Mobile Base Station Navigation and Call Handoff in Totally Mobile Wireless

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Outline of Presentation

1. Totally Mobile Wireless Networks
2. Movement and Handoff Strategies
   – Center of Gravity Movement
   – Social Potential Fields
3. MBS Movement with Power Control
   – Power Approach
   – Distance Approach
4. Conclusions

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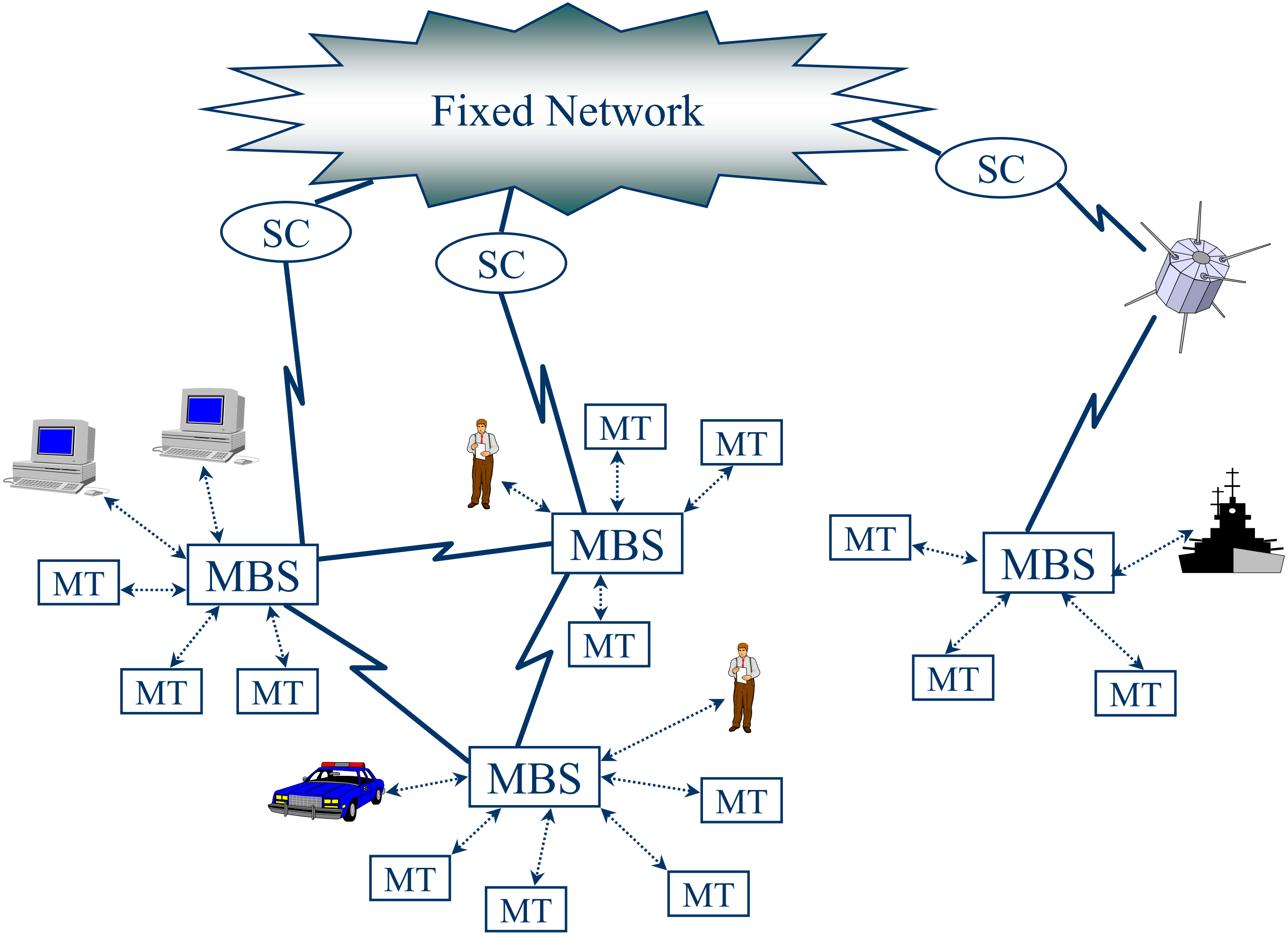
Totally Mobile Wireless Network

- Motivations
  - Rapidly deployable communication systems
  - Lower cost and delay in construction and planning

- Characteristics
  - Flexible, adaptive and dynamic
  - Mobile base station
    - Move in real-time like an autonomous robot
    - Stationary, be transported to locations when necessary
    - No fixed "cell" boundary, dynamic coverage area

