Group mobility and partition prediction in wireless ad-hoc networks

ICC 2002

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2002_07_04

Goal

- To propose a new characterization of group mobility based on existing group mobility models, which provides parameters that are sufficient for network partition prediction.

Outline

- Introduction
- Group mobility model
- Partition prediction
- Mobile node velocity clustering
- Discussion and conclusion

Introduction

Introduction

- Wireless ad hoc networks are networks dynamically formed by mobile host without the support of pre-existing fixed infrastructures.
- The mobile hosts are moving with diverse mobility patterns that will cause
  - frequent failures and
  - activations of the wireless links

Introduction

- Local scale topology changes
  - The changes in link availability
- Global scale topology changes
  - Network partitioning
    - Group mobility behavior

Group mobility model

Group mobility model

- In realistic ad hoc network application scenarios such as
  - Conference seminar sessions
  - Conventional events
  - Disaster relief operations
- Such user mobility can be modeled by a *group mobility model*

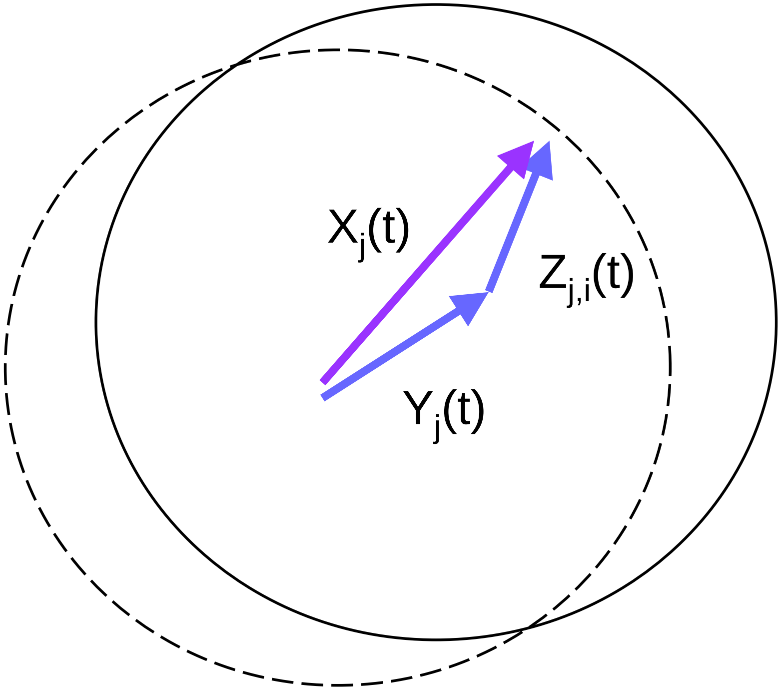
Reference Point Group Mobility Model (RPGM)[4]

- Logical reference center
  - Its movement is followed by all nodes in the group
  - The (x, y) represents the physical location
- Group members
  - Group motion vector
    - Maps out the location of the reference center
  - Random motion vector
    - The vector is independent from the node's previous location

How to locate a mobile node ?

- Ex.: At time t, the location of the i_{th} node in the j_{th} group is given by the following
  - Reference location: $Y_j(t)$
    - The displacement of the group reference center
  - Location displacement: $Z_{j,t}(t)$
    - Random motion vector
  - Node location: $X_j(t)= Y_j(t)+ Z_{j,t}(t)$

Node mobility



Two disadvantages

- We have to know the complete information about the mobility groups
  - The information includes
    - Number of member nodes
    - Member nodes’ movements
- The RPGM model represents the mobile nodes by their physical coordinates
  - It is difficult to discern
    - the group’s movement pattern and
    - the trend in the network topology changes

Reference Velocity Group Mobility Model (RVGM)

- It extends the RPGM model by proposing a *velocity* representation
- Each group has a group velocity
  - group velocity = mean group velocity
- The member nodes have velocities close to the group velocity but deviate slightly from it
  - Node movement: $V=(V_x, V_y)^T$

How to describe a mobile node ?

