Optimized Stateless Broadcasting in Wireless Multi-hop Networks

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Outline

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  - DDB 2 for Maximizing Network Lifetime
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Introduction

- Broadcasting is most simply and commonly realized by flooding whereby nodes broadcasts each received packet exactly once.
- Flooding generates a large number of redundant transmissions.
- This excessive broadcasting causes heavy contention and collisions, commonly referred to as the *broadcasting storm problem*.

Introduction

- Broadcasting protocol
  - Stateful
    - Barely affected by high traffic loads and collisions, but their performance suffers significantly in highly dynamic networks as the frequent topology changes.
  - Stateless
    - Do not require any knowledge of the neighborhood, but they perform well in specific scenarios but poorly in others, e.g., for varying node densities and traffic loads.

Introduction

- In this paper, the proposed protocol DDB (Dynamic Delayed Broadcasting) is stateless.

- Using Dynamic Forwarding Delay function(DFD) to allow nodes make locally optimal rebroadcasting decisions.

Related work

- Many broadcasting protocols have been proposed in order to cope with the broadcasting storm problem
  - Probability-based
  - Location-based
  - Neighbor-designated
  - Self-pruning
  - Energy-efficient

Dynamic Delayed Broadcasting Protocol

- DDB 1 for for Minimizing the Number or Transmission
  - Using addition area coverage
  - Using signal strength
- DDB 2 for Maximizing Network Lifetime

Dynamic Delayed Broadcasting Protocol

- DDB 1 with addition area coverage(AC)

$$AC(d) = 2\cdot\left(\int_{-\frac{d}{2}}^{1}\sqrt{1-x^2}\,dx - \int_{-\frac{d}{2}}^{-d+1}\sqrt{1-(x+d)^2}\,dx\right)$$

which immediately yields

$$AC(d) = \frac{d}{2}\sqrt{4-d^2} + 2\arcsin\left(\frac{d}{2}\right) \qquad (1)$$

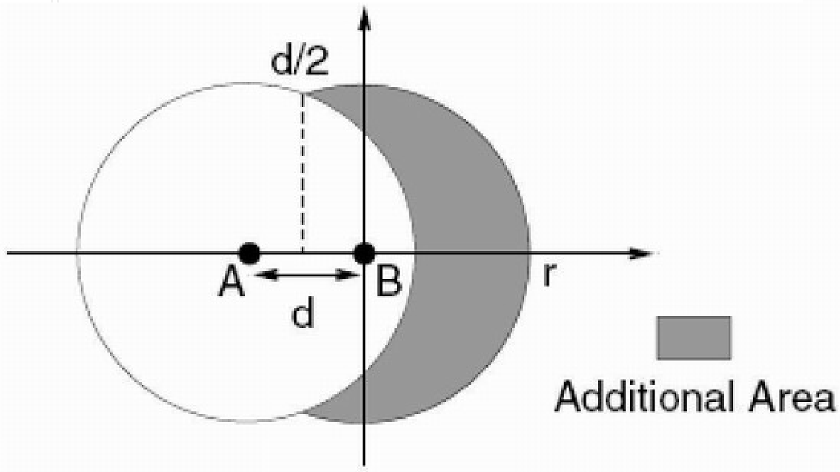


Fig. 1. Additional covered area

Dynamic Delayed Broadcasting Protocol

- DDB 1 with addition area coverage
  - AC(d) is maximal if node B is located just the boundary of the transmission range of node A, i.e. if d = 1.

$$AC_{MAX} = \left(\frac{\sqrt{3}}{2} + \frac{\pi}{3}\right) \simeq 1.91$$

  - Depending on AC(d), the node introduces a delay before relaying the packet.

$$Add\_Delay = Max\_Delay \cdot \sqrt{\frac{e - e^{\left(\frac{AC}{1.91}\right)}}{e - 1}} \qquad (2)$$

  - A rebroadcasting threshold(RT) also may be zero.
    If AC < RT, The node doesn't rebroadcast a packet.

