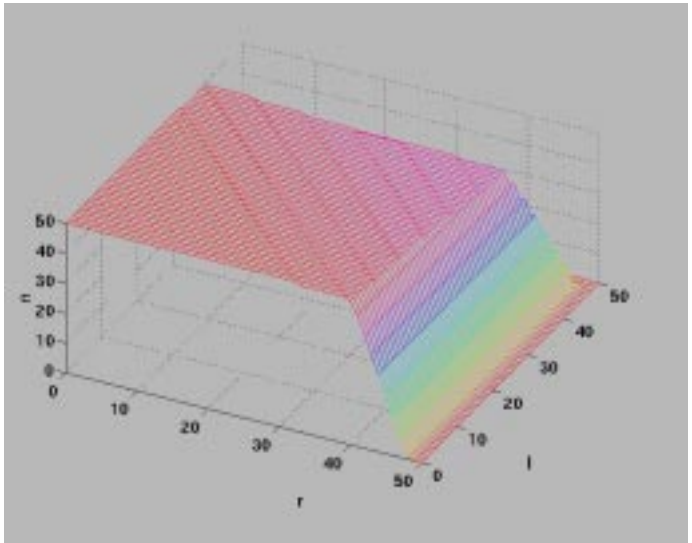
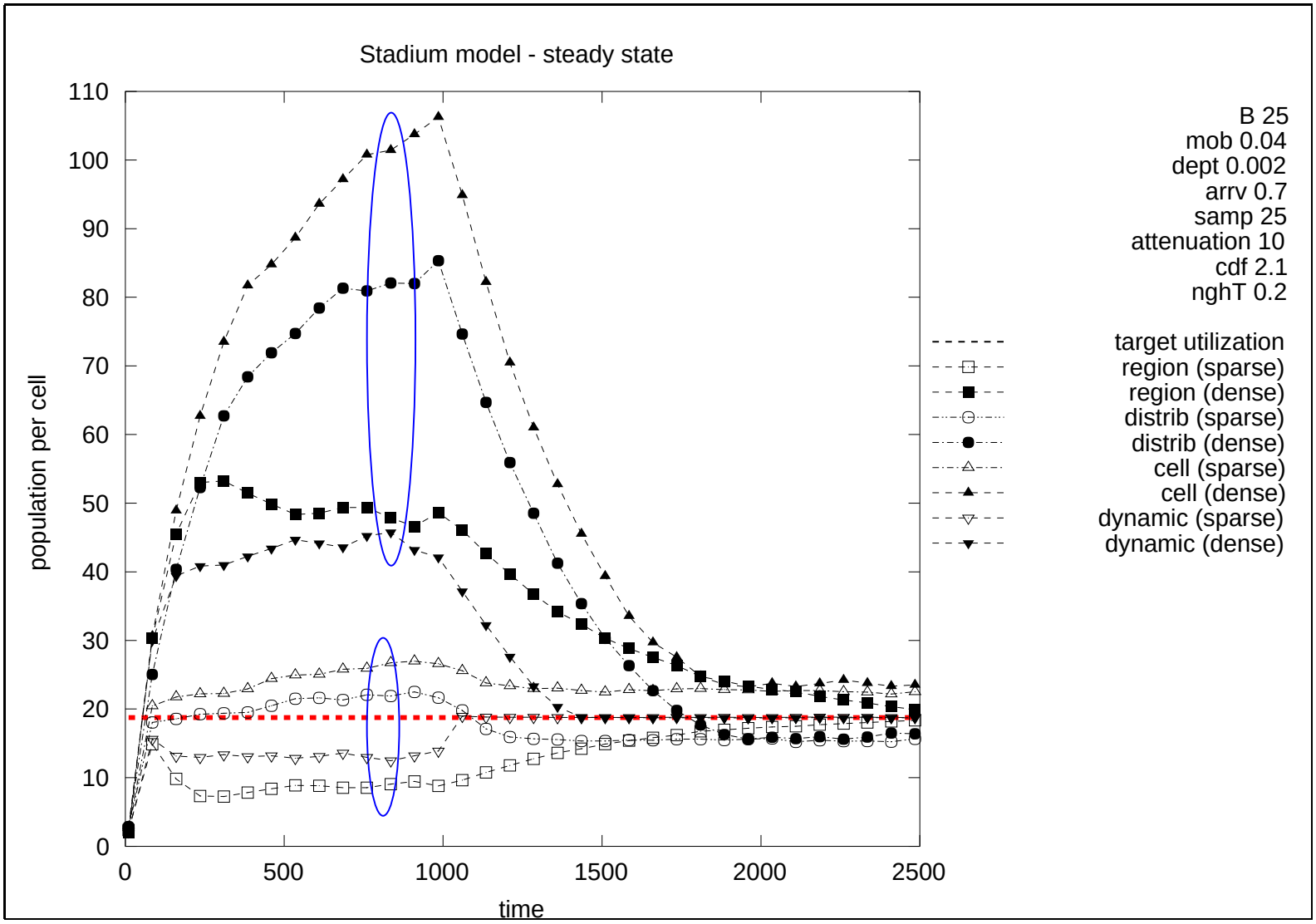
