Sprite：A Simple, Cheat-Proof, Credit-Based System for Mobile Ad-Hoc Networks

IEEE INFOCOM 2003

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Outline

- Introduction
- Approach overview
- Message-forwarding protocol
- Routing discovery and multicast
- Evaluations
- Conclusion

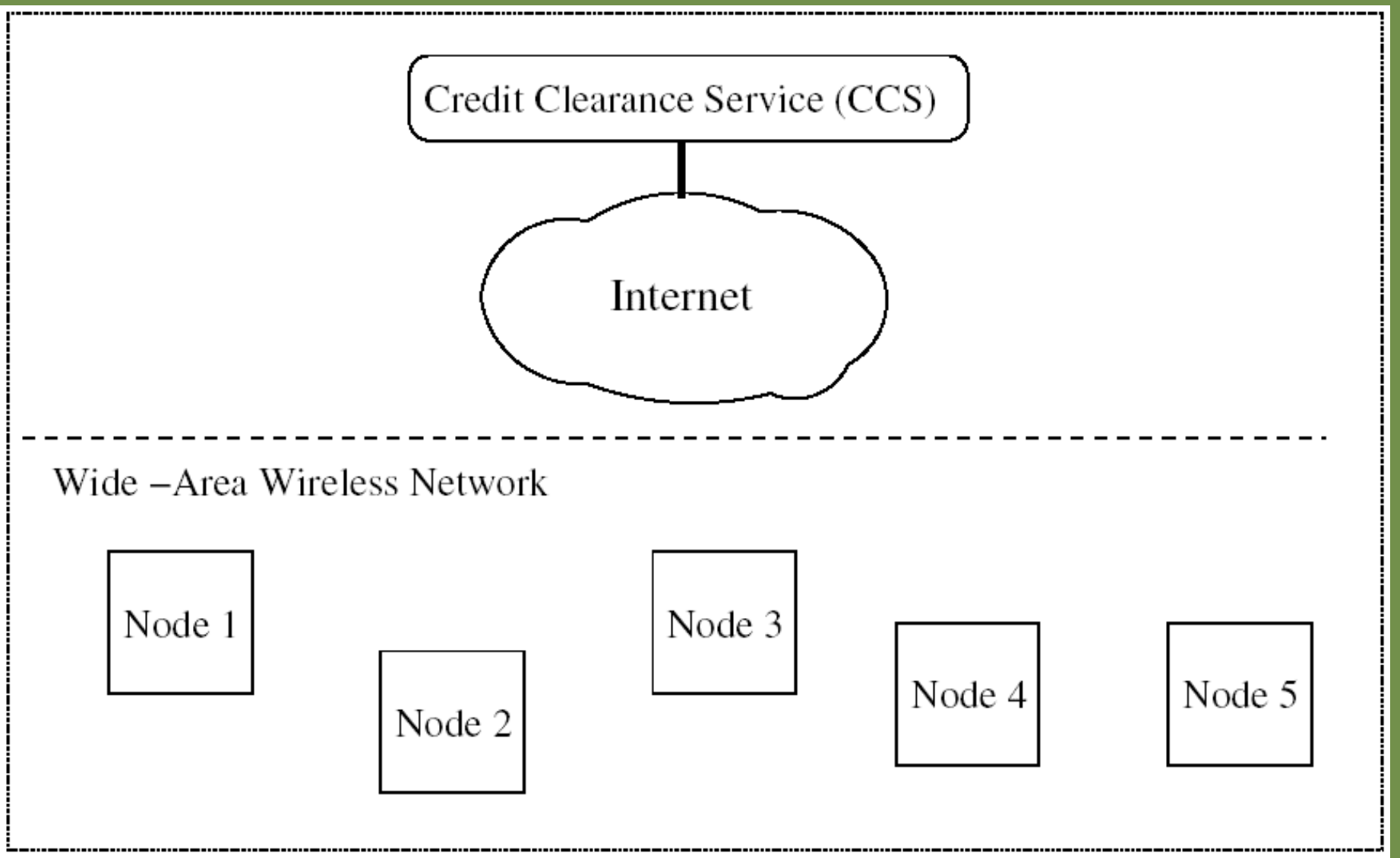
Introduction

- In order to make an ad hoc network functional, the nodes are assumed to follow a self-organizing protocol. As a result, cooperation among the nodes must be considered.
- A selfish nodes is an economically rational node whose objective is to maximize its own welfare. Since forwarding a message will incur a cost to a node, a selfish node will need incentive in order to forward others' messages.