Dynamic Delayed Broadcasting Protocol

- DDB 1 with addition area coverage

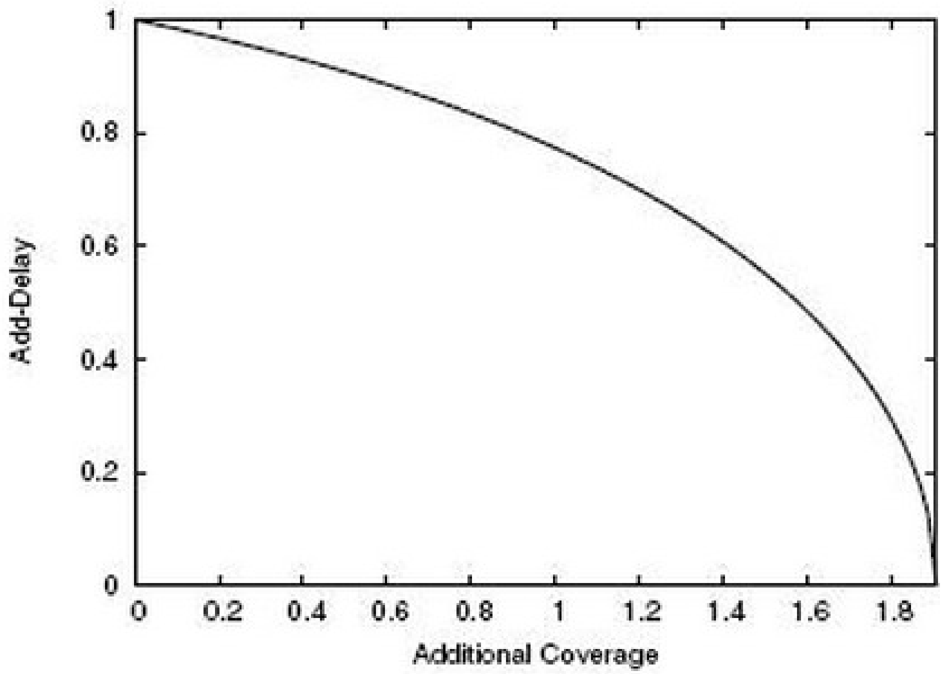
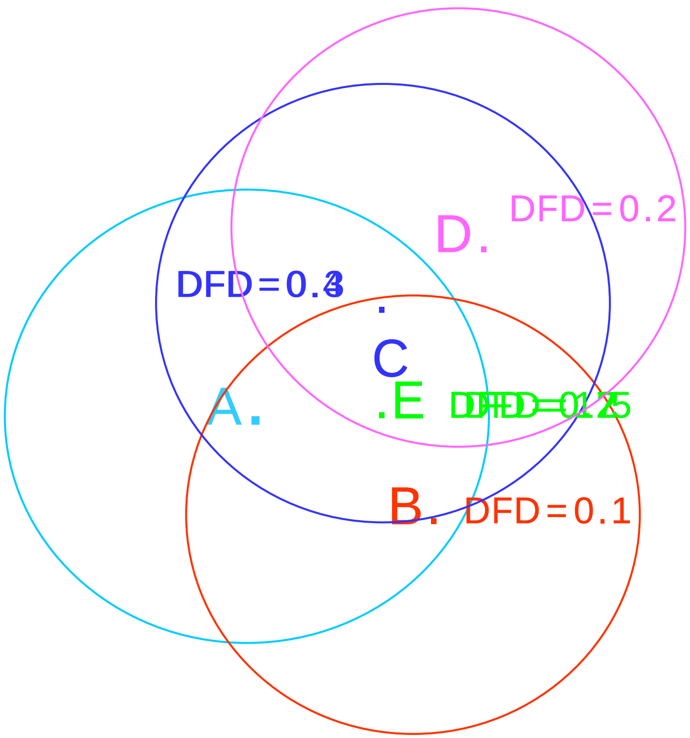


Fig.2 Delay introduced by the **DFD** function

Dynamic Delayed Broadcasting Protocol

- Illustrating Example of DDB 1 with addition area coverage



Dynamic Delayed Broadcasting Protocol

- DDB 1 with signal strength
  - Using the incoming signal strength as input to the DFD function.

$$Add\_Delay = Max\_Delay \cdot \sqrt{\frac{e - e^{\sqrt[\alpha]{10^{\left(\frac{S_r - P_r}{10}\right)}}}}{e - 1}} \qquad (3)$$

α : an attenuation factor

Sr:a receiver sensitivity

Pr:a receiver power measured in dBm

Dynamic Delayed Broadcasting Protocol

- DDB 2 for Maximizing Network Lifetime
  - We may expect that the traffic load is also uniformly distributed over all nodes, and thus the battery will deplete roughly at the same time at all nodes.

$$Add\_Delay = Max\_Delay \cdot \sqrt{\frac{e - e^{E_B}}{e - 1}} \qquad (4)$$

E_B is the remaining battery power of a node as percentage of the total battery capacity.

