# Performance Analysis of Downlink Power Control Algorithms for CDMA Systems

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# Outline

- Introduction
- Power Control
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  - Strategies
- Algorithms
  - Simulation Setup
  - PC Algorithms
- Comparison
- Future Work

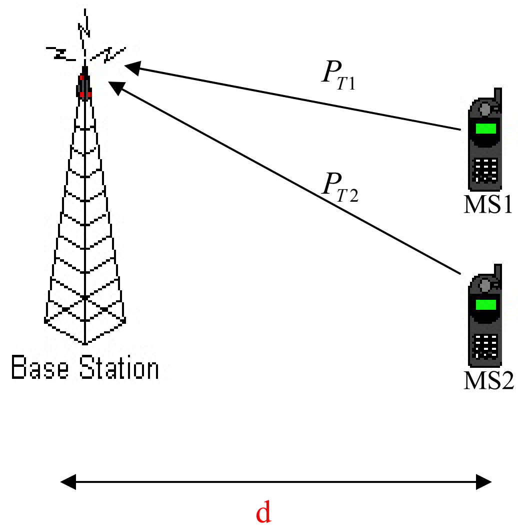
# Introduction

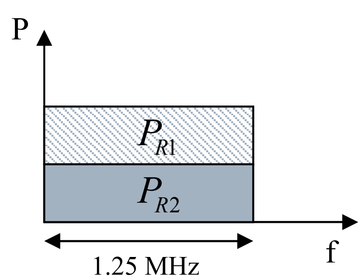
CDMA is a multiple access technique used in cdmaOne, CDMA2000, 1xEV-DO, 1xEV-DV and UMTS

# Properties of CDMA

- Protection against delay spread greater than one chip
- RAKE receiver
- Power Control Algorithms
- Intracell Interference
- Voice Activity Factor
- Soft Degradation
- Sectorization
- Capacity Gain

# Ideal CDMA System

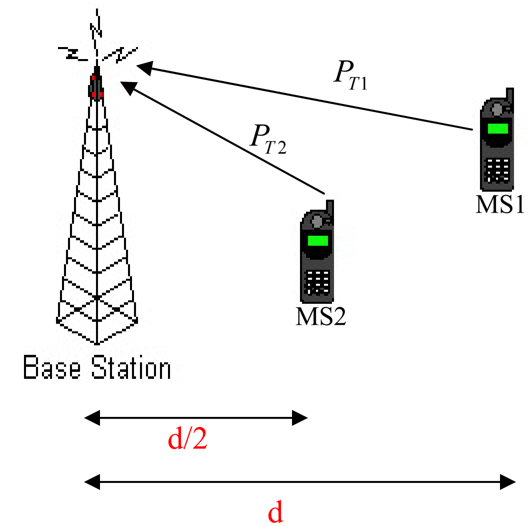


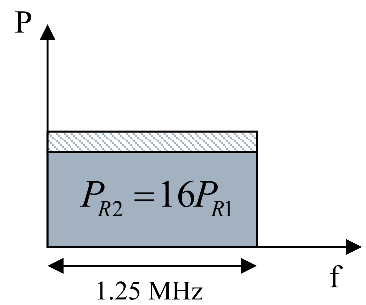




$$P_{R1} = P_{R2}$$

$$\frac{C}{I} = \frac{P_{R1}}{P_{R2}} = 1$$

# Near-Far Effect




$$P_{R2} = \frac{1}{(d/2)^4} \cdot P_{R1}$$

$$P_{R1} \approx \frac{1}{16} \cdot P_{R2}$$

$$\frac{C}{I} = \frac{P_{R1}}{P_{R2}} = \frac{1}{16}$$

# What is Power Control?

Power control refers to the strategies or techniques required in order to adjust, correct and manage the power from the BS/MS in both directions (i.e. uplink and downlink) in an efficient manner.

# Other Advantages of PC

1. Maintain a satisfactory voice quality for most users
2. Increase overall system capacity while meeting QoS requirements
3. Reduce the average transmit power from mobiles or from cells and sectors
4. Maintain performance objectives such as BER, FER, capacity estimates, dropped-call rate and overall coverage capacity.

# PC Strategies

- **UPLINK (Reverse Link) PC**
  Controls the mobile's transmit power

  - **Open-Loop PC**
    Mobile measures received power and adjusts its transmit power accordingly. (*Note:* 85dB dynamic range, rapid response is in $\mu$sec)

  - **Closed-Loop PC**
    BS measures received power from all mobiles and simultaneously commands the individual mobiles to raise or lower transmit uplink power so that the received SNR from all MSs at the BS is the same (800 commands/sec, $\pm$ 1dB)

    - Closed Outer-loop PC
    - Closed Inner-loop PC

# PC Strategies (cont.)

- DOWNLINK (Forward Link) PC

  Base station periodically reduces transmit power (±0.5 dB every 15-20 ms) to mobile until mobile senses increasing error rate. (*Note:* Dynamic range is about ±6 dB around nominal transmit power)

# PC Strategies (contd)

- Intracell Interference
  - Undesired CDMA signals appear as noise at the receiver output
  - With PC, the equivalent $E_b/N_0$ for CDMA receiver is given by

$$\frac{E_b}{N_{0,eq}} = \frac{E_b}{N_0 + (M-1) \cdot E_c}$$

$$\frac{E_b}{N_{0,eq}} \approx \frac{E_b}{(M-1)E_c} = \frac{P/R_b}{(M-1)P/R_c}$$

$$\frac{E_b}{N_{0,eq}} \approx \frac{1}{(M-1)} \cdot \frac{R_c}{R_b}$$

*Processing Gain*

# PC Algorithms Studied

- Distance Based Power Allocation
- Distributed Balancing Power Control
- Multiple step SIR based power control with fixed step size
- Adaptive Step Power Control
- Modified Adaptive Step Power Control (with buffer)

# Simulation Setup

- Characteristic of each forward link is independent and identical
- Fixed number of mobiles per cell
- Mobiles are uniformly located within the cell
- All mobiles are listening at all times
- Effect of shadow fading (lognormal distribution) and path loss have been considered

