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Mobility-Adaptive Protocols for Managing Large Ad Hoc Networks

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Outline

- Introduction
- B-Protocol Description
  - B-nodes selection
  - B-links establishment
  - Properties of the B-protocol
- Simulation Results
- Conclusions

Introduction

Ad hoc Networks

- Collection of devices which are all mobile
- Constraint to a geographical location
- Mostly used in cases of emergency
- Also used in places where wired backbone is unavailable

Examples:

- Disaster recovery situations
- Battle field communications
- Law enforcement operations
- *Distributed microsensing* for large ad hoc networks

Objective:

- Scalability for large ad hoc networks
- Adaptiveness to mobility of nodes
- Minimize bandwidth and energy overhead

Introduction

Typical Problems

Clustering

- Partitioning of the network
- Identification of vital nodes

Routing

- Discovering routes from source to destination
- Maintaining the routes
- Rediscovery and repair of the routes

Topology Management

- Maintain the links
- Minimize the changes in underlying graph

B-Protocol Description

B-Protocol

- Also known as backbone protocols
- Sets up and maintains a connected network (B-network)
- B-network convey the time-sensitive network management information from every node in the network with minor overhead and in a timely manner
- Comprises two major tasks:

  (a) B-nodes selection

  (b) B-links establishment

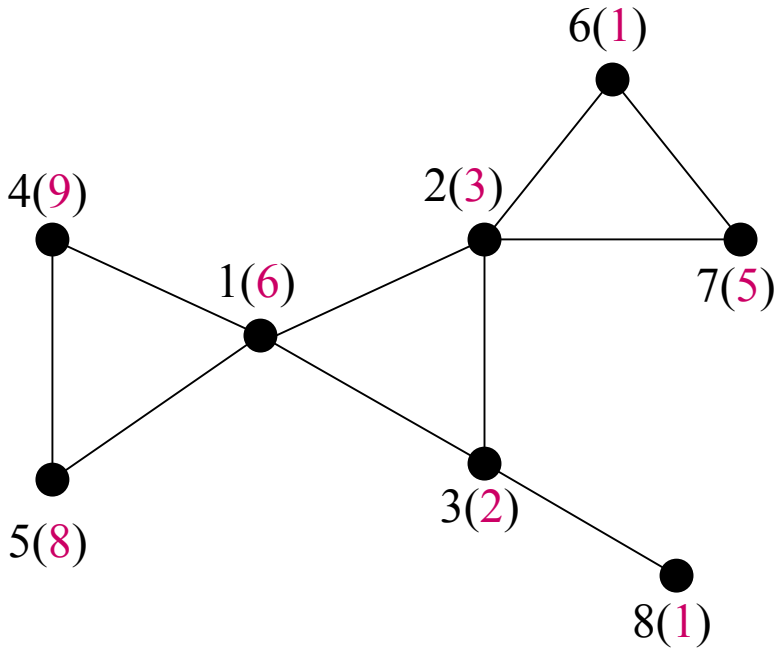
Nodes that are not selected as B-nodes are termed F- nodes that belong to the flat network.

B-nodes Selection

- Executed at each node based on a node's own weight
- Weight is computed based on what is most critical to that node for the specific network application
- The highest weight of a node is more suitable to be a B-node
- A node knows
  - Its own identifier (ID) and weight
  - Ids, weights and roles (B-node or F-node) of one-hop neighbors
- Once a node *b* determines its role as B-node, all its neighbors may become the F-nodes served under *b* unless they have decided to join another node
- B-nodes selection is adaptive to node mobility and changes in its local status