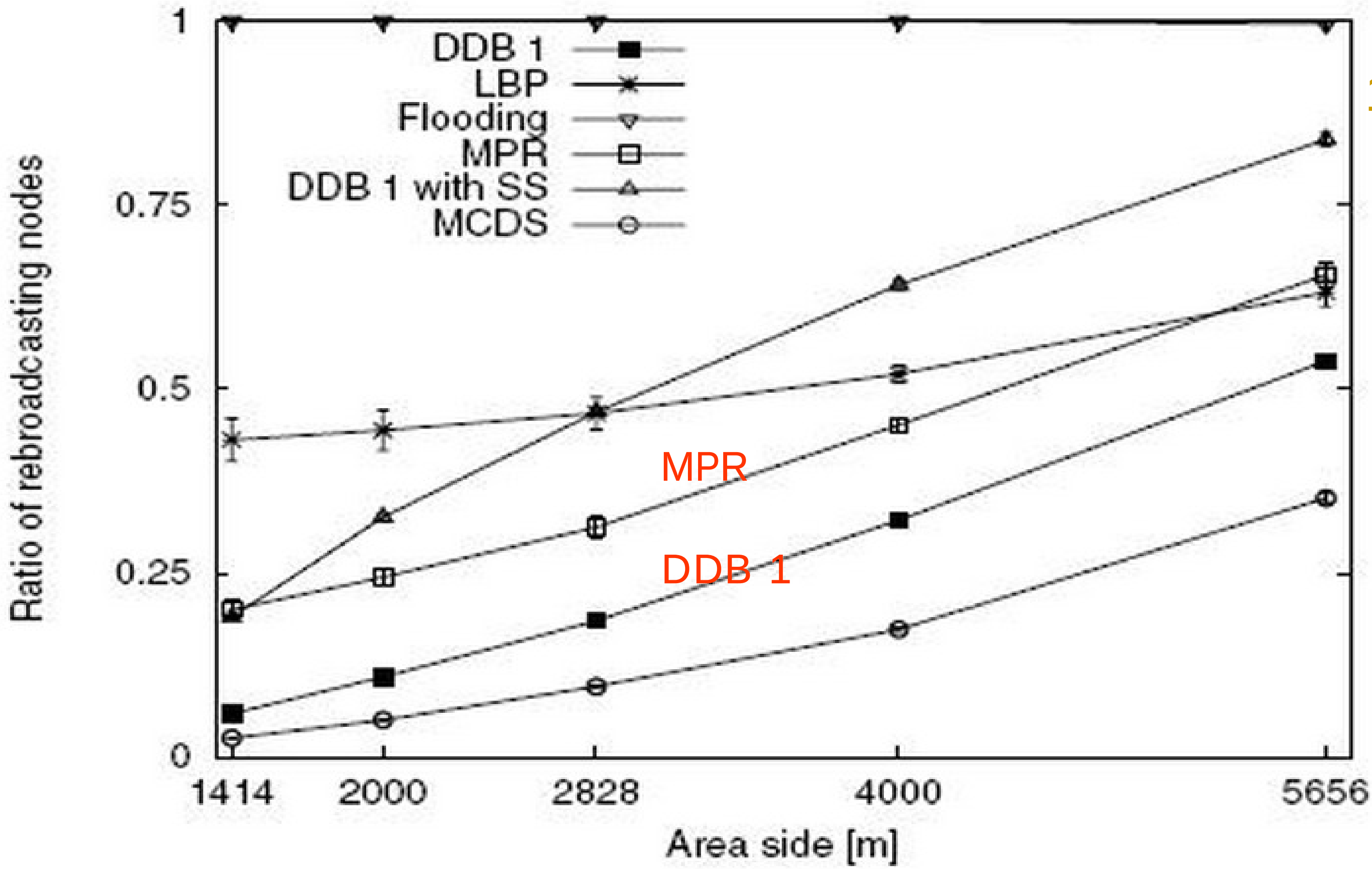
Dynamic Delayed Broadcasting Protocol

- Optimizations
  - First Always Forwarding Policy
    - Able to cope with varying network conditions such as node density and traffic load.
  - Cross-Layer Information
    - DDB should be able to access packets on the MAC layer, more precisely in the queue of the wireless interface.