# 1. Distance Based Power Allocation (DBPA) [Lagrange et. al. 2001]

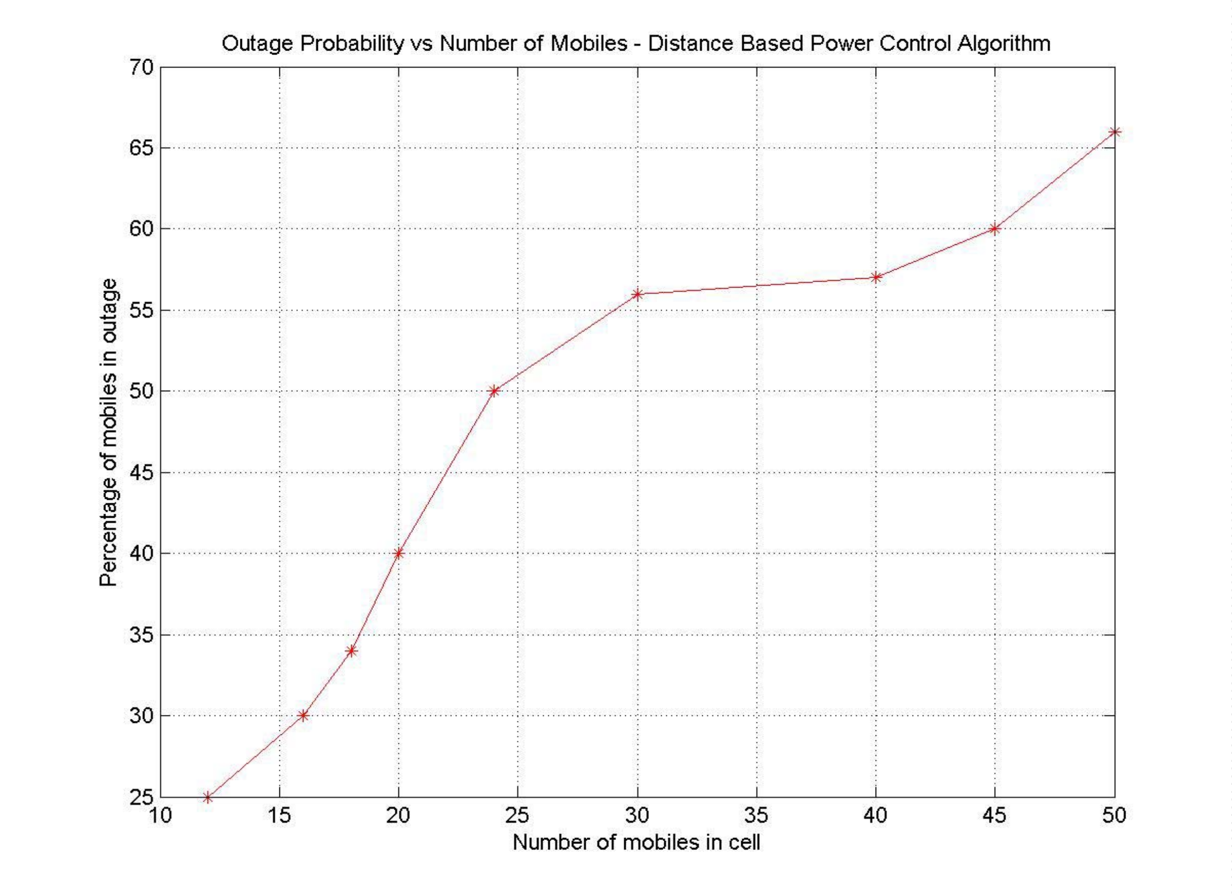
- Uses the base station to mobile distance to allocate transmit power for each of the served mobiles

- No correction or feedback is provided

- $P_m = k.(d/r)^n$

  $P_m$ = power transmitted by BS
  d =distance of mobile from BS
  r = maximum radial distance of the cell

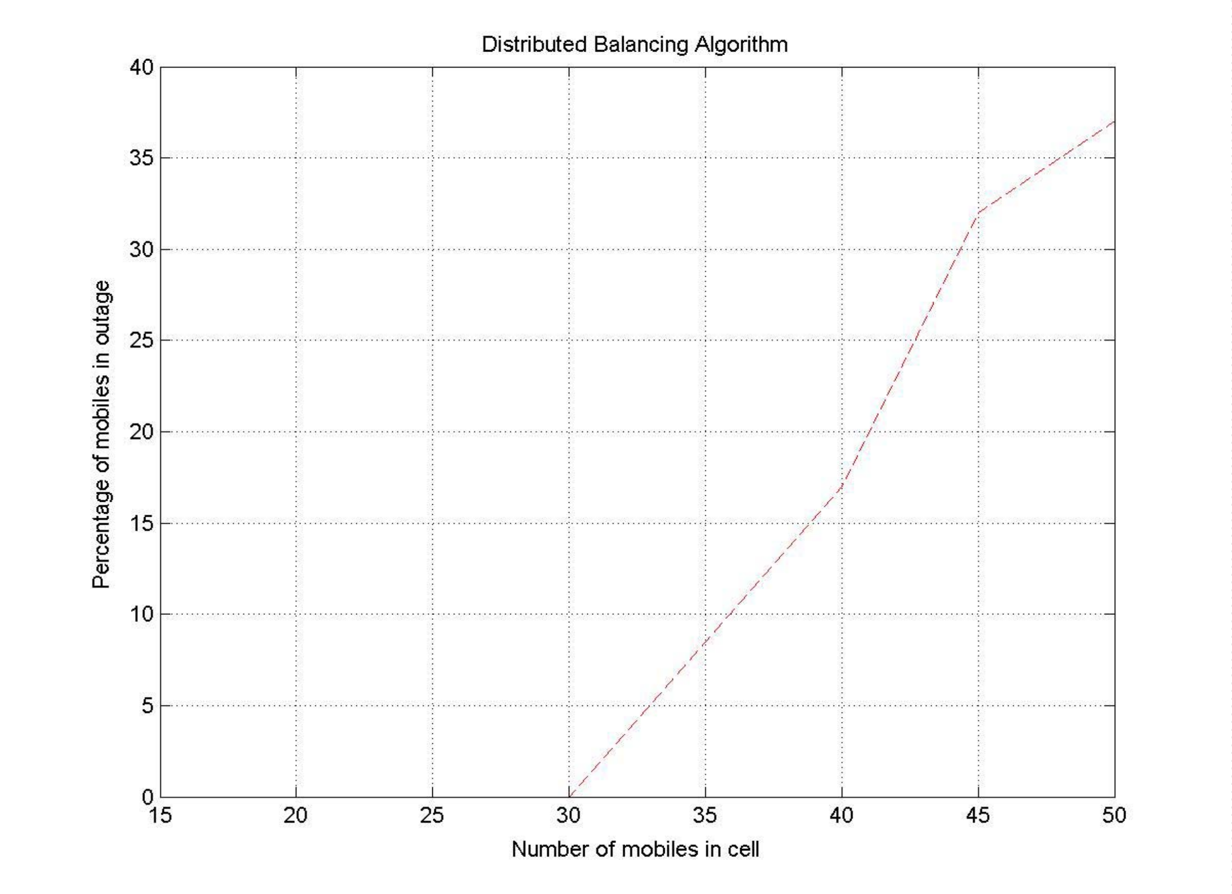
# DBPA – Outage Percentage vs. Number of Users



