Mobility Entropy and Message Routing in Community-Structured Delay Tolerant Networks

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The University of Tokyo / NICT

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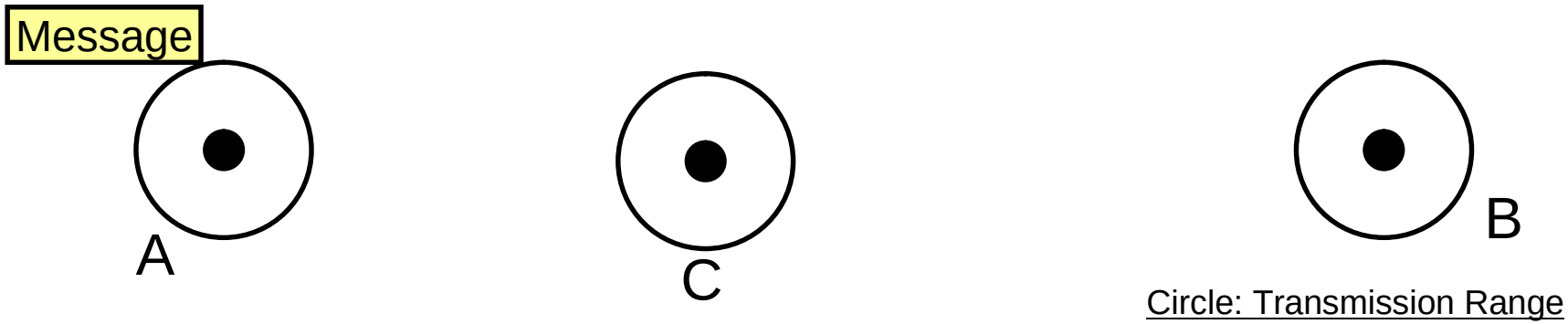
Introduction

- Message delivery in DTNs



- How can they manage routing, when 100 nodes?
- A large number of node mobility patterns

- Contribution of this work:
  - Mobility Entropy, Community-Structured Environment (CSE)
  - Potential-based Entropy Adaptive Routing (PEAR)

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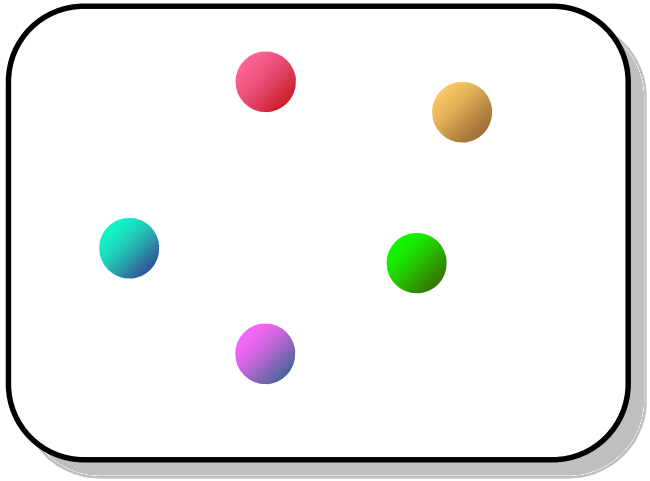
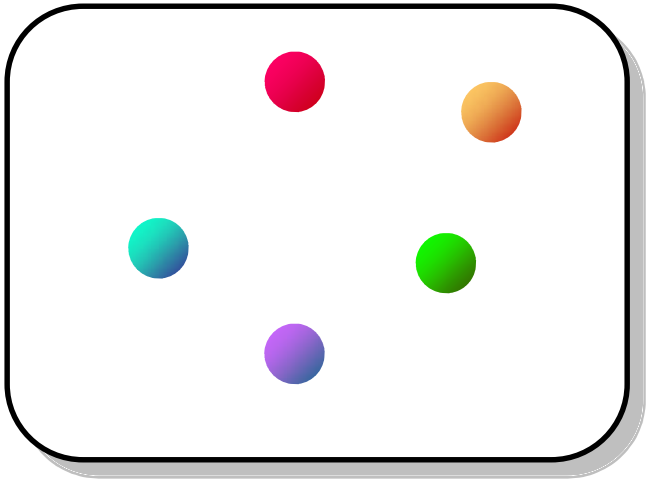
Mobility Entropy and Message Routing

- Mobility Entropy represents uniformity of node distribution.