Introduction (cont.)

- The system uses credit to provide incentive to selfish nodes.
- Determines charge and credit from a game-theoretic perspective, and motivates each node to report its actions honestly.
- Model the system as a game and prove the correctness of the system under this model.

System architecture



System architecture (cont.)

- When a node sends its own messages, the node will lose credit to the network because other nodes incur a cost to forward the messages.
- A node needs to report to the CCS which messages it has helped to forward.

Who pays whom?

- Charging only the sender will be a more robust and general approach.
- Any node who has ever tried to forward a message should be compensated, no matter successful or not.
- CCS believes that a node has forwarded a message if and only if there is a successor of that node on the path reporting a valid receipt of the message.

Objectives of the payment scheme

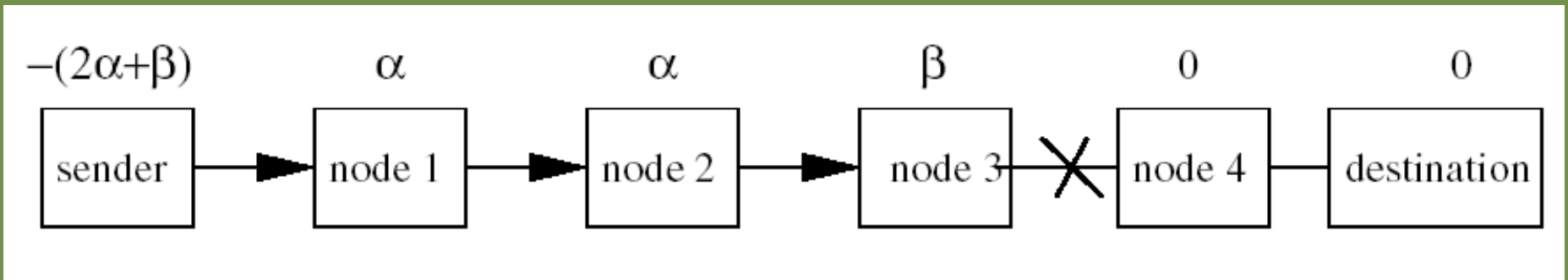
- Prevent cheating actions and to provide incentive for the nodes to cooperate.
- In order to prevent one type of cheating actions, CCS charges the sender more than it gives to the other nodes.

Cheating actions in the receipt-submission game

- After receiving a message, the node saves a receipt but does not forward the message.
- The node has received a message but does not report the receipt.
- The node does not receive a message but falsely claims that it has received the message.

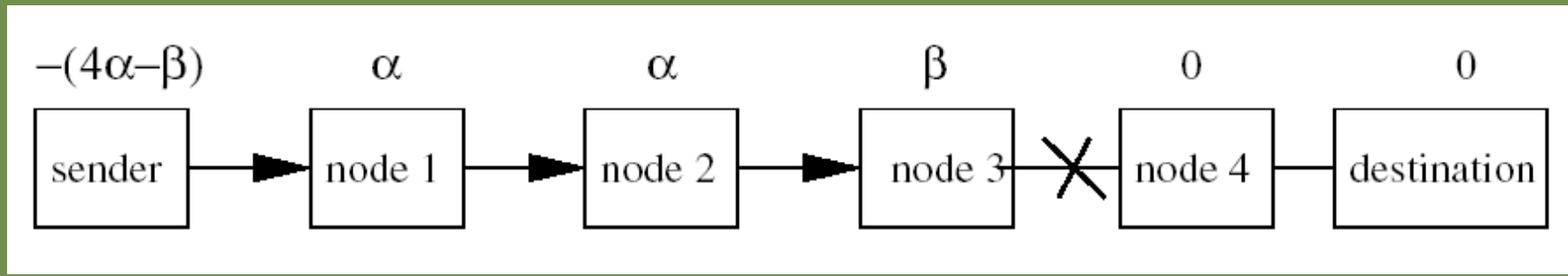
Motivating nodes to forward messages

- CCS should give more credit to a node who forwards a message than to a node who does not forward a message.
- The CCS determines the last node on the path that has ever received the message.