# 2. Distributed Balancing Algorithm (DB) [Chang, Ren 1994]

- Calculates the optimal transmit power assignment for each mobile within the cell, taking into consideration all the neighboring cells
- The optimal transmit power assignment for a mobile is proportional to the ratio of the total received power of the mobile to the link gain between its base station and itself
- Gives the best achievable performance, but it is relatively difficult to implement

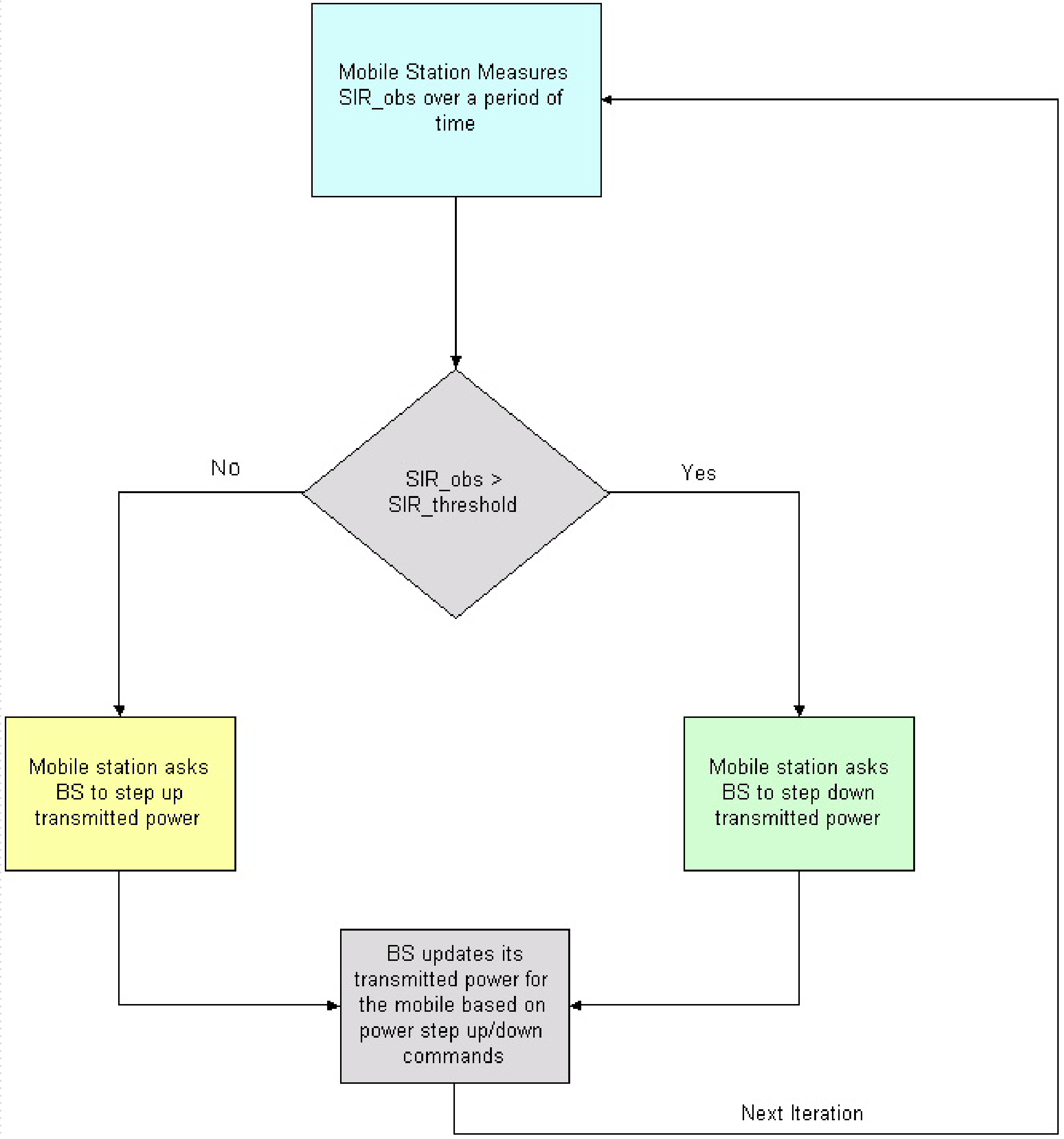
# Distributed Balancing – Outage Percentage vs. Number of Users