Both Terminals (MT) and Base Stations (MBS) are Mobile



Applications

- Battlefield, located at a remote part of the world
  - ⇒ Following troops
- Special events, amusement parks and sport stadiums
  - ⇒ Sudden rise of traffic, short duration
- Fast growing cities, disaster areas
  - ⇒ Temporary communication systems, replacement of damaged/overloaded fixed base stations

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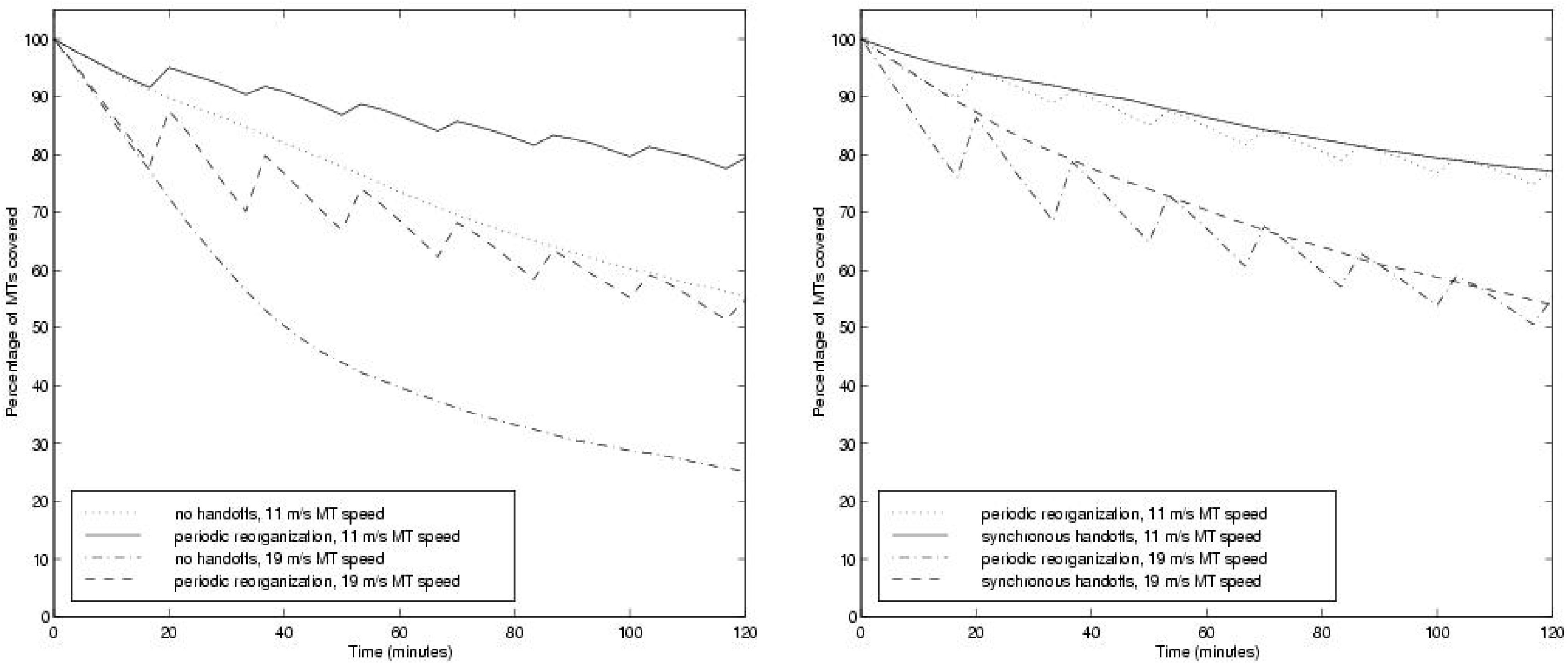
Simple Movement and Handoff Strategies

- The first MBS movement strategy we consider is Center of Gravity (COG), where every MBS calculates the gravimetric center of the MT it supports and moves towards this location
- Handoffs between MBS take place according to three strategies
  - No handoffs
  - Synchronous handoffs (periodic reorganizations)
  - Asynchronous handoffs