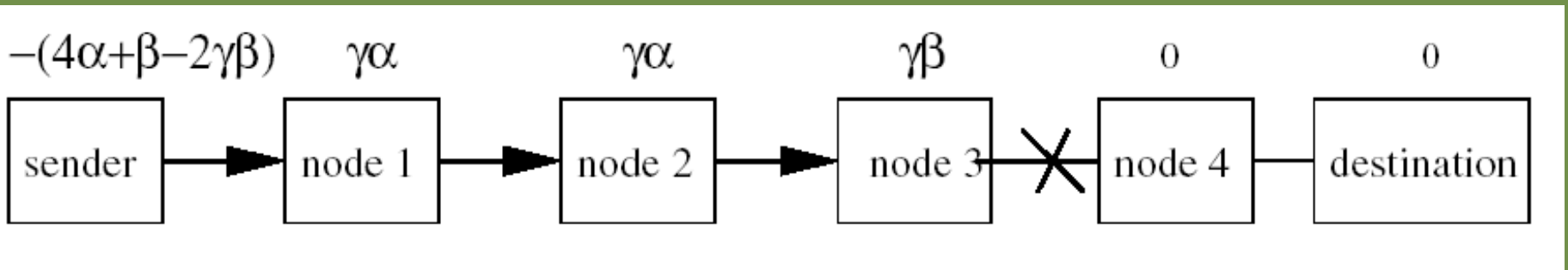
Motivating nodes to report receipts

- The last node can collude with the sender, if the last node does not report its receipt, the sender saves α while the last node loses β.
- In order to prevent this cheating action, the CCS charges the sender an extra amount of credit if the destination does not report the receipt of a message.



Preventing false receipts

- To prevent such attack depends on the destination.
- Greatly reducing the amount of credit given to the intermediate nodes, if the message is not reported to be received by the destination.



Message-forwarding protocol

- Send (m, p, $seq_0(0,d)$, s) to the next node
- n_i receives (m, p, seq, s), and checks three conditions:

  (1) n_i is on the path

  (2) the message has a sequence number greater than $seq_i(0,d)$

  (3) the signature is valid

  $p = (n_0, n_1, \ldots\ldots, n_e, \ldots, n_d)$

  n_e is the last node

Computing payments

The CCS charges C from node n_0 , and pays P_i to node n_i ,

$$C = (d-1)\alpha + \beta - (d-e)\gamma\beta$$

$$P_i = \begin{cases} \alpha & \text{if } i < e = d \\ \beta & \text{if } i = e = d \\ \gamma\alpha & \text{if } i < e < d \\ \gamma\beta & \text{if } i = e < d. \end{cases}$$

When the destination submits its receipt, the node will get its full credit of α.

A formal model and analysis

Players : $n_0, n_1, \ldots\ldots, n_e, \ldots, n_d$

Players' information : $$T_i = \begin{cases} TRUE & \text{if } 0 < i \leq e' \\ FALSE & \text{if } e' < i \leq d. \end{cases}$$

Actions : A_i = True or False

Cost of Actions : $$U_i = \begin{cases} \delta & \text{if } T_i = FALSE \text{ and } A_i = TRUE \\ 0 & \text{otherwise.} \end{cases}$$

Payment : $$P_i = \begin{cases} \alpha & \text{if } i < e = d \\ \beta & \text{if } i = e = d \\ \gamma\alpha & \text{if } i < e < d \\ \gamma\beta & \text{if } i = e < d. \end{cases}$$

Welfare : $$W_i = P_i - U_i$$

A formal model and analysis (cont.)