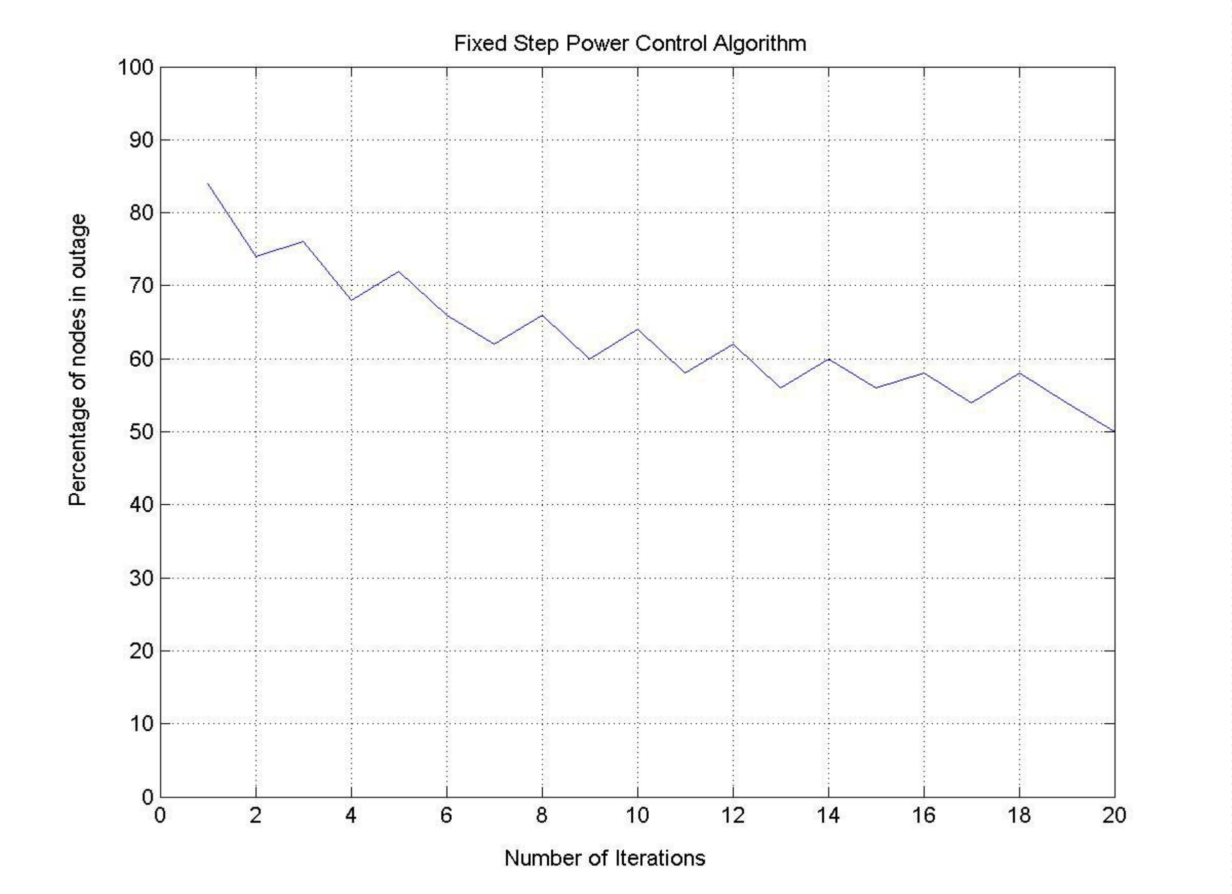
# 3. Multiple Step SIR-based Power Control (MSPC)[Chang,Ren 1994]

- Closed-loop control (uses feedback from the mobile to adjust the transmitted power of the base station)
- Mobile station measures SIR_obs over a certain period and compares with SIR_threshold
- If SIR_obs > SIR_threshold the mobile sends a power-down command, otherwise sends a power-up command to base station
- Base station updates its transmitted power for the mobile based on the power-up/down commands
- PC updates usually take place in multiple fixed-size steps

# MSPC Flowchart



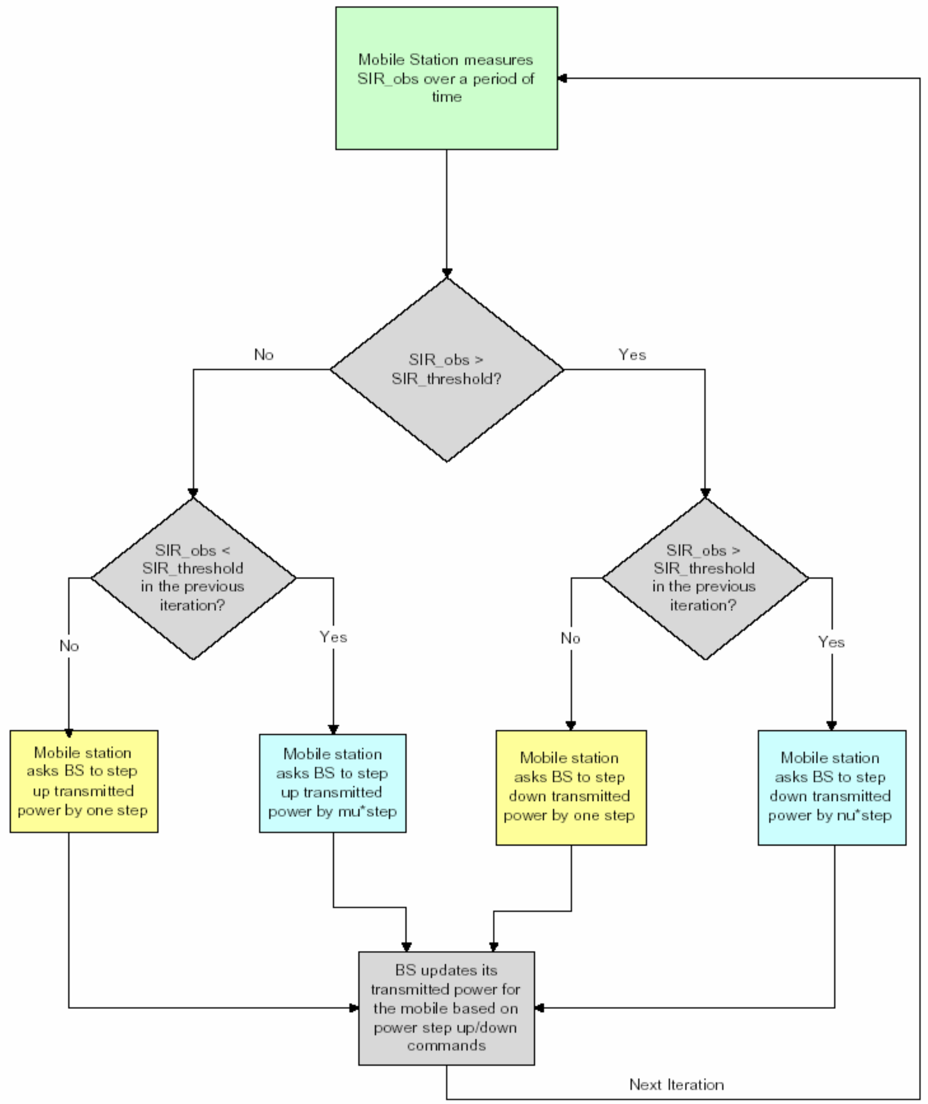
# MSPC- Outage Percentage vs. Number of Iterations