B-nodes Selection

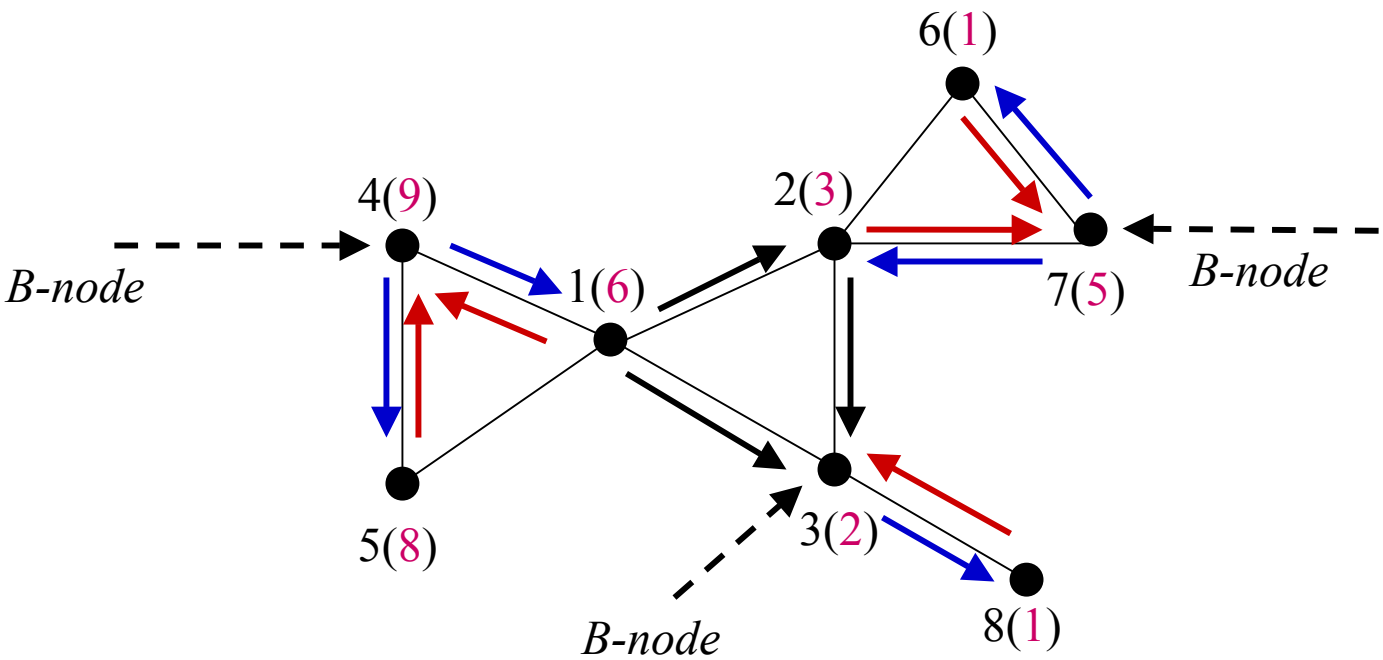
Illustrative Example:



Numbers represent node IDs and numbers within parentheses represent the node weights

B-nodes Selection

Illustrative Example:



B-links Establishment

- Determines the inter-B-nodes links to be established in order for the network to be connected
- Two types of B-links:
  - Physical – when a direct link between B-nodes at most three hops away can be established without involving intermediate F-nodes (via power control or directional antenna)
  - Virtual – when a direct link between B-nodes at most three hops away cannot be established. In this case, virtual link is implemented among two B-nodes by a corresponding physical path with at most three links
- The rules stated follow the theorem proven in [Chlamtac '96]

B-links Establishment

Theorem 1 [Chlamtac '96]:

Given a set B of network nodes such that no two of them are neighbors and every other node has a link to a node in B, then a connected backbone is guaranteed to arise if each node in B establishes links to all other nodes in B that are at most three hops away. Moreover, these links are all needed for the deterministic guarantee in the worst case, in the sense that if any of them is left out then it is not true anymore that the arising backbone is connected for any underlying flat network.

Properties of B-protocol

1. Each node in flat network knows only its one-hop neighbors. This induces the minimum possible overhead
2. B-link establishment is run at each B-node only with no knowledge of the surrounding B-nodes. Again, this induces the minimum overhead
3. Every B-node serves a number of F-nodes each of which is at most three-hops away. B-node selection protocol guarantees that all the F-nodes are served by only one neighboring B-node
4. There are no two B-nodes that are neighbors in the flat network. This guarantees that B-nodes are evenly distributed in the network