- Theorem 1: In the receipt-submission game, truth-telling is an optimal strategy for every node.
- Theorem 2: The receipt-submission game is collusion-resistant.
- Theorem 3: The receipt-submission game is cheat-proof.

Analysis of performance

- An intermediate node can expect a net gain of :

$$p_2\alpha + (p_1-p_2)\gamma\alpha + (1-p_1)\gamma\beta - \gamma\beta$$

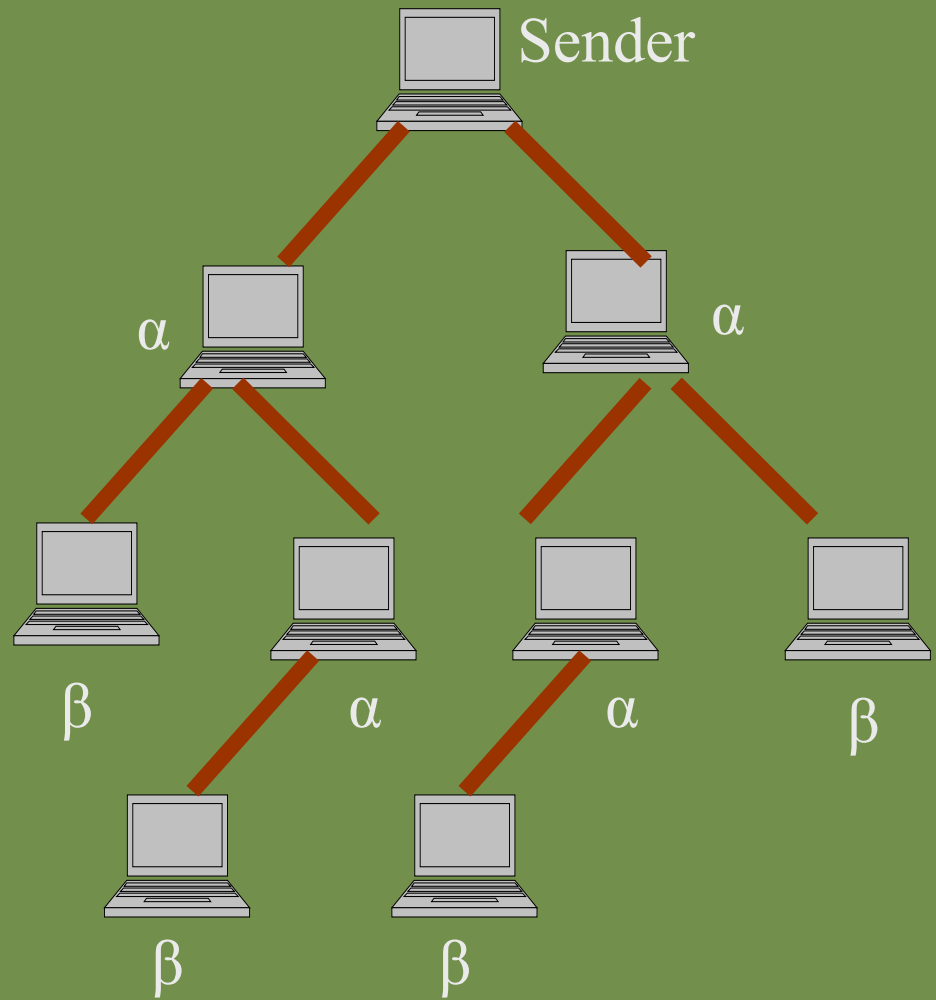
$$\equiv p_2(1-\gamma)\alpha + p_1\gamma(\alpha-\beta) \quad > 0$$