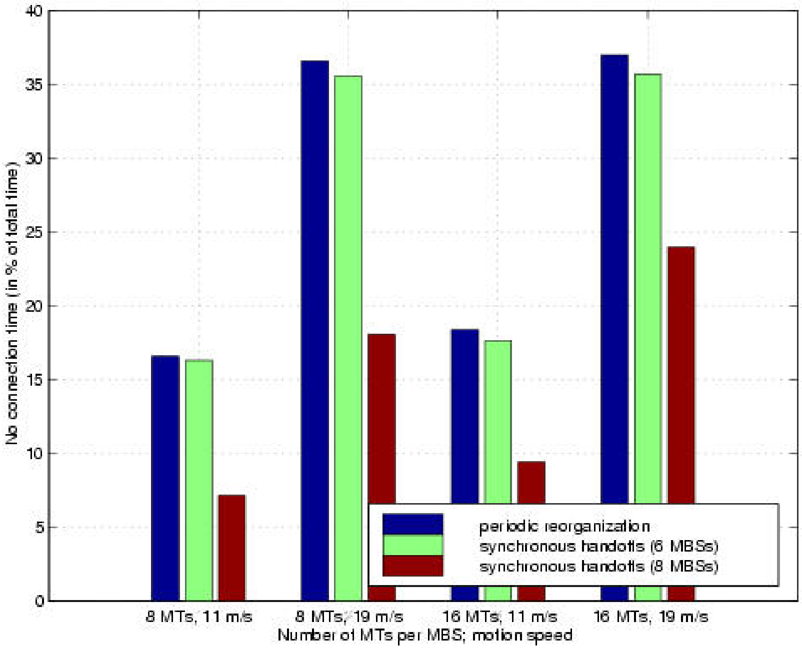
Simulated Terminal Coverage for Simple Movement and Handoff Strategies

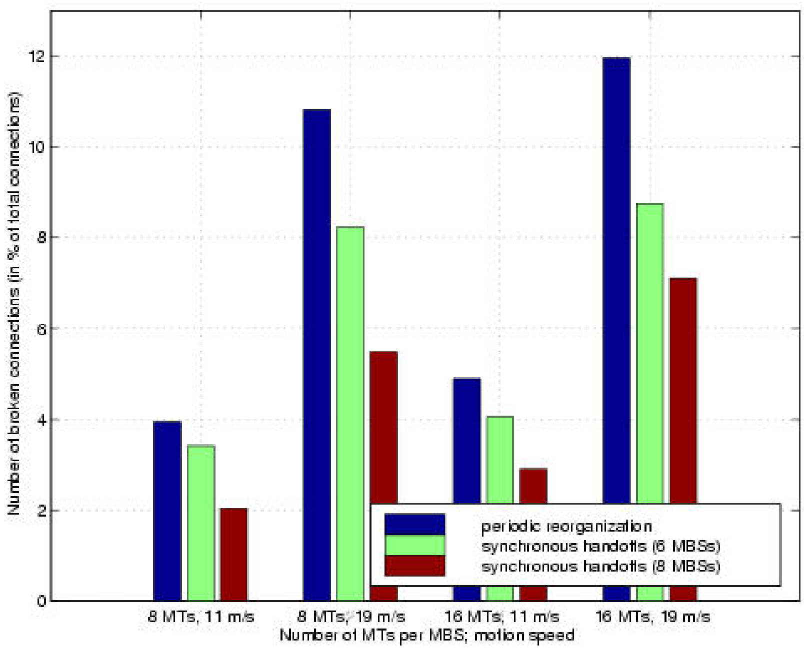


- Individual MBS coverage areas are subject to high overlap (which diminishes the aggregate coverage area)
- MBS may experience difficulties in keeping up with MT "swarm"

Two Additional Statistics

- "Average No Connectivity Time" per MT measures the timespan during which a terminal is not in contact with any base station
- "Number of Broken Connections" counts the number of call interruptions that occur because a terminal leaves the cell of a base station without being handed-off





Social Potential Fields (SPF) for MBS Movement

- **The MBSs and the MTs are two groups that interact via adequate force laws**
- **The force between the mobile entity i and j is given by**

$$F_{ij}(r_{ij}) = -\frac{c_1}{r_{ij}^{a}} + \frac{c_2}{r_{ij}^{b}} \qquad c_1, c_2 \geq 0, \quad a > b > 0$$

with r_{ij} distance between i and j

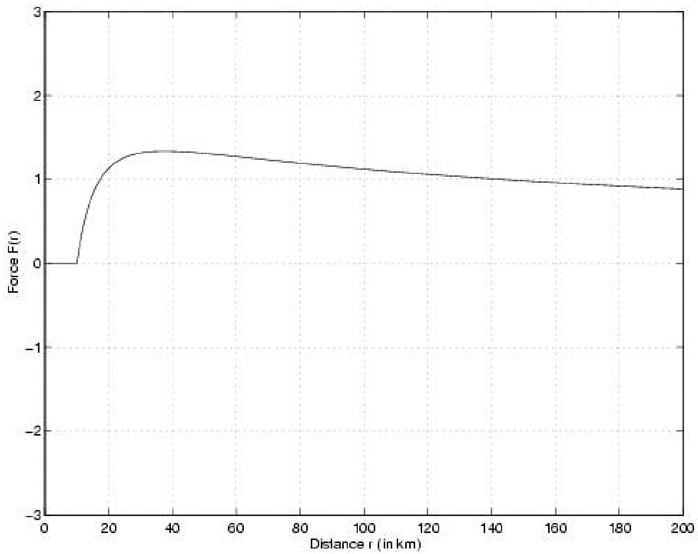
- **First term represents a repulsive force, second term an attractive force**