- The relationship of the i_{th} node in the j_{th} group is described as
  - Group velocity: $W_j(t) \sim P_{j,t}(w)$
    - Reference velocity
  - Location velocity deviation: $U_{j,i}(t) \sim Q_{j,t}(u)$
  - Node velocity: $V_{j,i}(t) = W_j(t) + U_{j,i}(t)$
  - $P_{j,t}(w)$ and $Q_{j,t}(u)$ are distributions
  - Velocity = d (distance) / d (time)

$$V_{j,t}(t) = \frac{dX_{j,i}(t)}{dt} = \frac{dY_j(t)}{dt} + \frac{dZ_{j,i}(t)}{dt} = W_j(t) + U_{j,i}(t)$$

Two advantages

- It directly provide the mobility parameters
  - The mean group velocity
  - The variance in the node velocity within the group
- By modeling the node velocities in a group as a R.V with distribution $Q_{j,t}(u)$, we can define the membership of node and group
  - By integrating the deviation, we can get the position

Comparison

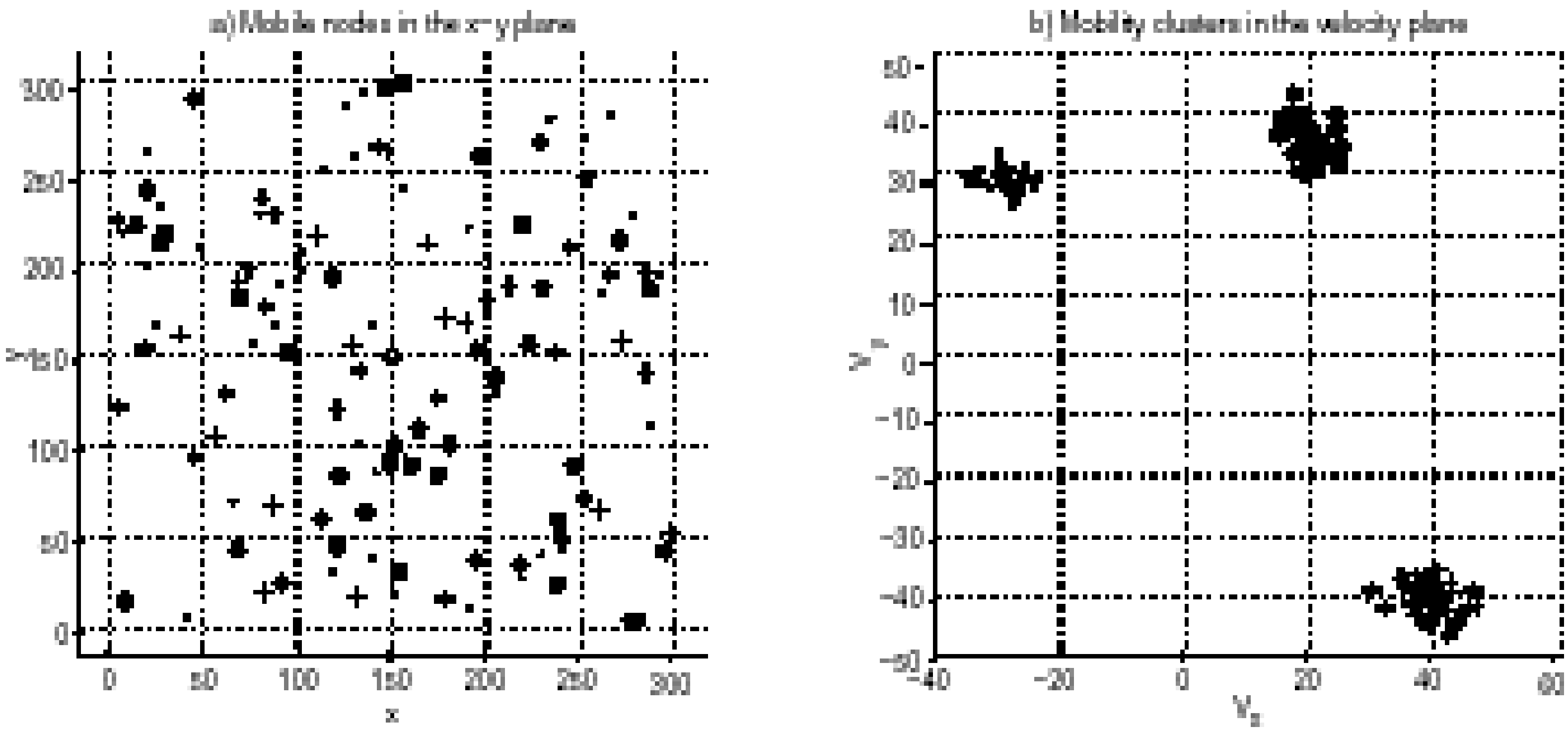
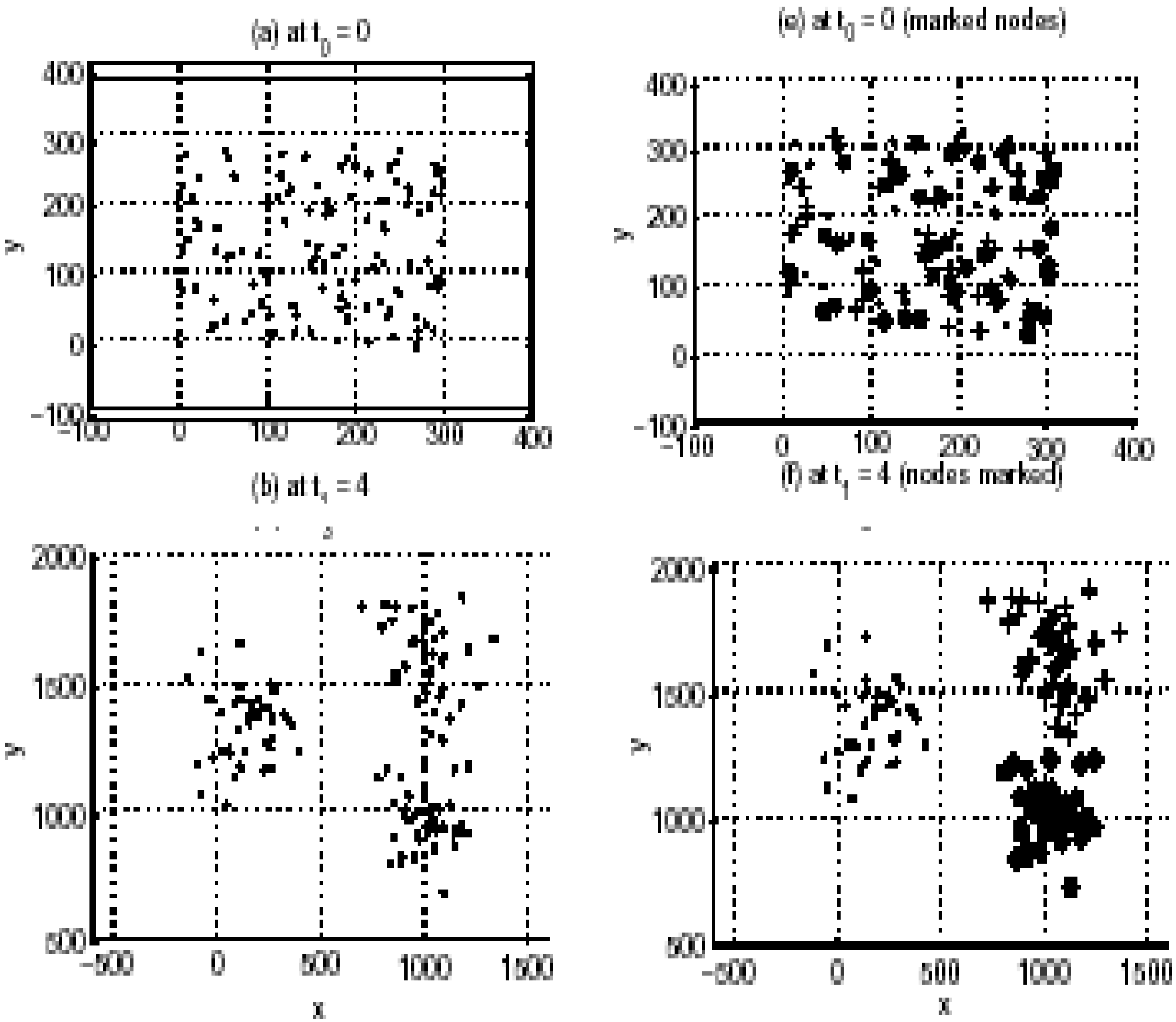


Fig. 1. Mobile Nodes Represented by Their a) Physical Coordinates and b) Velocities

Partition prediction

Network Partition and Group Mobility Pattern



Partition prediction algorithm

- If such mean group mobility velocities are known to all the groups in the network, then the occurrence of network partitioning can be predicted