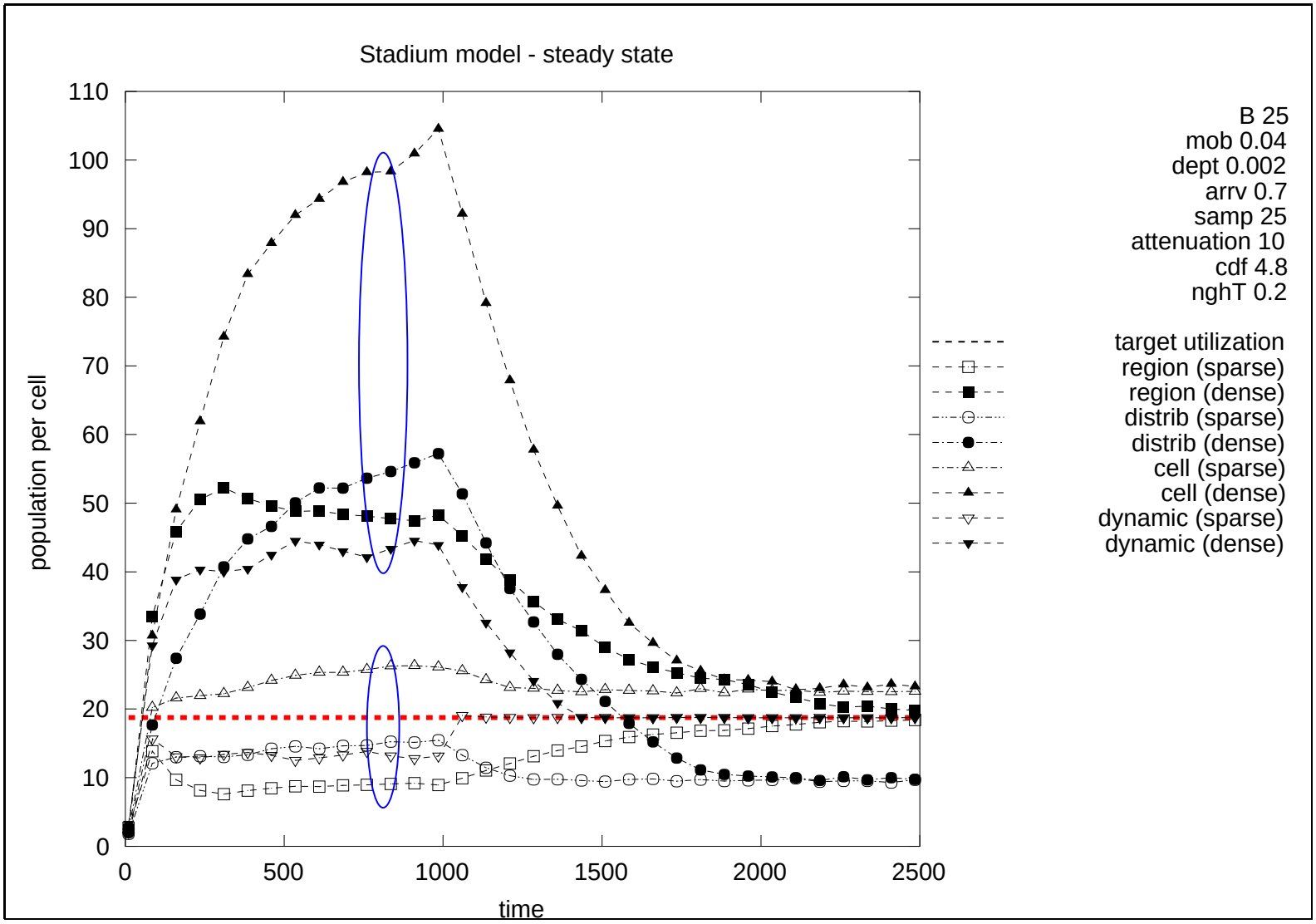