Three Forces to Control MBS Movement

- **Between 2 MBSs: When r_{ij} is small, repulsive force dominates to maintain sufficient separation; when r_{ij} is big, attractive force dominates to limit useless scattering**
- **Between a MT and its MBS: A unilateral attractive force which makes the MBS follow the MT**
- **Between 2 MBSs: r_{ij} corresponds to load factor (current load / capacity) instead of distance; aims to gather MBSs together to relieve hot-spots.**

Three Forces to Control MBS Movement (cont'd)

- **Example: Force between MT and its MBS**



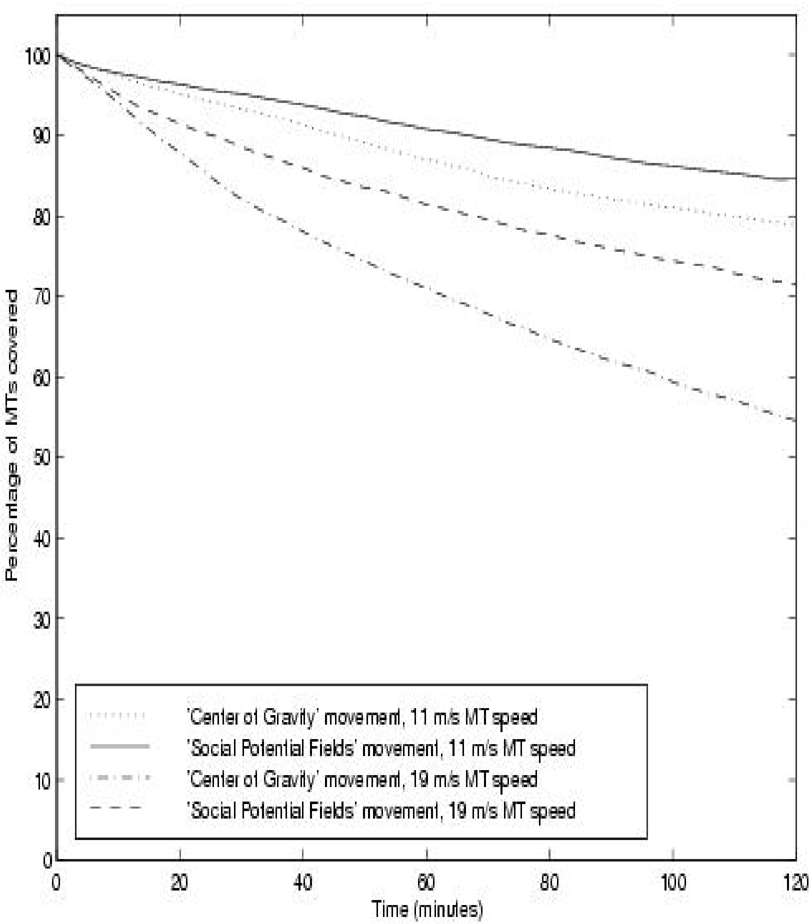
- **The total force a MBS experiences is therefor**