Assumptions

- All mobility groups have circular coverage area of diameter D
- The velocities of the groups and nodes are time invariant
- The network topology can be viewed as a collection of equal size circles

Example

- Only two groups in the network
  - C_j with velocity W_j
  - C_k with velocity W_k
- Find the relative velocity

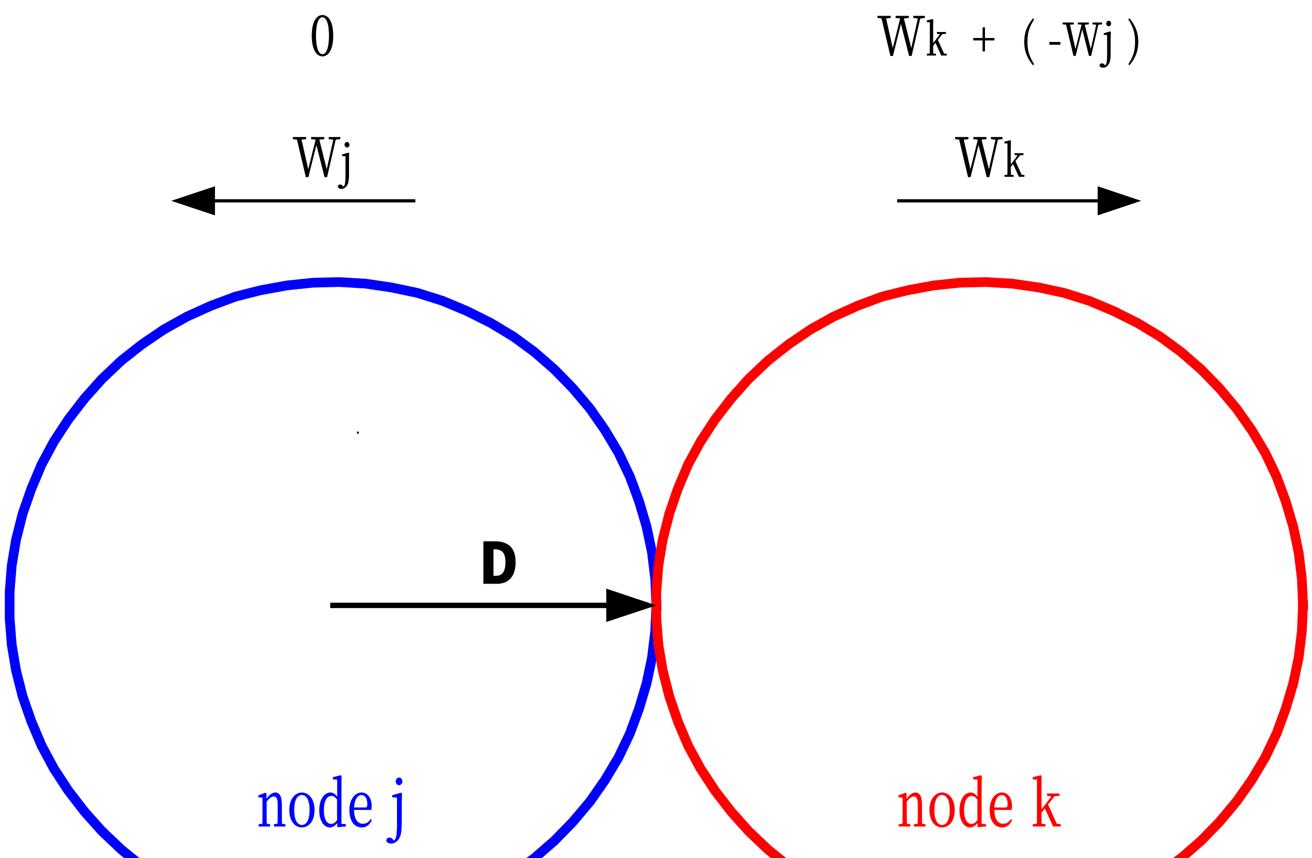
$$W_{jk} = W_k + (-W_j) \quad \text{and} \quad W_{jk} = (w_{jk,x}, w_{jk,y})$$

where

$$w_{jk,x} = w_{k,x} - w_{j,x},$$

$$w_{jk,y} = w_{k,y} - w_{k,y}$$

Example (cont'd)



Example (cont'd)