Figure 4: State-dependent admission region for $N=50$

Simulation Scenarios - Transient State



Simulation Scenarios - Transient State



Simulation Scenarios - Transient State

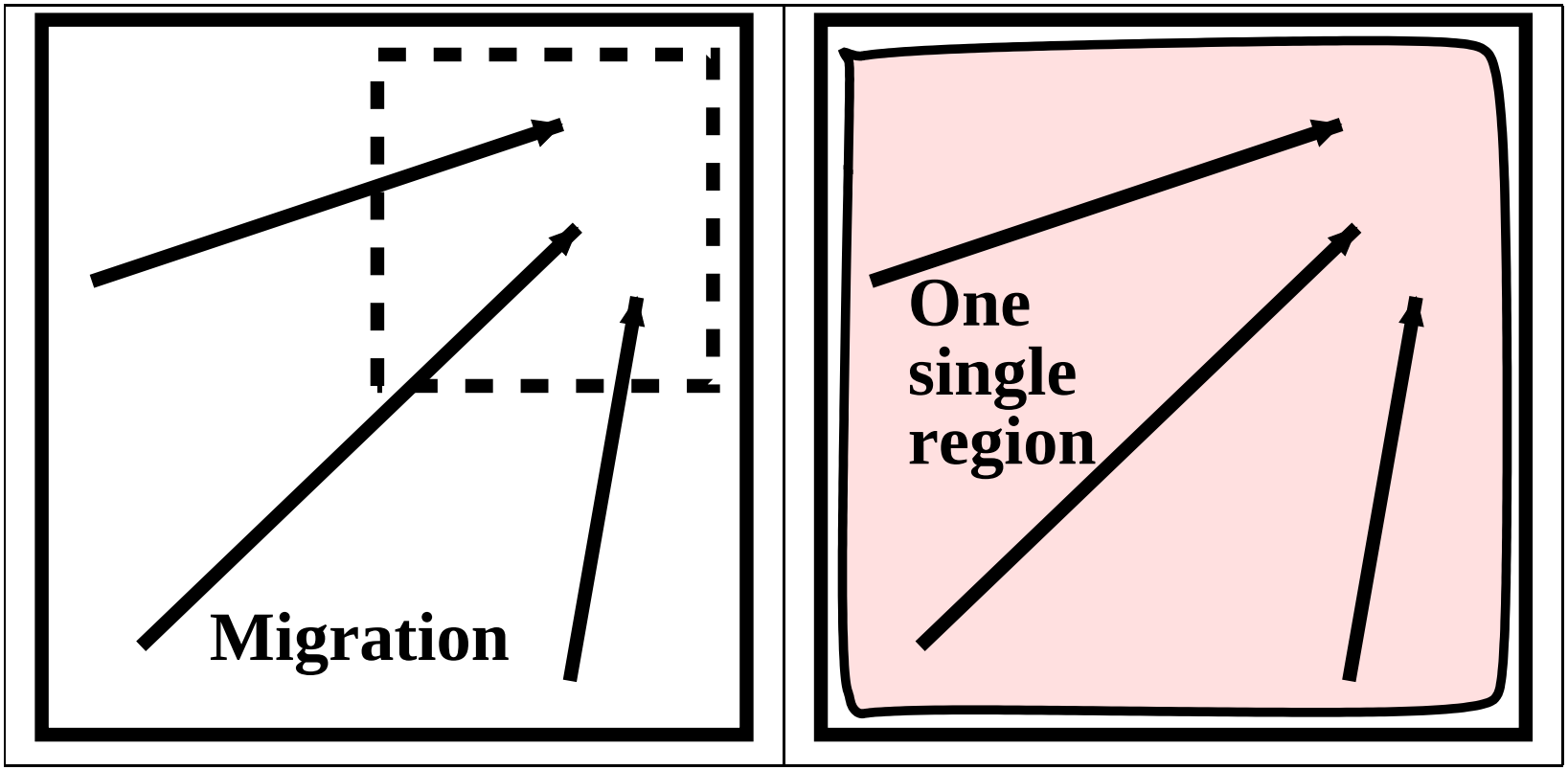
- cell based admission cannot control the load
- region based does not adapt to changing conditions
- dynamic scheme
  - reacts faster to changing conditions
  - population decays faster in the dense area
  - population increases faster in the sparse area