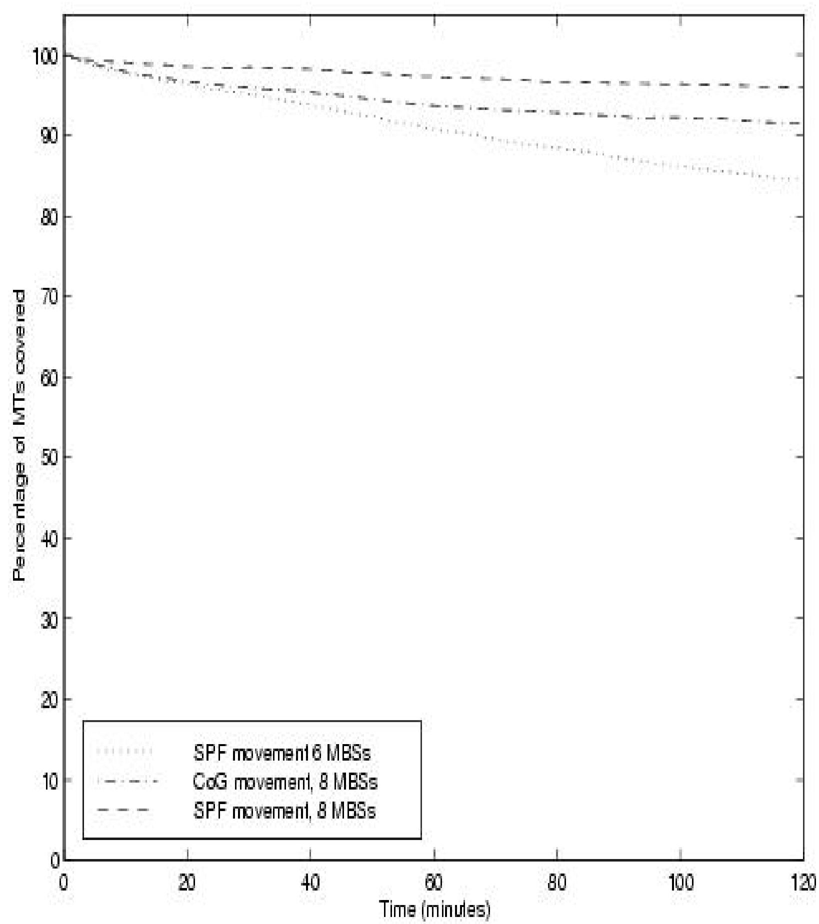
$$F = \sum_{k} \sum_{(i,j)} F_{ij_k}$$

where k represents the type of the force component

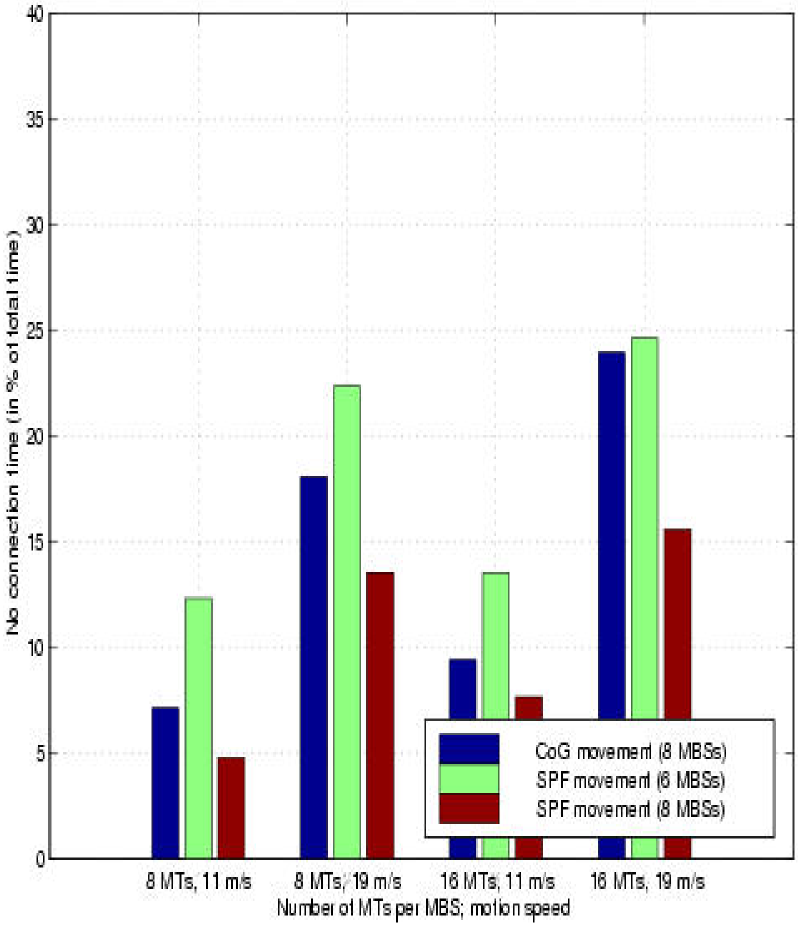
- **The MBS moves in the direction of F in order to reduce the quantity of the total force**