Simulation

- DDB Comparison with
  - LBP :location-based broadcasting protocol
  - MPR:multipoint relaying
  - Simple flooding
- Only vary one of the important network parameters, i.e., density, mobility, and congestion.
- Simulation parameters
  - Max_Delay set to 2 ms
  - RT set to 40% of the maximal additional covered area

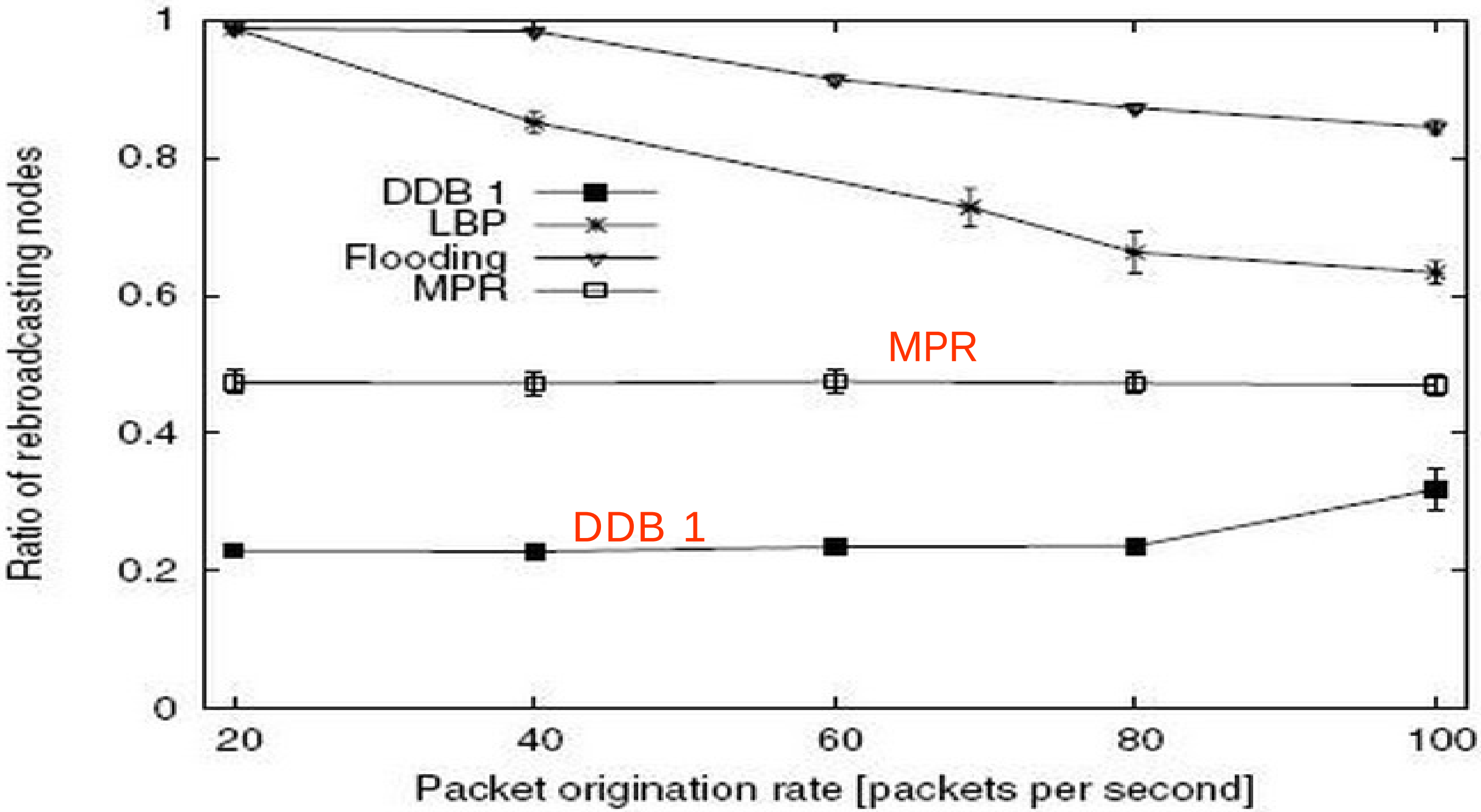
Simulation



1000 nodes

DDB outperforms other protocols.