Small Entropy

- Locally Distributed
- Contact with only a small set of nodes
- Message Delivery by Routing



Large Entropy

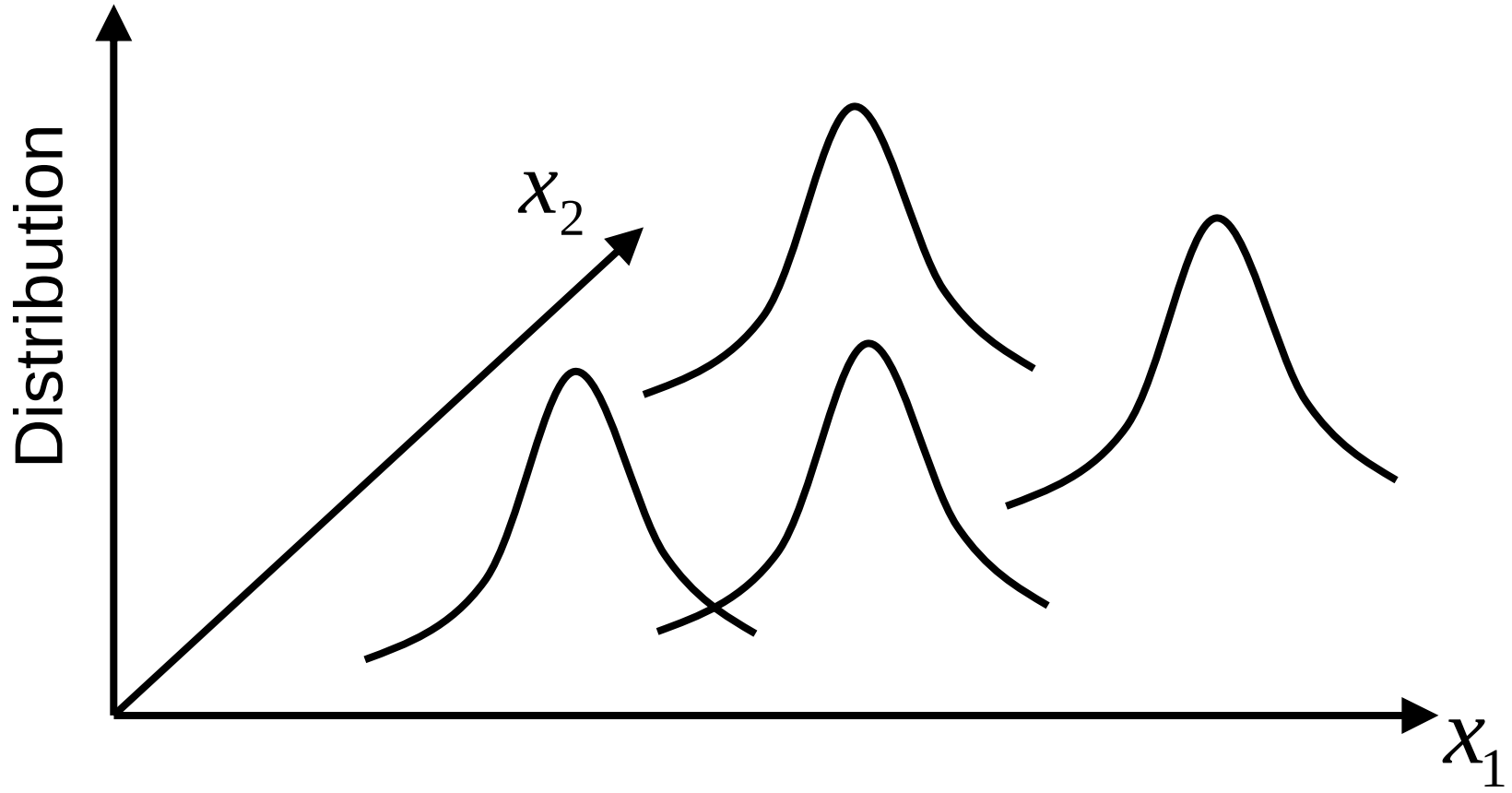
- Widely Distributed
- Contact with many nodes
- Message Delivery by Mobility