p_1 is the probability that the message arrives at the next node,

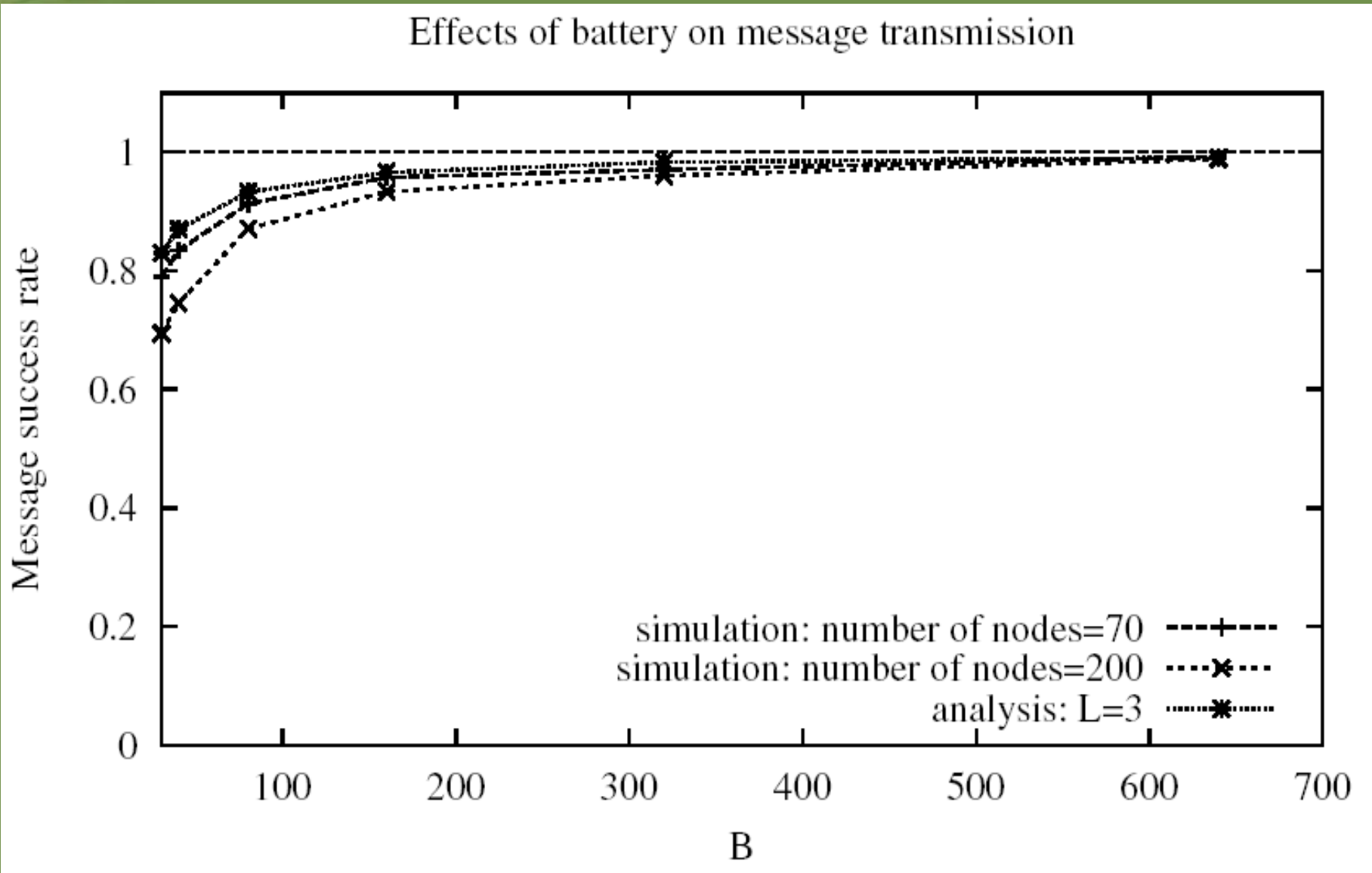
p_2 is the probability that the message arrives at the destination.