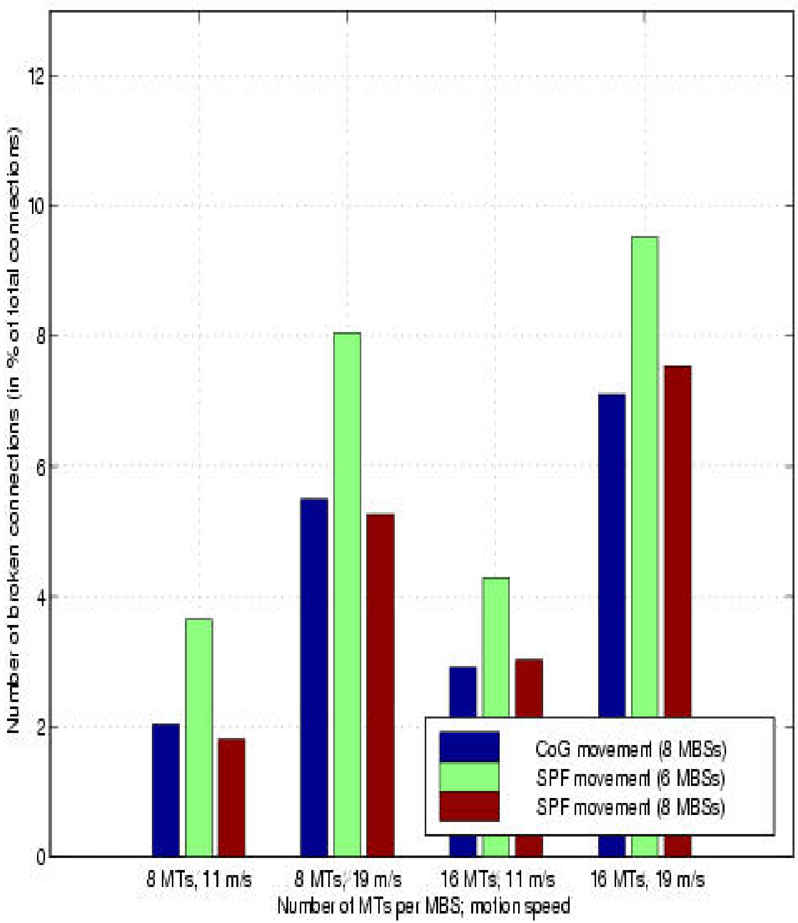
Simulated Terminal Coverage for SPF Movement





Additional Statistics for SPF Movement





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Power Update Algorithm

$$P_{t_i}^{(k+1)} = \frac{\gamma \cdot \delta}{SIR_i^{(k)}} P_{t_i}^{(k)}, \quad \delta \geq 1$$

- P_{t_i} **transmitter power of MT i**
- SIR **uplink co-channel Signal-to-Interference ratio**
- γ **link quality threshold**
- δ **protective margin to account for uncertainty due to MBS mobility**

$\Rightarrow$ **Outage occurs if transmitter reaches maximum power level** P_{max}

Movement Strategy – Power Approach (MSP)

- **Cost function**

$$\min \Phi_{MSP} = \sum_i P_{t_i} \qquad \forall i \in \textbf{MT supported by this MBS}$$

- **Aim to find MBS velocity V_{BS} such that total transmitter power is minimized**

$$V_{BS}^{x\ (n+1)} = V_{BS}^{x\ (n)} - \eta \sum_i \left. \frac{\partial P_{t_i}}{\partial V_{BS}^{x}} \right|_{\vec{V}_{BS}^{\ (n)}}$$

$$V_{BS}^{y\ (n+1)} = V_{BS}^{y\ (n)} - \eta \sum_i \left. \frac{\partial P_{t_i}}{\partial V_{BS}^{y}} \right|_{\vec{V}_{BS}^{\ (n)}}$$

Movement Strategy – Distance Approach (MSR)

- **Cost function**

$$\min \Phi_{MSR} = \sum_i SIR_i^a \cdot r_i^b \qquad \forall i \in \text{MT supported by this MBS}$$