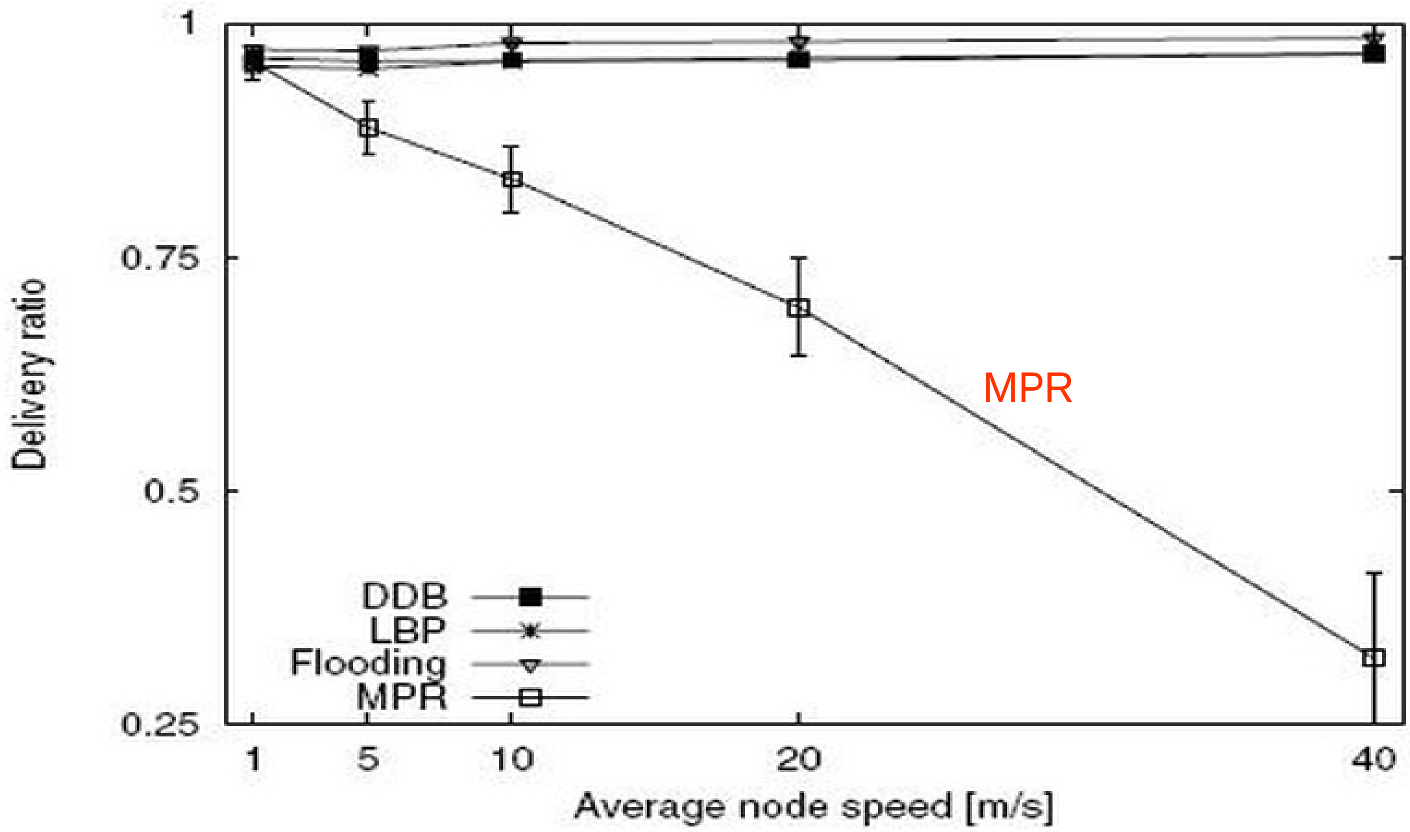
Simulation



Stateful protocols performs well.