Simulation Scenarios - Steady State

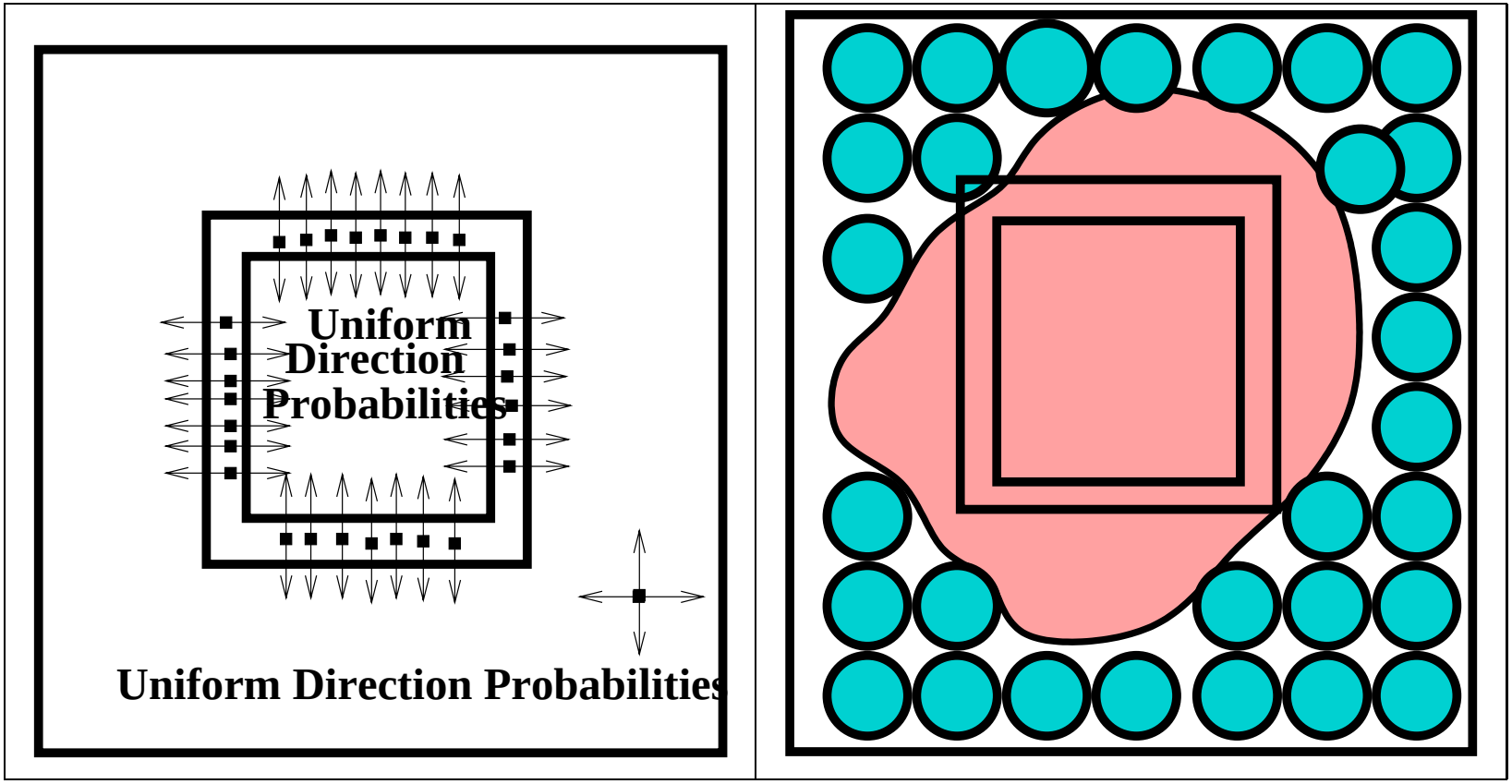
- state - schemes are compared when traffic reached equilibrium