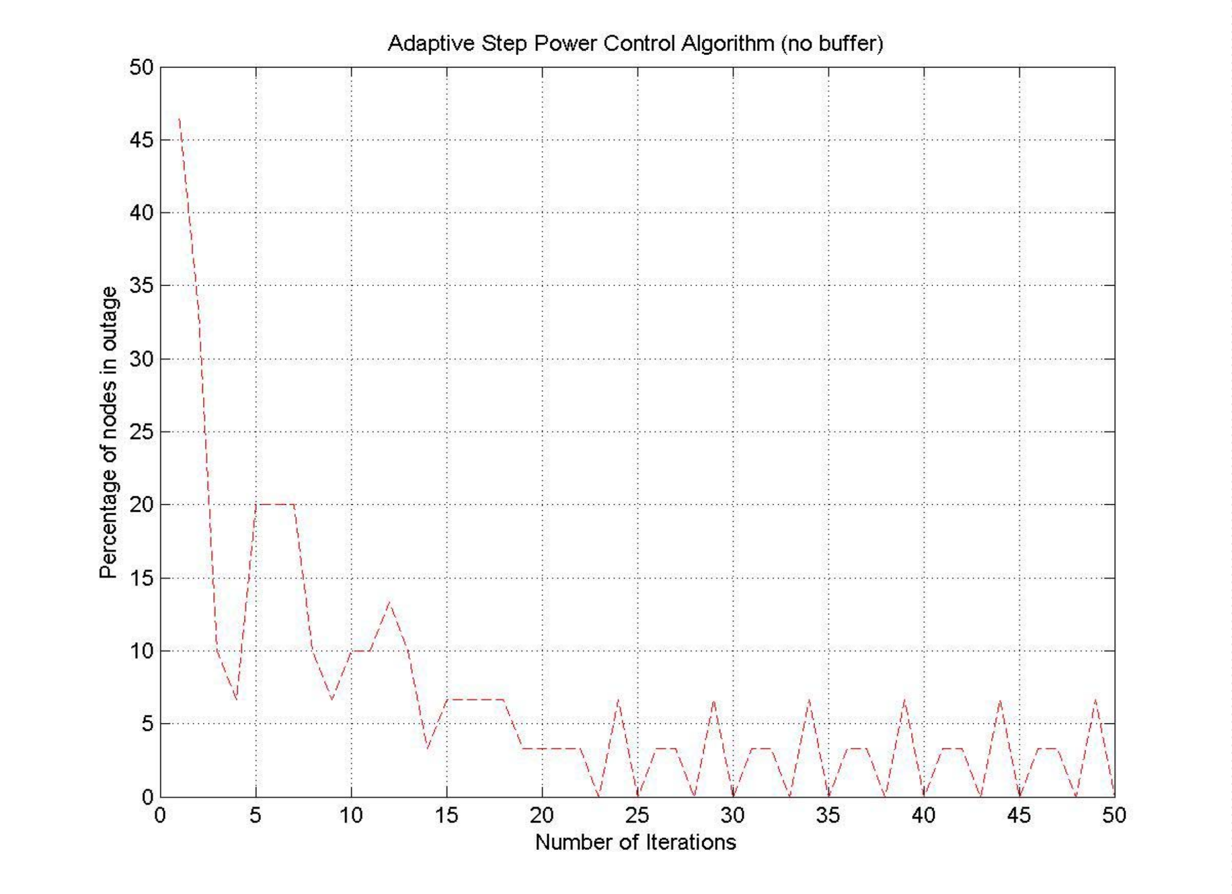
# 4. Adaptive Step Power Control (ASPC) [Lagrange et. al. 2002]

- Uses adaptive step sizes to achieve faster convergence
- Step size depends on the previous state
- If one power-up/down command, the step is *delta*.
- If two or more consecutive power-up commands, the step size is *mu*delta*
- If two or more consecutive power-down commands, the step size is *nu*delta*