- The amount time to change from total overlap to completely separation is given by

$$T_{jk} = \frac{D}{\sqrt{w_{jk,x}^2 + w_{jk,y}^2}}$$

- The occurrence of network partitioning can be prediction as a sequence of expected time of separation T_{jk}s between the various pairs of groups

Mobile node velocity clustering

Mobile node velocity clustering

- The only information we may have is the velocity of the mobile node
  - GPS can help us to get the information
- Problem
  - The identification of the mobility clusters in the velocity space

Sequential Clustering Algorithm

- The SC algorithm classifies a set of data points into clusters based on a *distance measure*
- Advantages
  - It requires little prior information
  - It learns and adapts its classification
  - It sequentially processes the data points

Processing steps

- Distance measurement
  - It measures the distance between the data point and the center
- Classification
  - It selects the minimum distance measured and
  - Comparers with the preset distance threshold α
- Self-learning
  - For each data point classified, the algorithm self-learns about the cluster by updating the cluster center

SC algorithm

$m = 1$

$C_m = \{x_1\}$

For $i = 2$ to end of data set

  Find C_k: $d(x_i, C_k) = \min_{1 \le j \le m} d(x_i, C_j)$

  If $d(x_i, C_k) > \alpha$ AND $(m < m_{max})$ then

    $m = m + 1$

    $C_m = \{x_i\}$

  Else

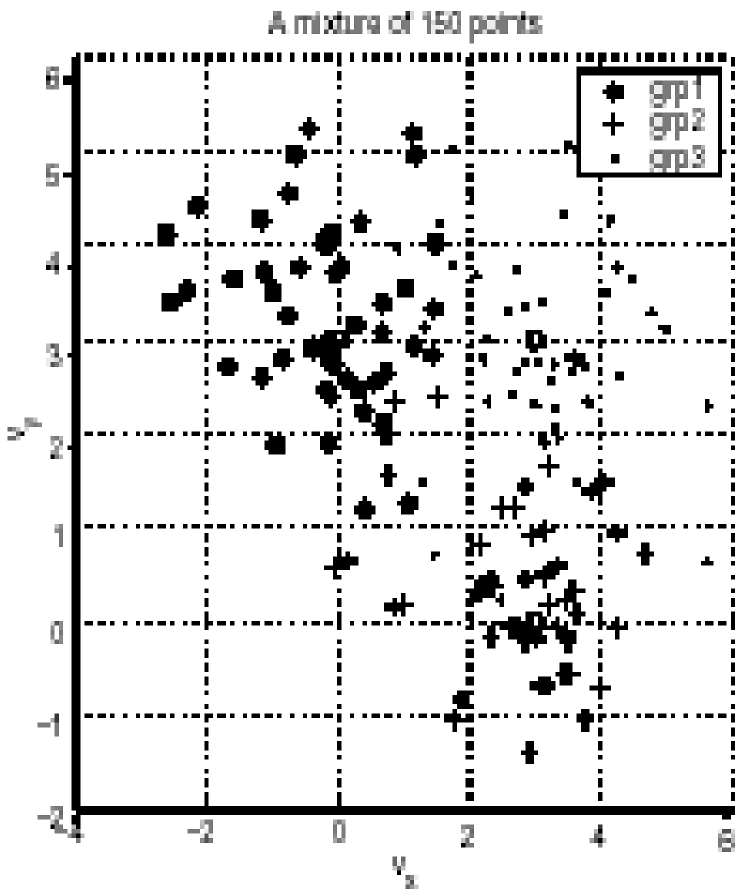
    $C_k = C_k \cup \{x_i\}$

    update the center of C_k

  End

End

Performance of SC algorithm



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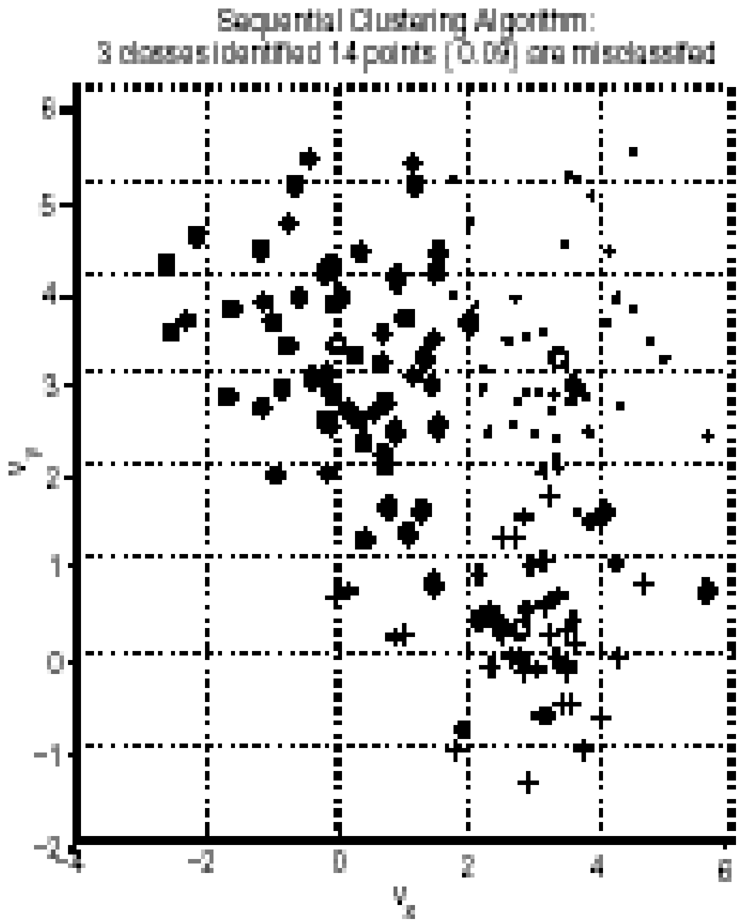

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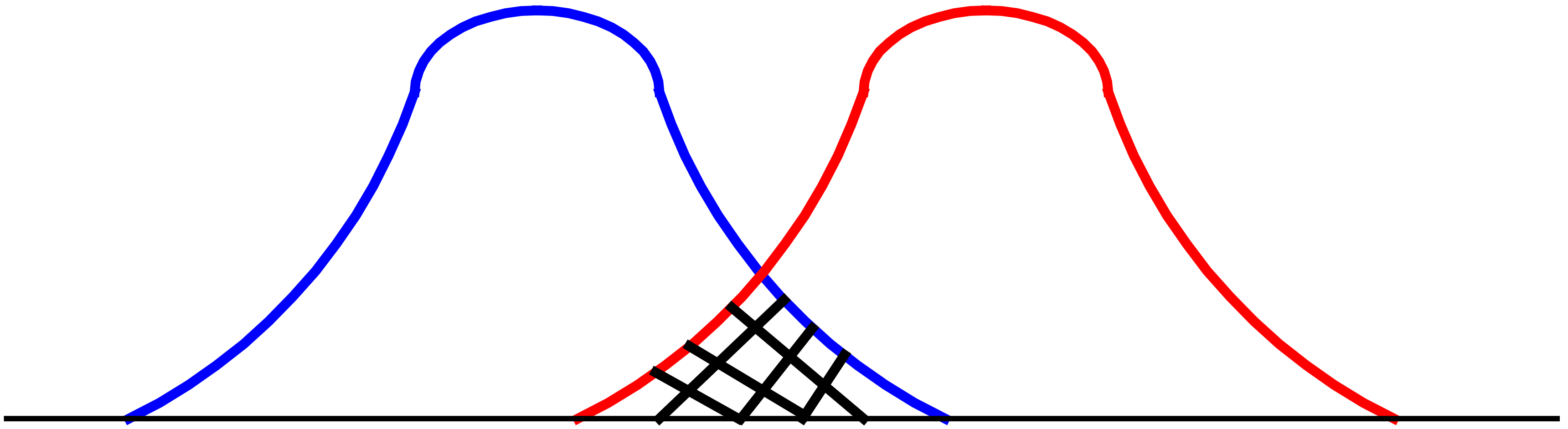
Performance of SC algorithm (cont’d)



Discussion

- The accuracy of the SC algorithm
- How to effectively collect the velocities without high communication cost
- Combine with the routing protocol

Conclusion

- The cause and effect relationship between group mobility and network partition
- The author proposes a new and enhanced characterization of the mobility group based on existing models
- How mobility groups can be determined from node velocities

Conclusion (cont’d)

- Using a simple data clustering algorithm such that it can accurately identify the mobility groups and estimate the characteristic parameter
- The clustering algorithm is effective with respect to mobility group identification