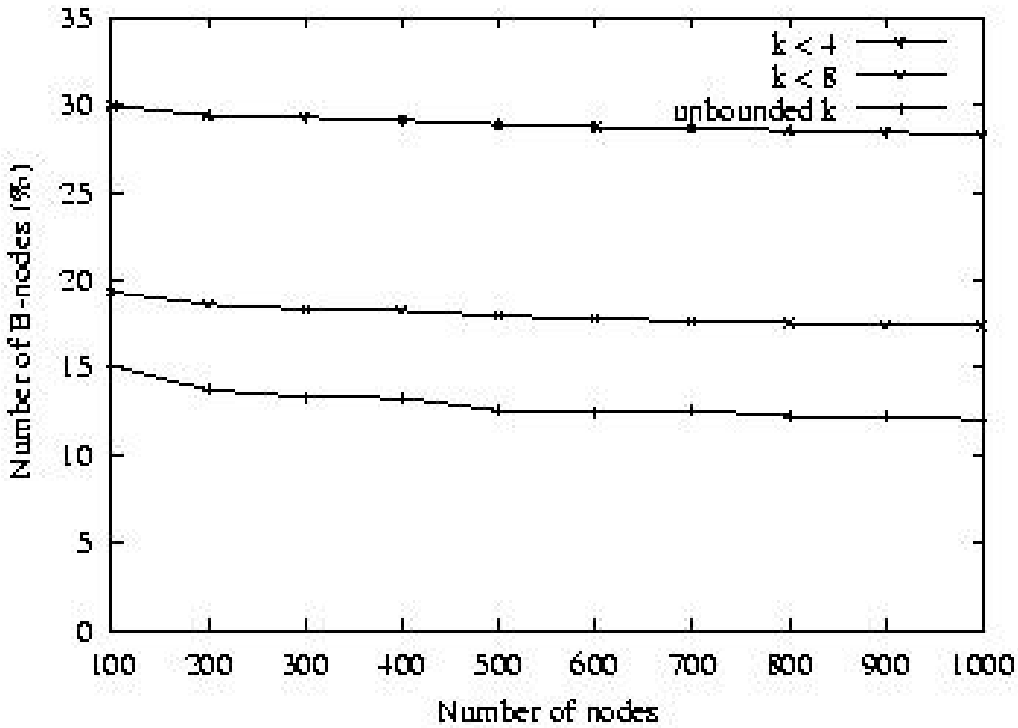
Properties of B-protocol

5. B-node selection is based on the node's current status (weight)
6. The B-network is always connected provided that the underlying flat network is connected
7. B-protocols takes into account different technologies and mechanisms that can be used to link the B-nodes in the network. Two types of B-links are provided; namely physical and virtual links. Physical links are used when there is a direct link between B-nodes at most three hops away and virtual links are used when there is a direct link cannot be established

Simulation Environment

- A simulator used for an ad hoc network of nodes ranges 100 - 1000
- Nodes can freely move around in a rectangular region (a grid)
- Node movements are discretized to grid units of 1 meter
- A node determines its direction randomly by choosing between its current direction (with 75% probability) and uniformly among all other directions (with 25% probability)
- When a node hits a grid boundary, it bounces back into the region with an angle determined by the incoming direction
- Fixed transmission range of each node (250 m) and the grid size have been chosen to obtain a good network connectivity
- Each packet contains the time-stamped, node identified weight of the sending node. All packets are sent for the one-hop neighbors only

Simulation Results



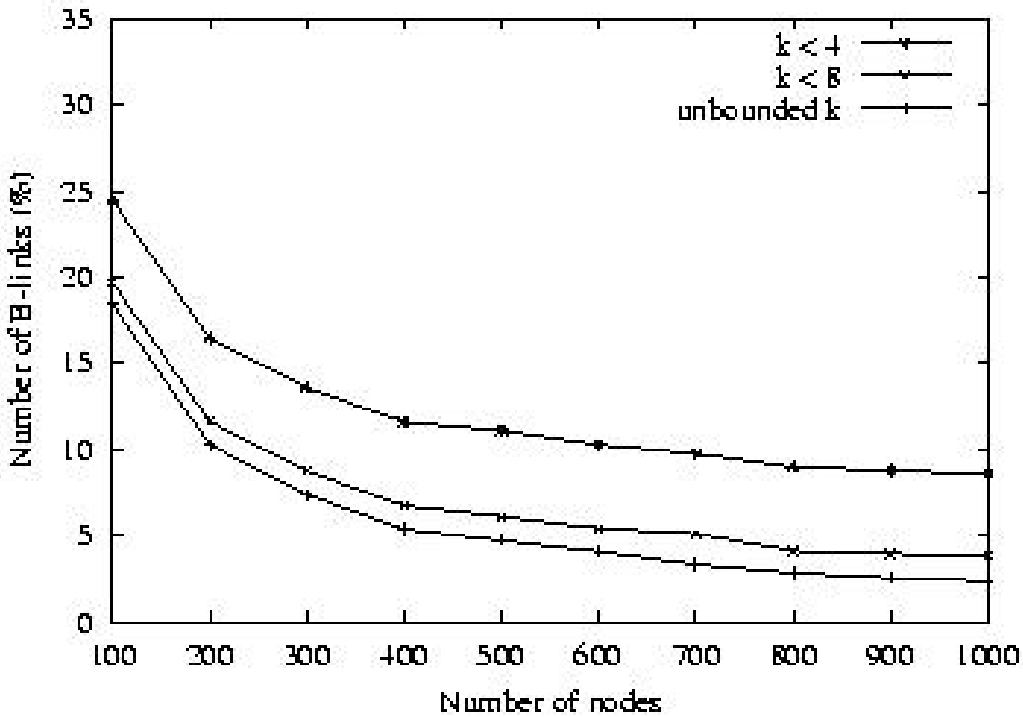
k is the total number of F-nodes a B-node can serve at any point in time