- scenarios
  - stadium
  - downtown
  - highway
  - manhattan

Simulation Scenarios - Stadium

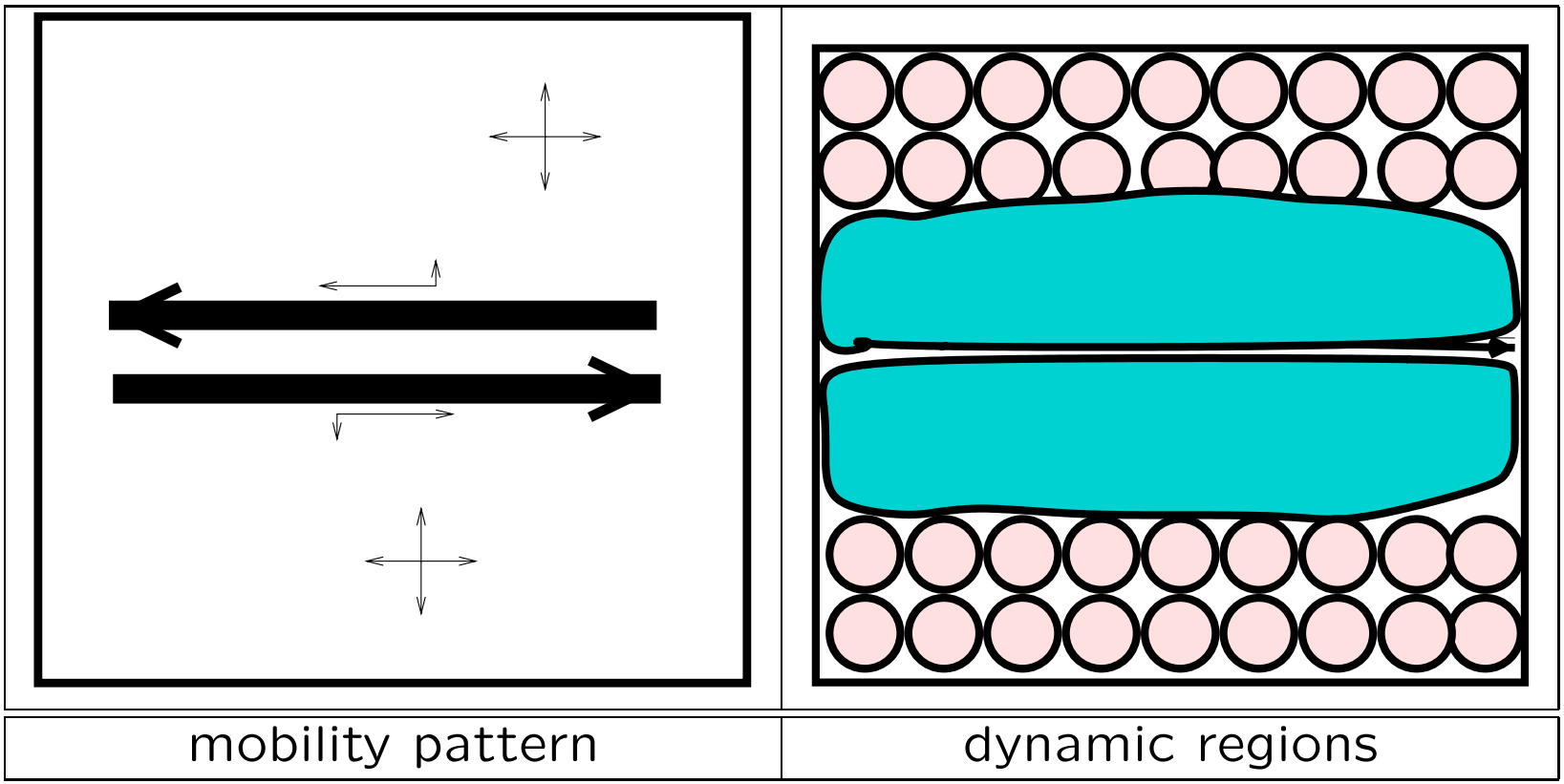


Simulation Scenarios - Downtown



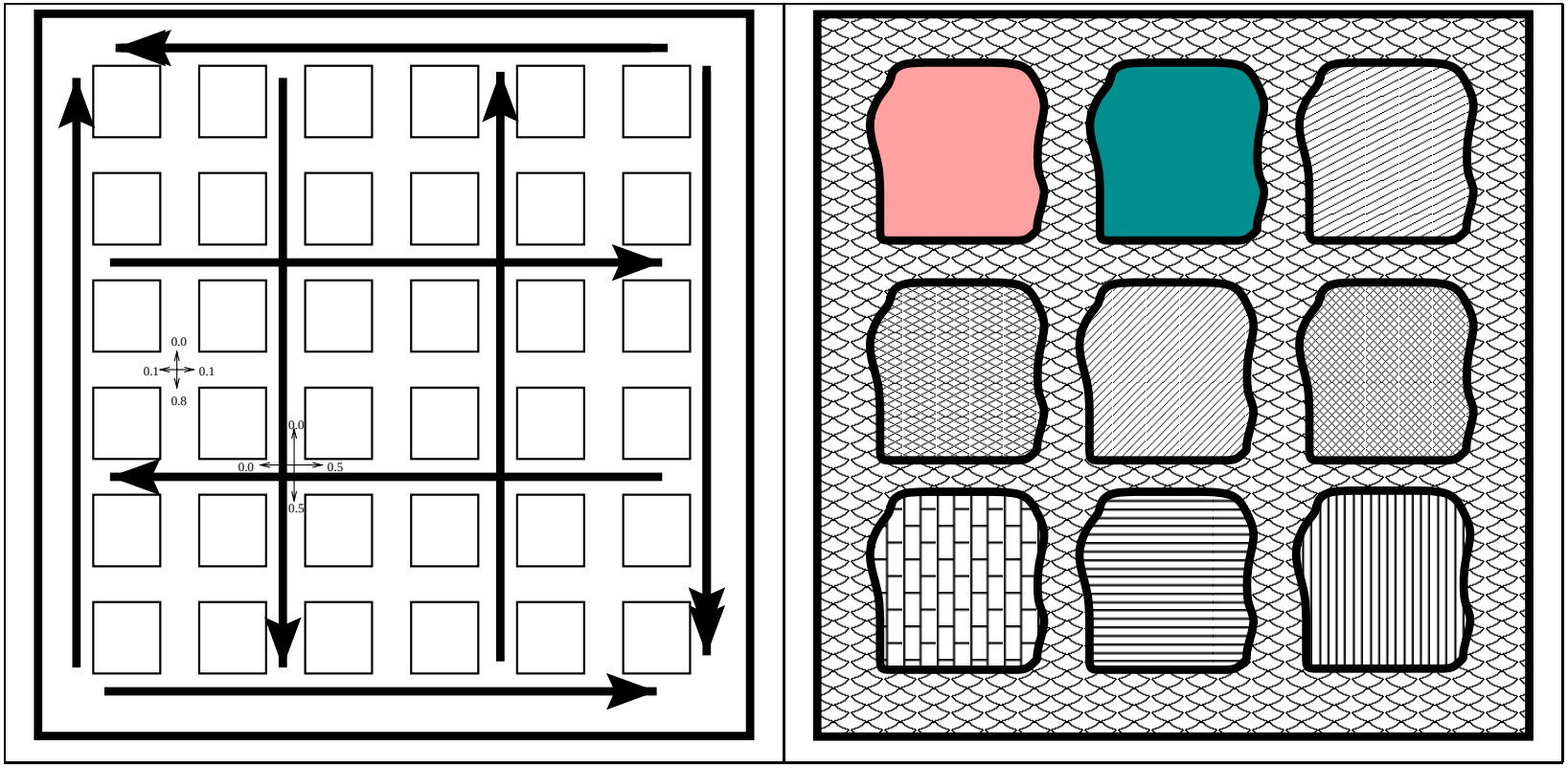
mobility pattern	dynamic regions