# ASPC Flowchart



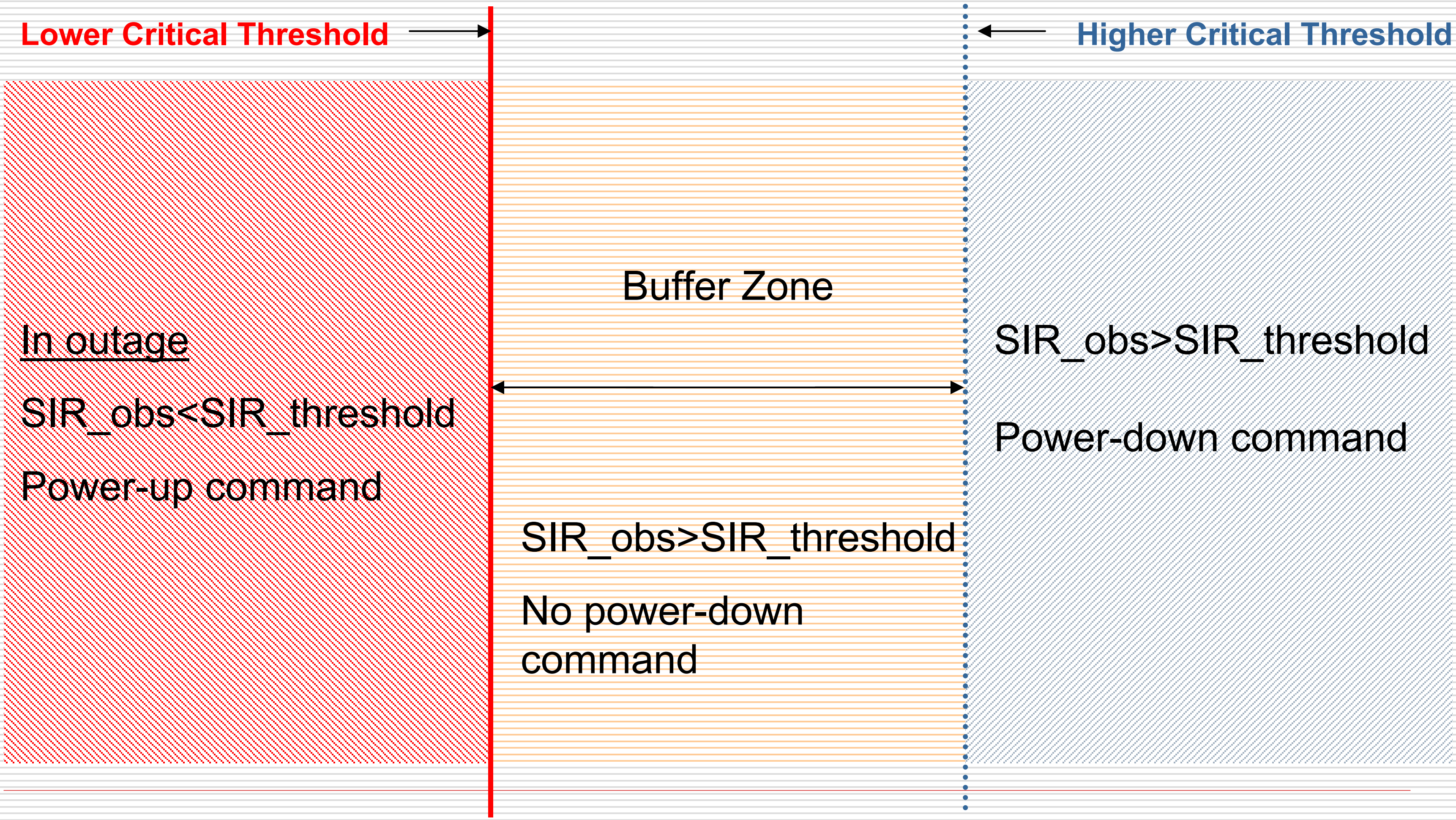
# ASPC – Outage Percentage vs. Number of Iterations



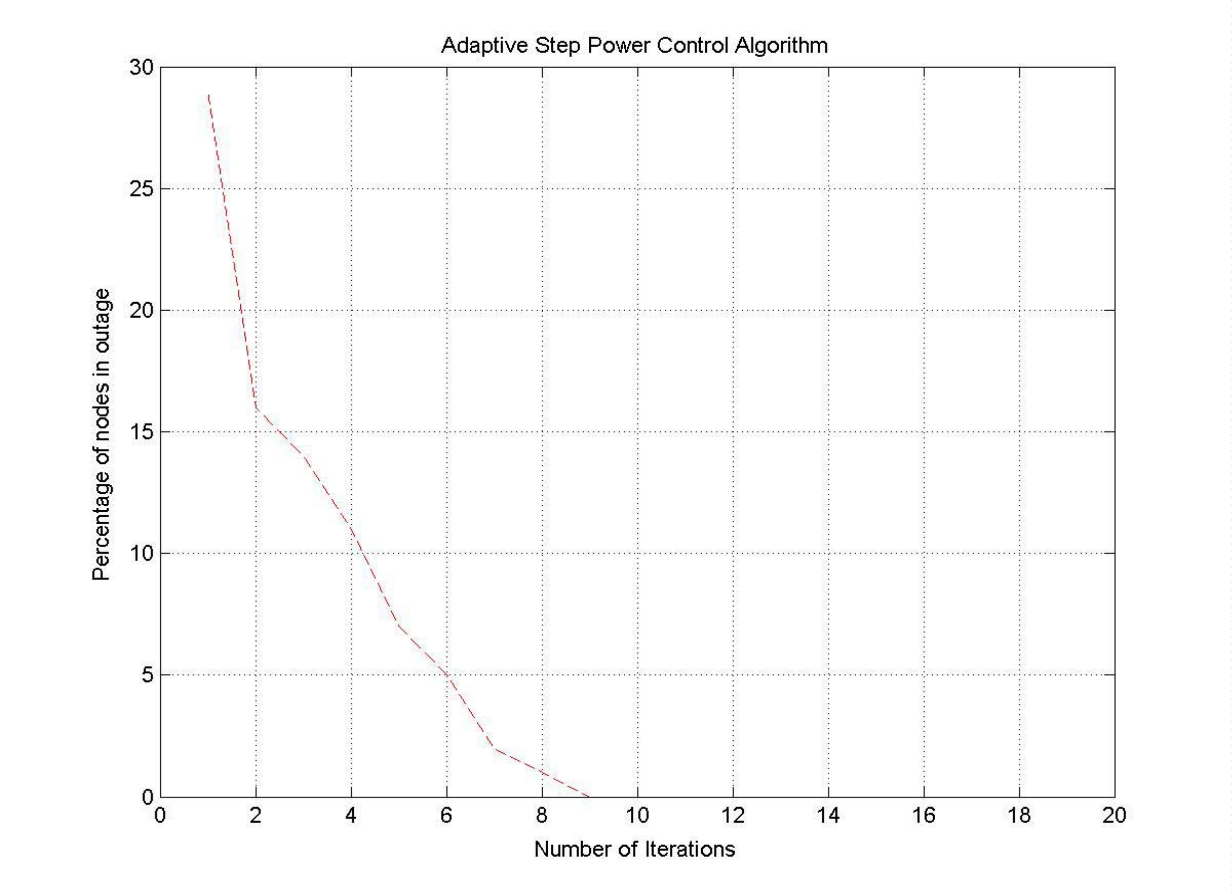
# 5. Modified Adaptive Step Power Control (M-ASPC)