Three cases:

- *k* < *n* (where n is total number of nodes in network)
- *k* < 4
- *k* < 8

Figure 1: Number of B-nodes (% w.r.t the number of the network nodes)

Simulation Results



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Three cases:

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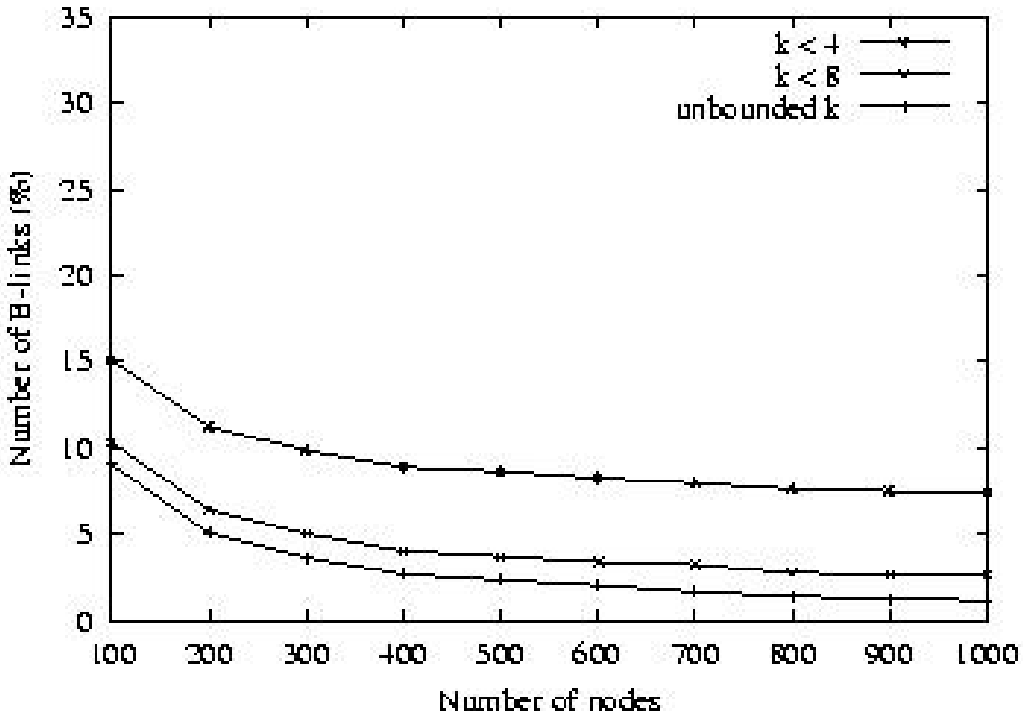
Figure 2: Number of B-links (%) when a physical link between any two B-nodes can be established directly.

Simulation Results



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Three cases:

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Figure 3: Number of B-links (%) when a link between B-nodes is implemented by a physical path with at most three hops away

Conclusions

- Proposed B-protocol for management of large ad hoc networks
- B-protocol is mobility-adaptive and generates the minimum possible overhead for construction and maintenance of the B-network
- Demonstrated that the number of B-nodes and B-links are just a small fraction of the total nodes and links in the flat network through simulation studies
- B-protocol is an efficient solution for mobility and node/link failures in very large ad hoc networks