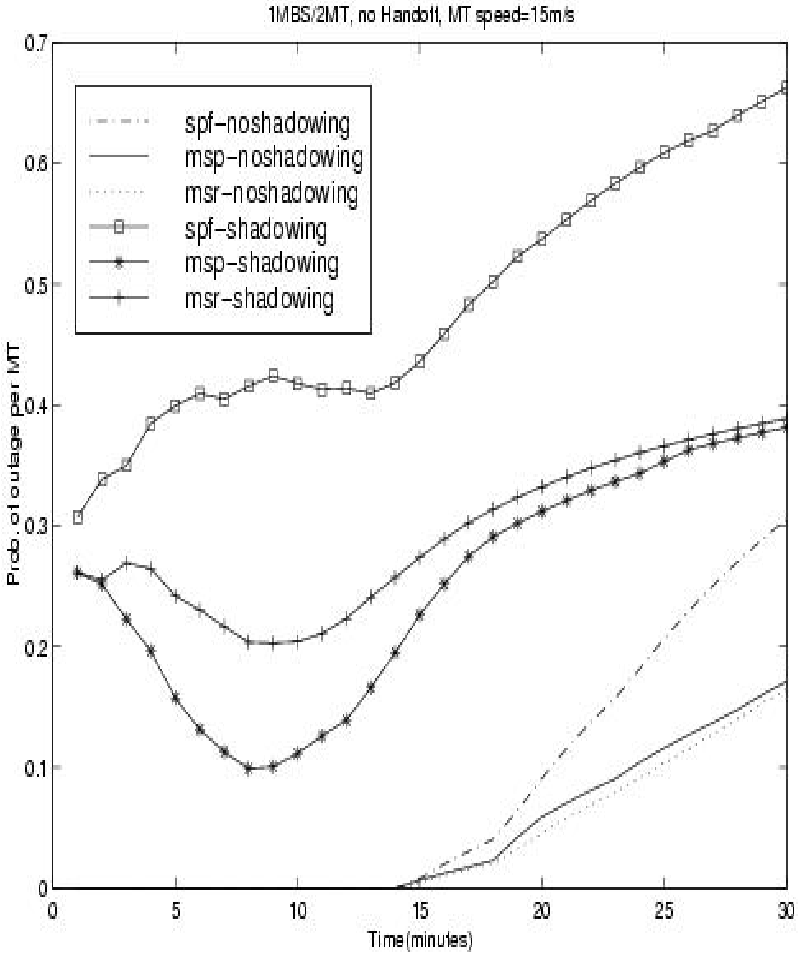
with r_i distance between MT i and MBS

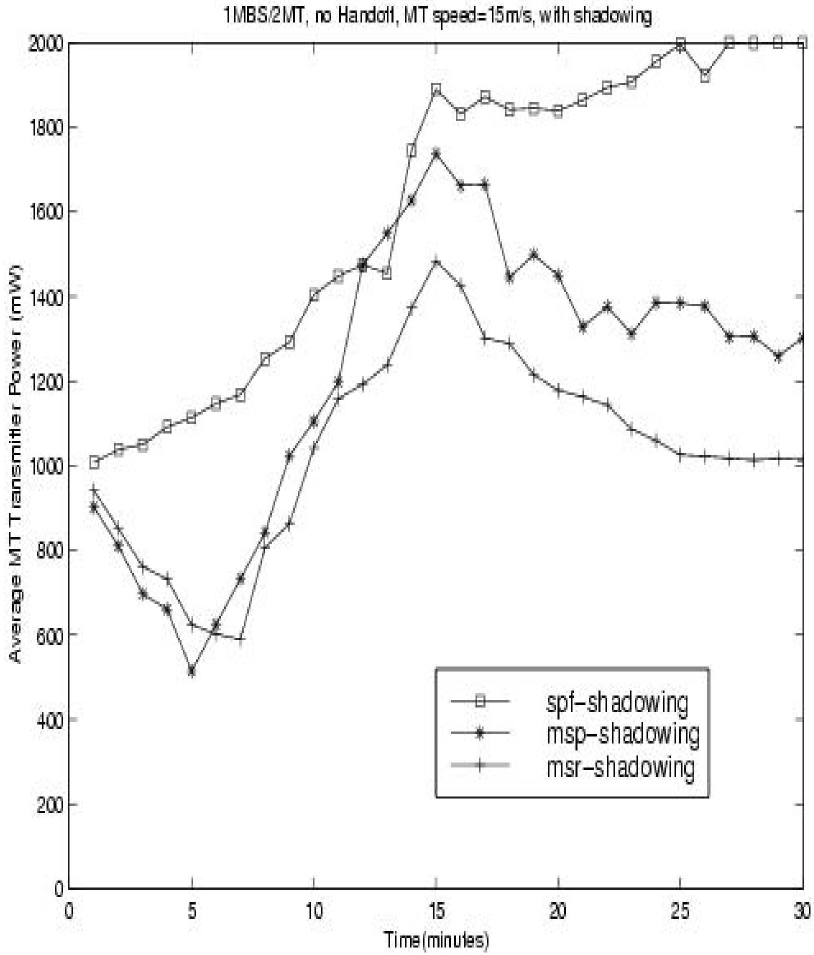
- **Aim to find MBS velocity V_{BS} such that total transmitter power is minimized**

$$V_{BS}^{x\ (n+1)} = V_{BS}^{x\ (n)} - \eta \frac{\partial \Phi_{MSR}}{\partial V_{BS}^{x}} \bigg|_{\overrightarrow{V_{BS}^{(n)}}}$$