- Modification of ASPC algorithm to do away with the small oscillations in outage probability versus number of iterations plot
- Introduction of two SIR_thresholds (lower and upper critical thresholds) in place of a single threshold

# M-ASPC (contd.)

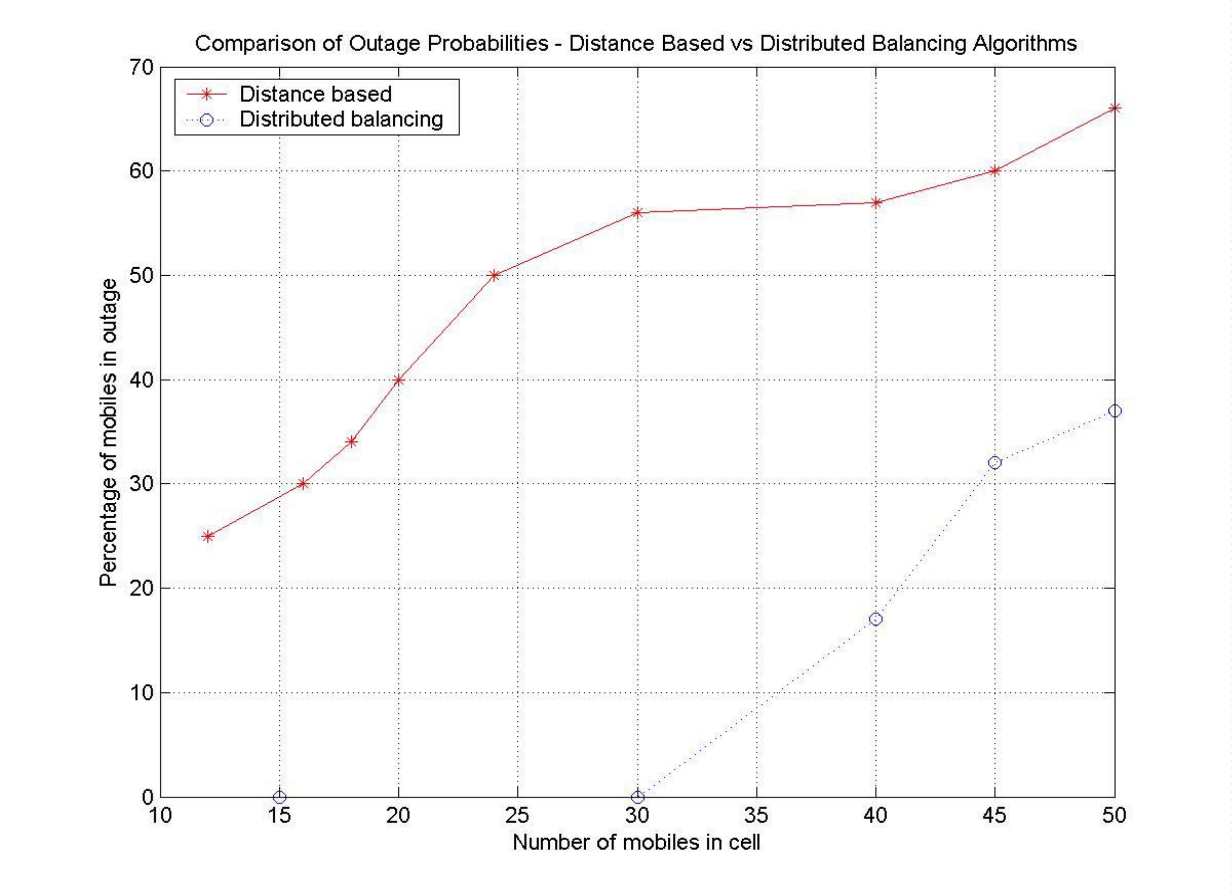

Lower Critical Threshold
Higher Critical Threshold
In outage
SIR_obs<SIR_threshold
Power-up command
Buffer Zone
SIR_obs>SIR_threshold
No power-down command
SIR_obs>SIR_threshold
Power-down command