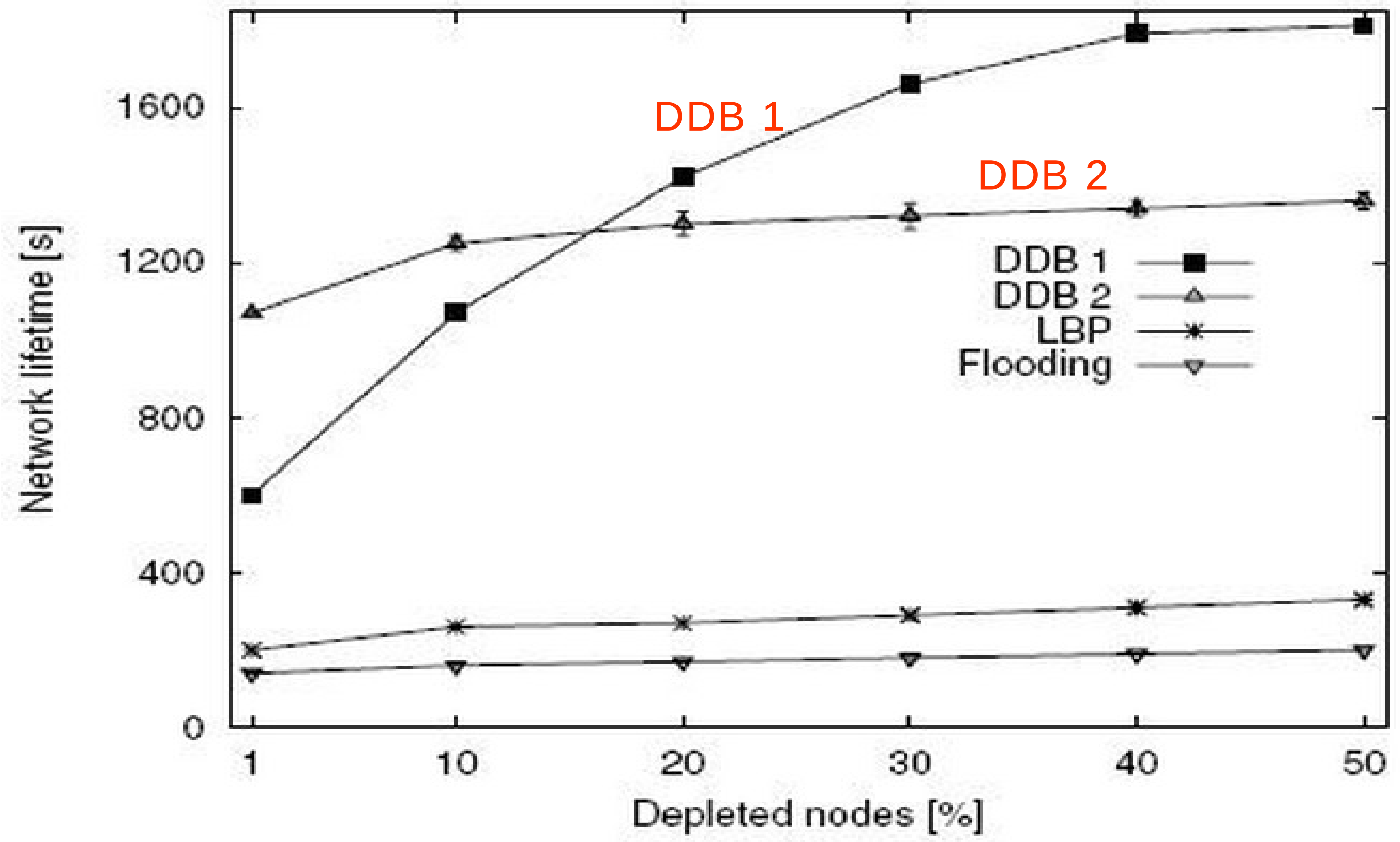
80 nodes ,each with 19 neighbors

Simulation



Stateless protocols are unaffected and the performance remains constant independent of the mobility.

Simulation



DDB 1
DDB 2
Network lifetime [s]
1600
1200
800
400
0
1
10
20
30
40
50
Depleted nodes [%]
DDB 1
DDB 2
LBP
Flooding

Conclusion

- DDB still performs well under heavy traffic and high load density, whereas other protocols' performance degrade, such as LBP.
- DDB is stateless, its performance is completely unaffected in highly dynamic networks.
- The biggest advantage of DDB is its simplicity and economical use of network resource because no control messages are transmitted.