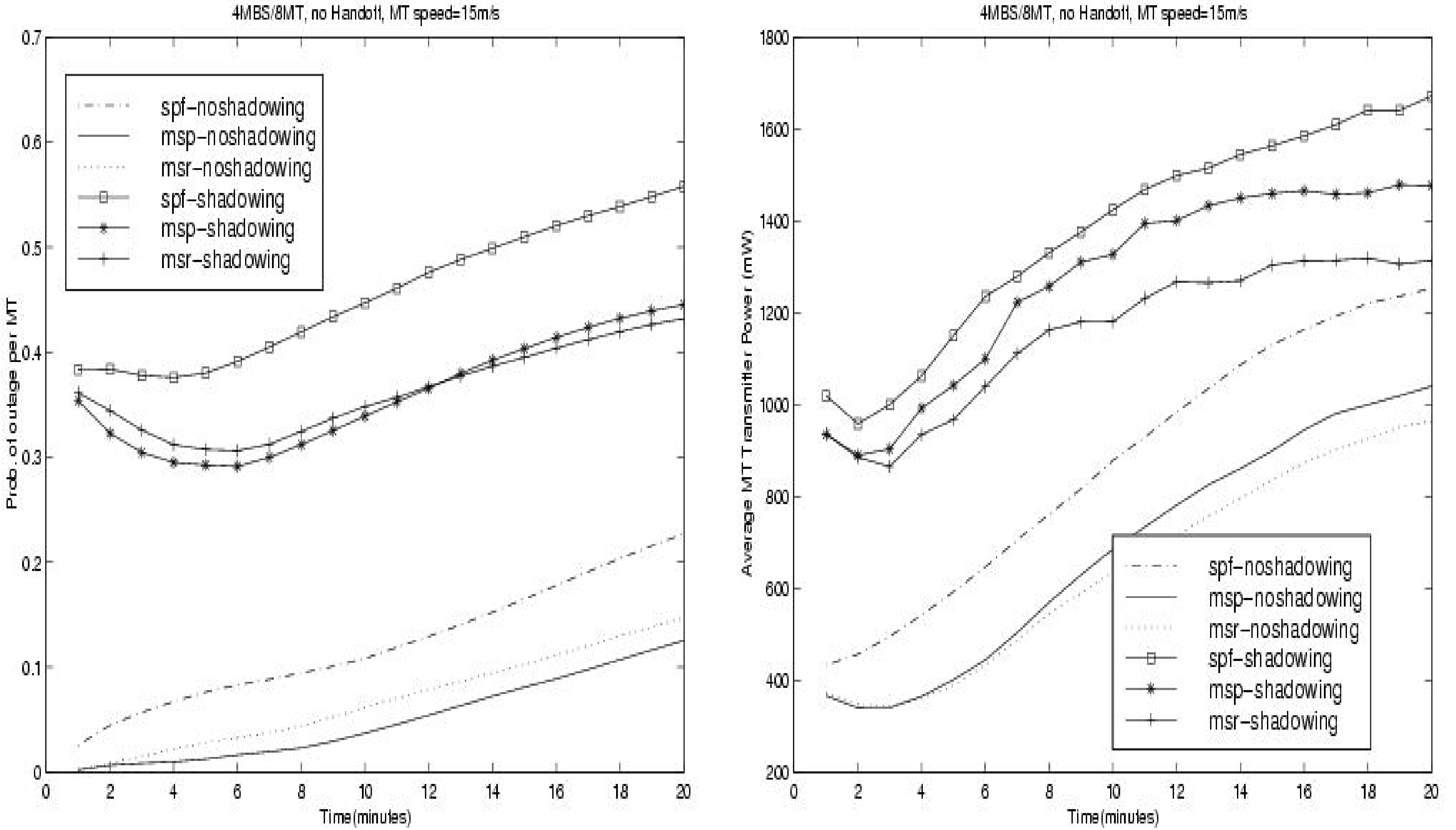
$$V_{BS}^{y\ (n+1)} = V_{BS}^{y\ (n)} - \eta \frac{\partial \Phi_{MSR}}{\partial V_{BS}^{y}} \bigg|_{\overrightarrow{V_{BS}^{(n)}}}$$

Simulation Results for MSP and MSR





Simulation Results for MSP and MSR (cont'd)



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SPF, MSP, MSR Comparison

- Especially for a small number of MTs per MBS, MSR and MSP perform significantly better than SPF in terms of terminal coverage
- SPF consumes more power since in average more MTs are in outage
- In general MSR has a slightly higher probability of outage than MSP but a lower power consumption – which represents a tradeoff between outage and transmitter power
- With a higher number of MTs per MBS the improvement of MSP and MSP over SPF is not as significant