# M-ASPC - Outage Percentage vs. Number of Iterations

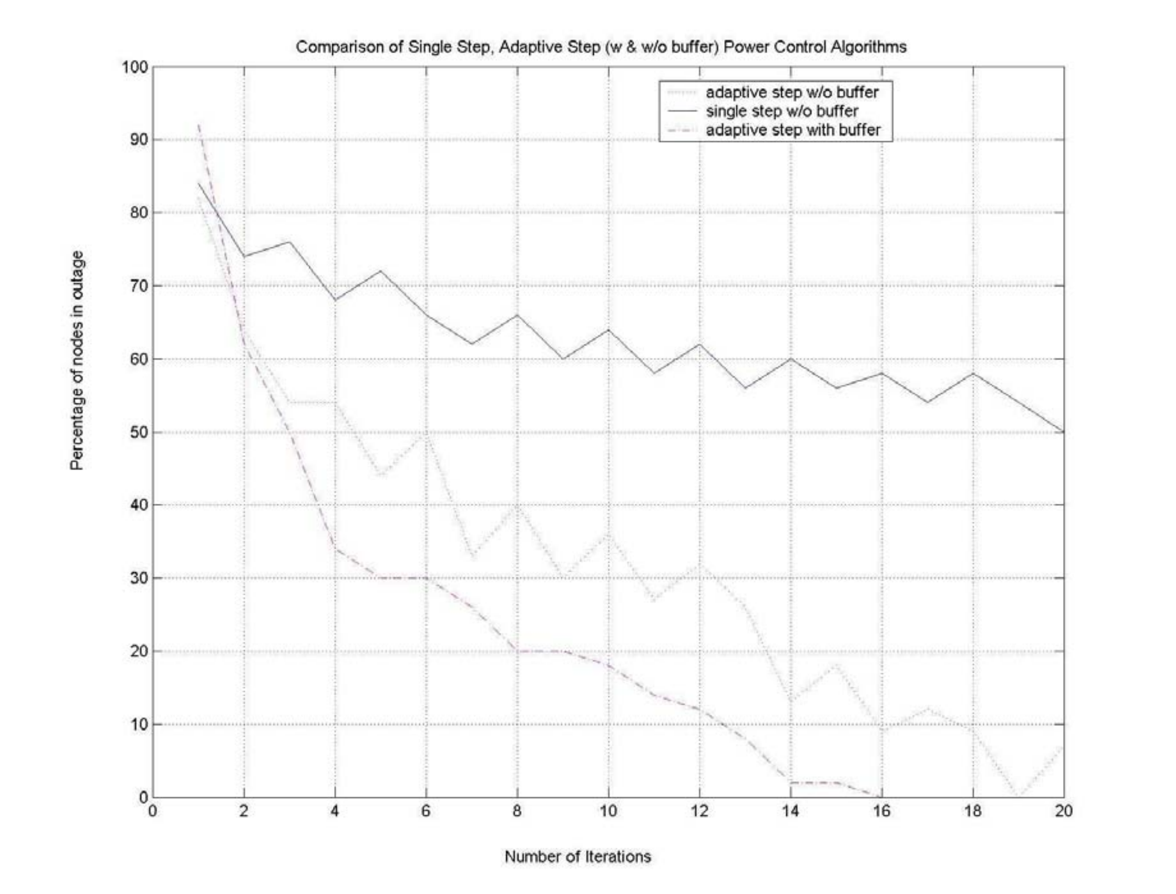


# Performance Comparison of Power Control Algorithms

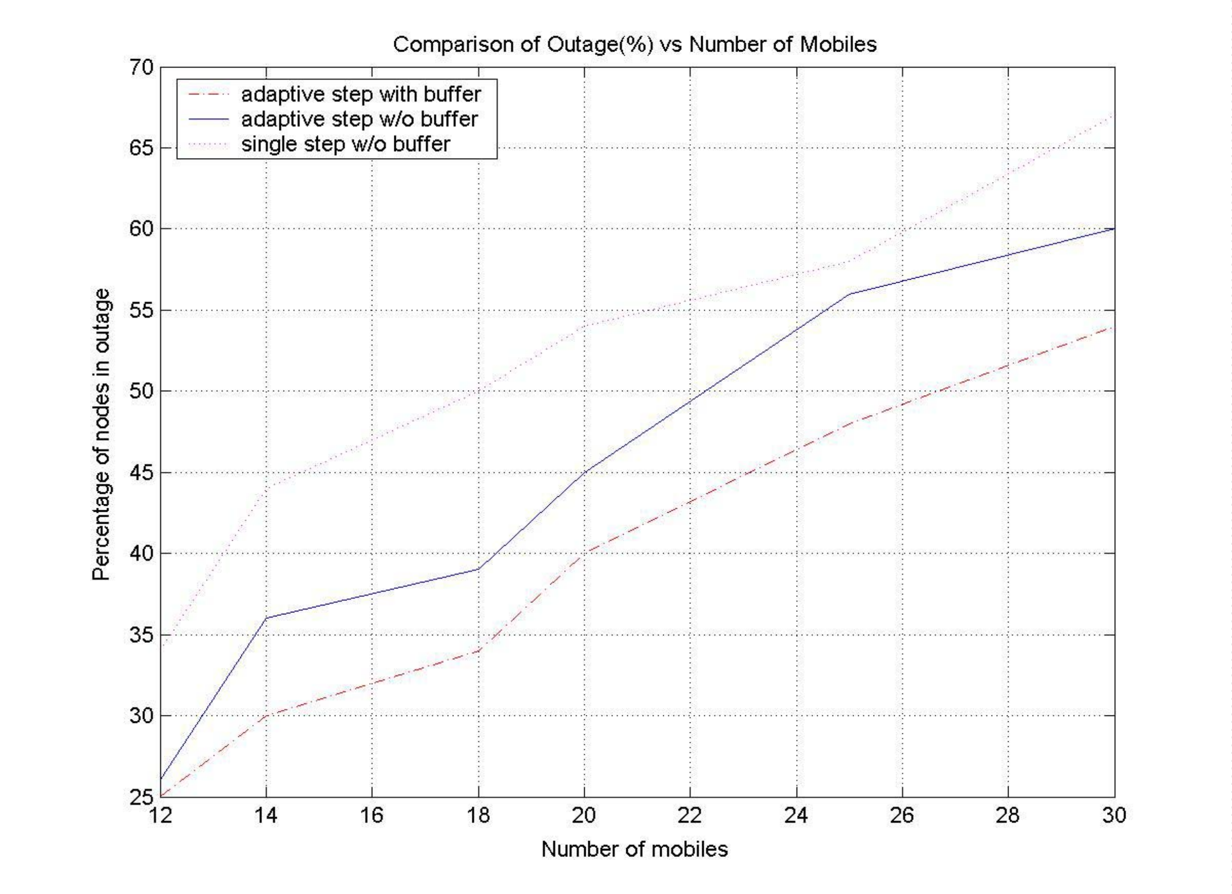
# DBPA and DB – Outage Percentage vs. Number of Mobiles



# FSPC, ASPC, M-ASPC with Buffer: Outage % vs. No. of Iterations



# FSPC, ASPC and M-ASPC: Outage % vs. No. of Mobiles



# Future Work

- Performance with mobiles moving in and out of the cell (i.e. handoff)
- Performance with admission control (i.e. call-blocking)
- Extension of M-ASPC to multi-cell scenarios