Route discovery and multicast

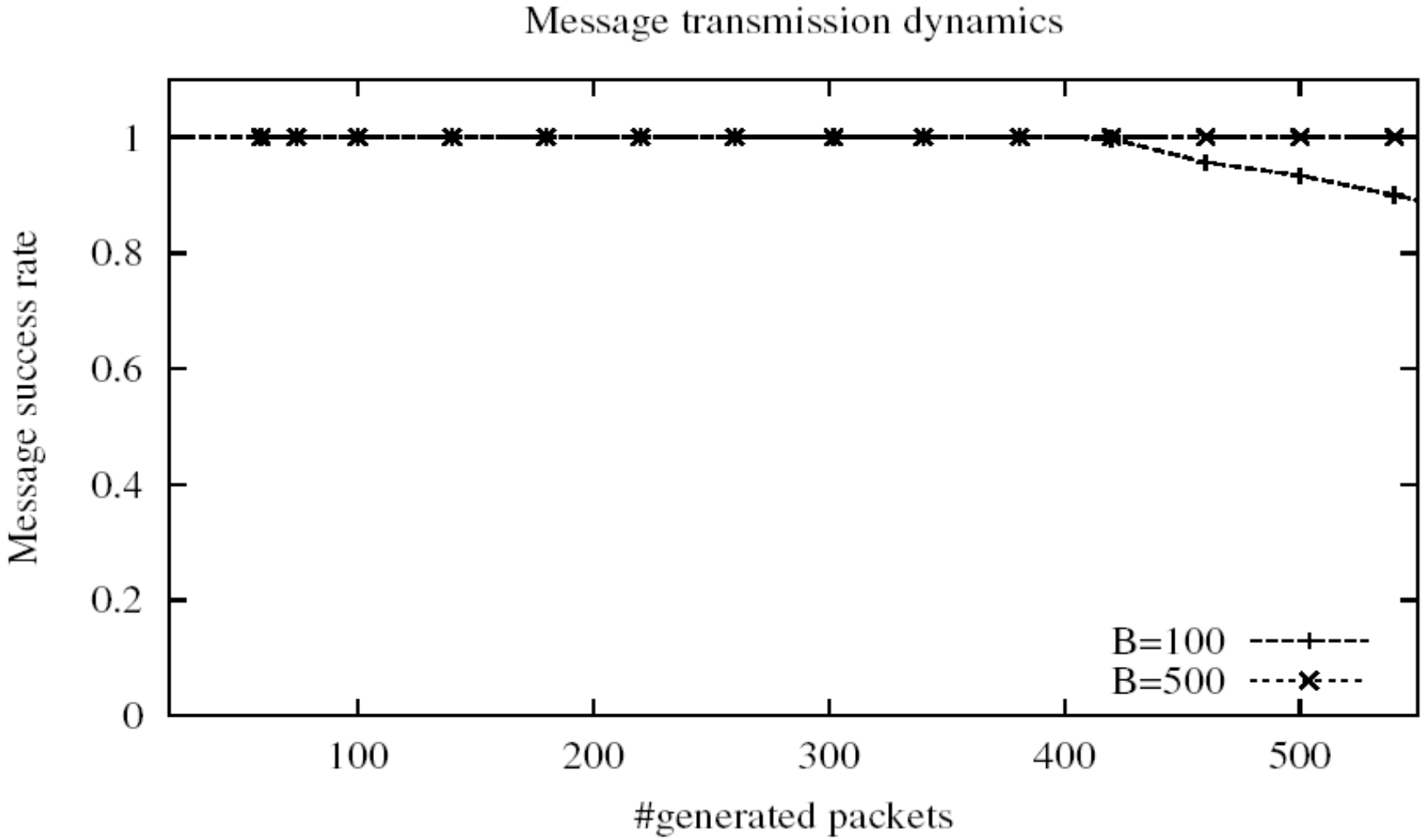
- CCS builds a tree based on the accepted ROUTE REQUEST messages.



Evaluations



Evaluations (cont.)



Conclusion

- Sprite, a system to provide incentive to mobile nodes to cooperate.
- Simulations and analysis showed that the nodes can cooperate and forward each other's messages, unless the resource of the nodes is extremely low.