Simulation Scenarios - Highway



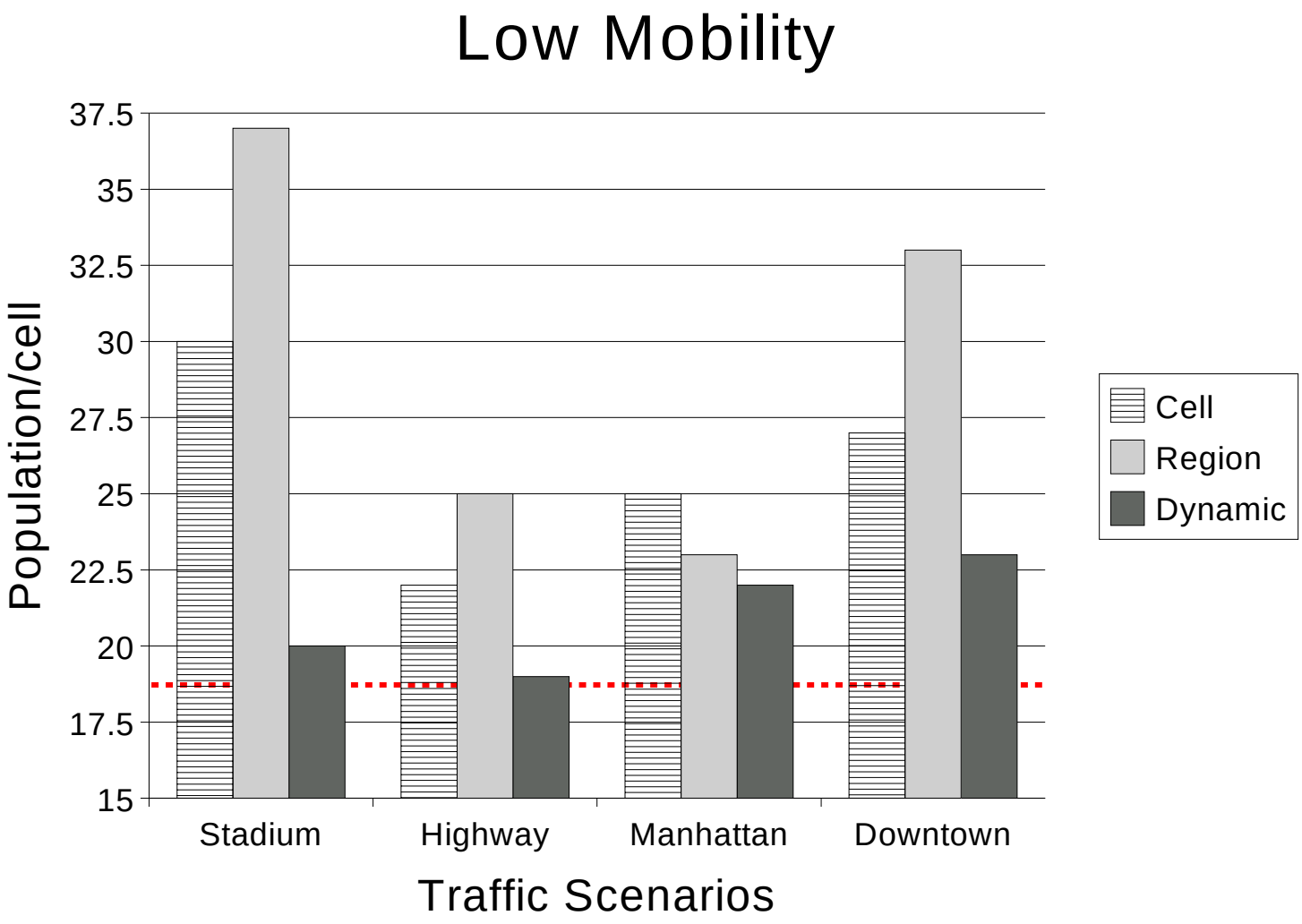
mobility pattern	dynamic regions

Simulation Scenarios - Manhattan

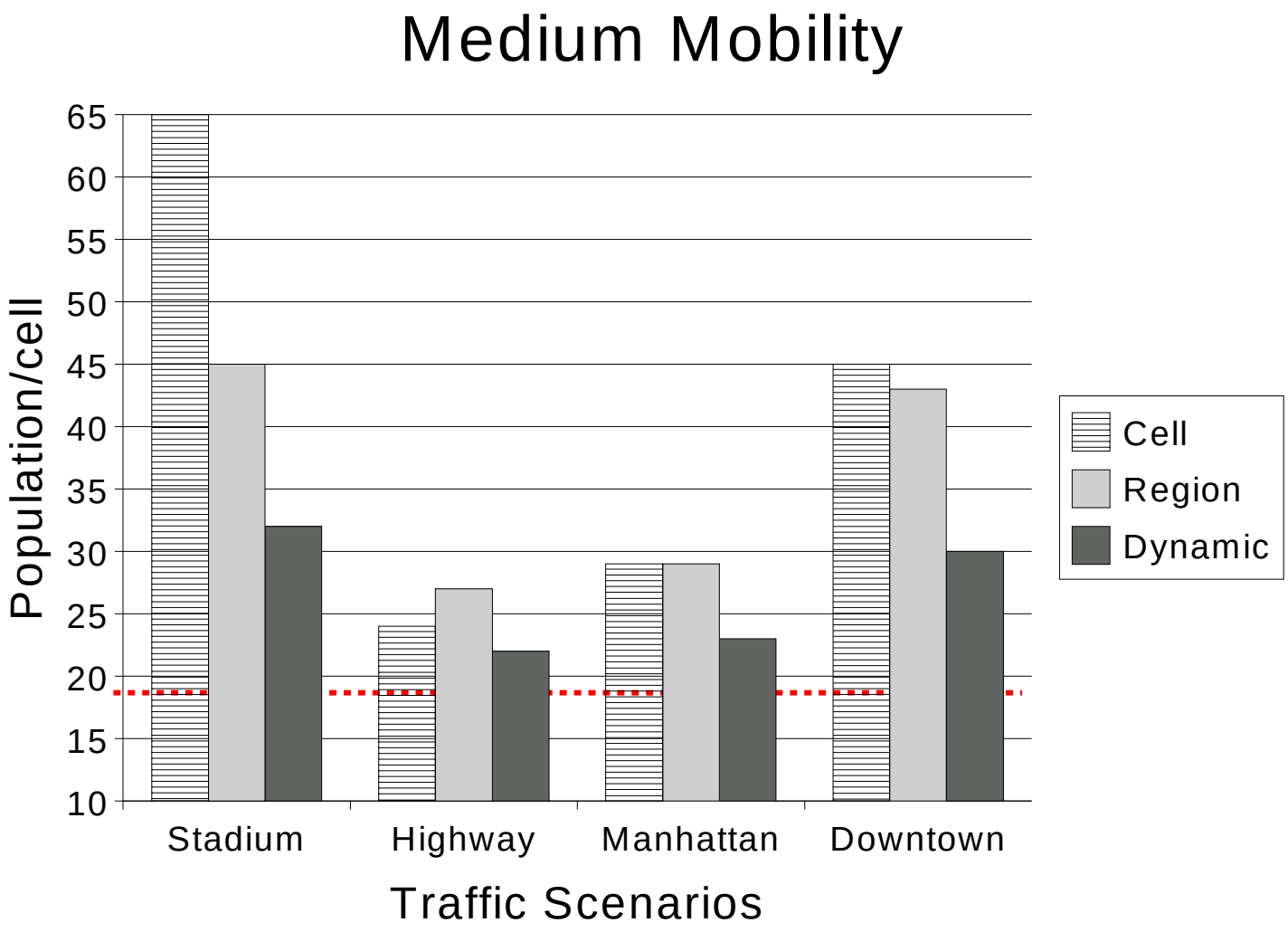


mobility pattern	dynamic regions

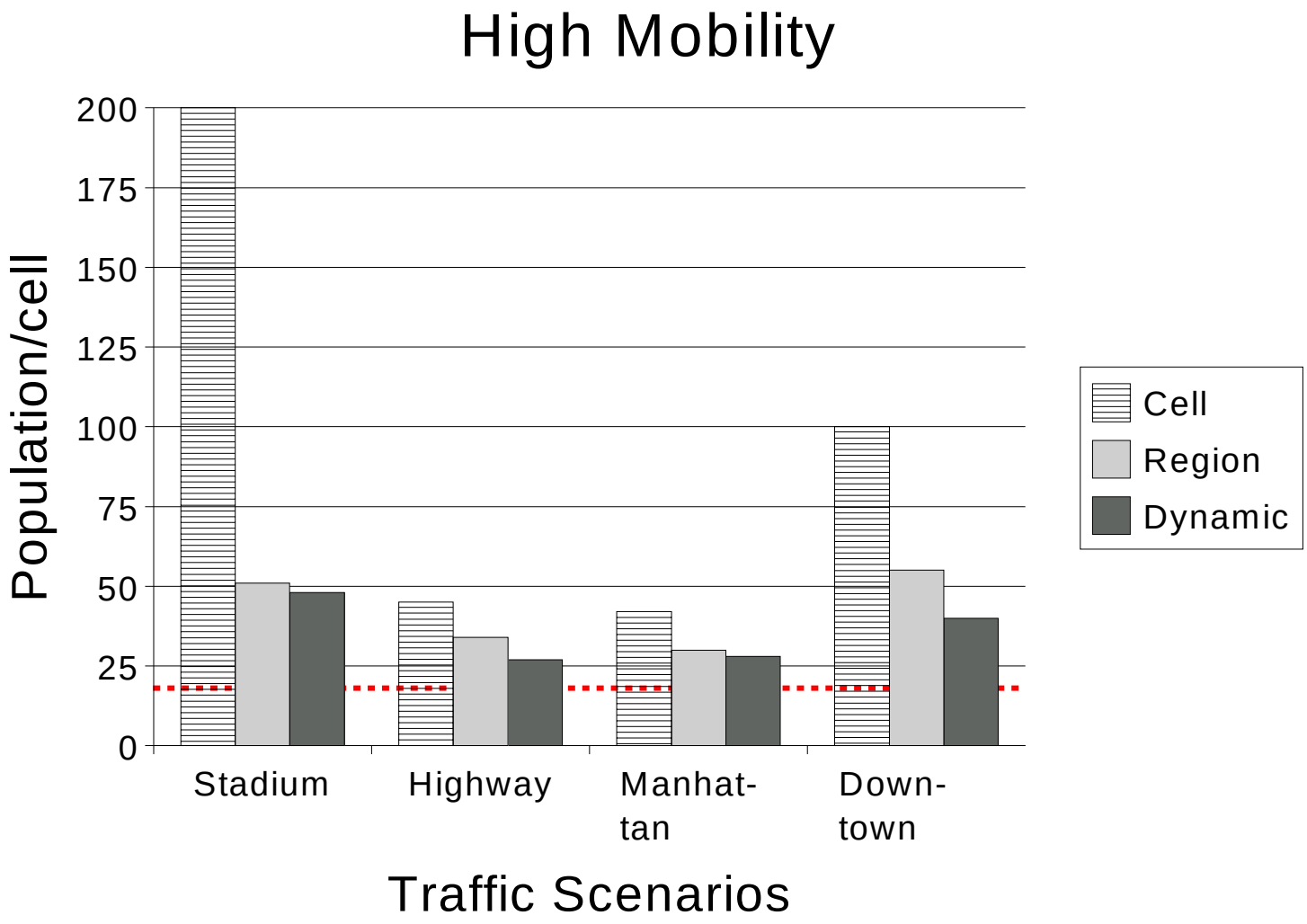
Simulation Results



Simulation Results



Simulation Results



Conclusion

Dynamic Region Based Call-Admission

- doesn't simply use local information to admit a call
- adapts more rapidly to mobility changes
- allows more calls in the underloaded areas
- accepts less calls that may lead to overload
- captures advantages of cell-based and region-based schemes
  - $S = 0 \Longrightarrow$ cell-based decision
  - $S = \infty \Longrightarrow$ region-based decision
- eliminates the need to set individual thresholds for each region/cell