Distribution of Nodes

Small Entropy Case

- Short overlapping of node distribution

  ➔ Small Contact Areas

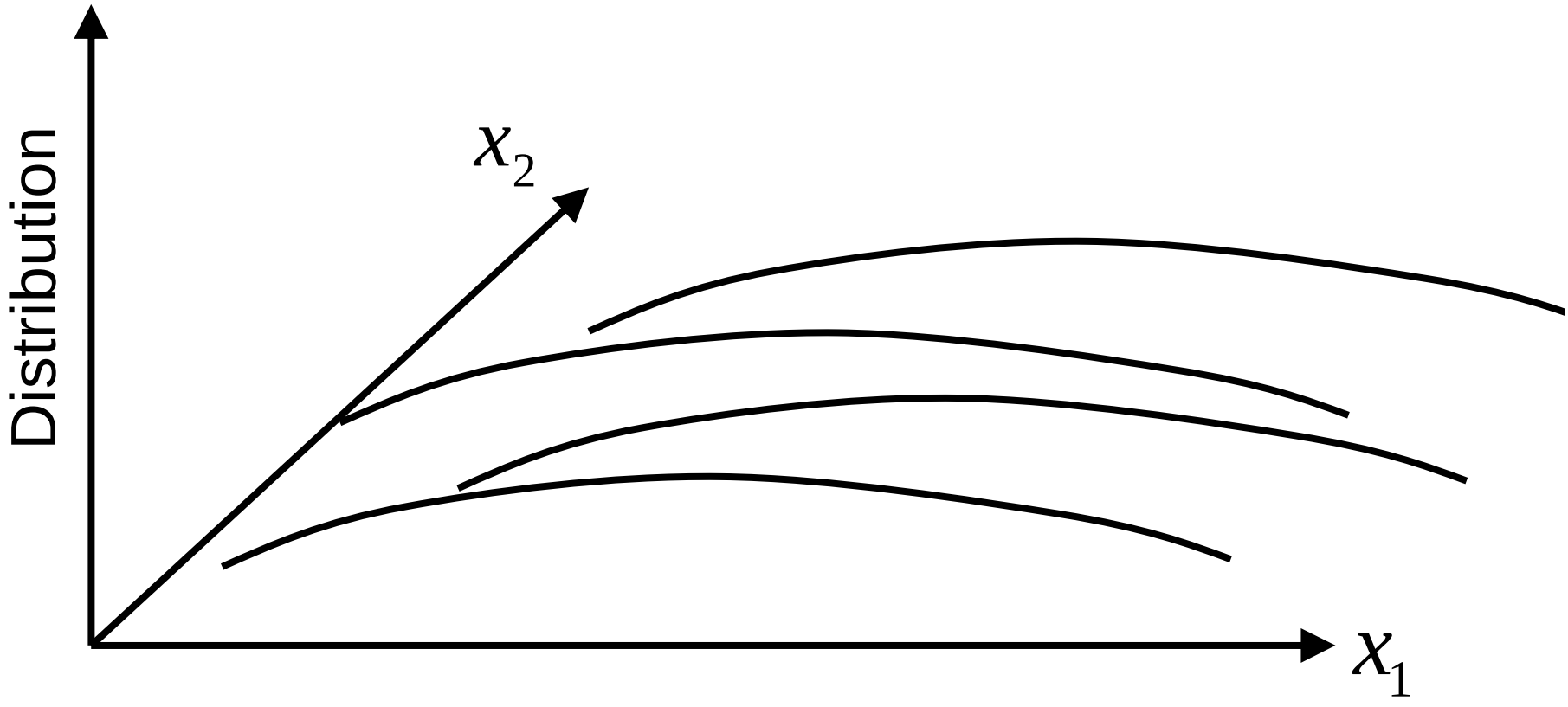


Distribution of Nodes

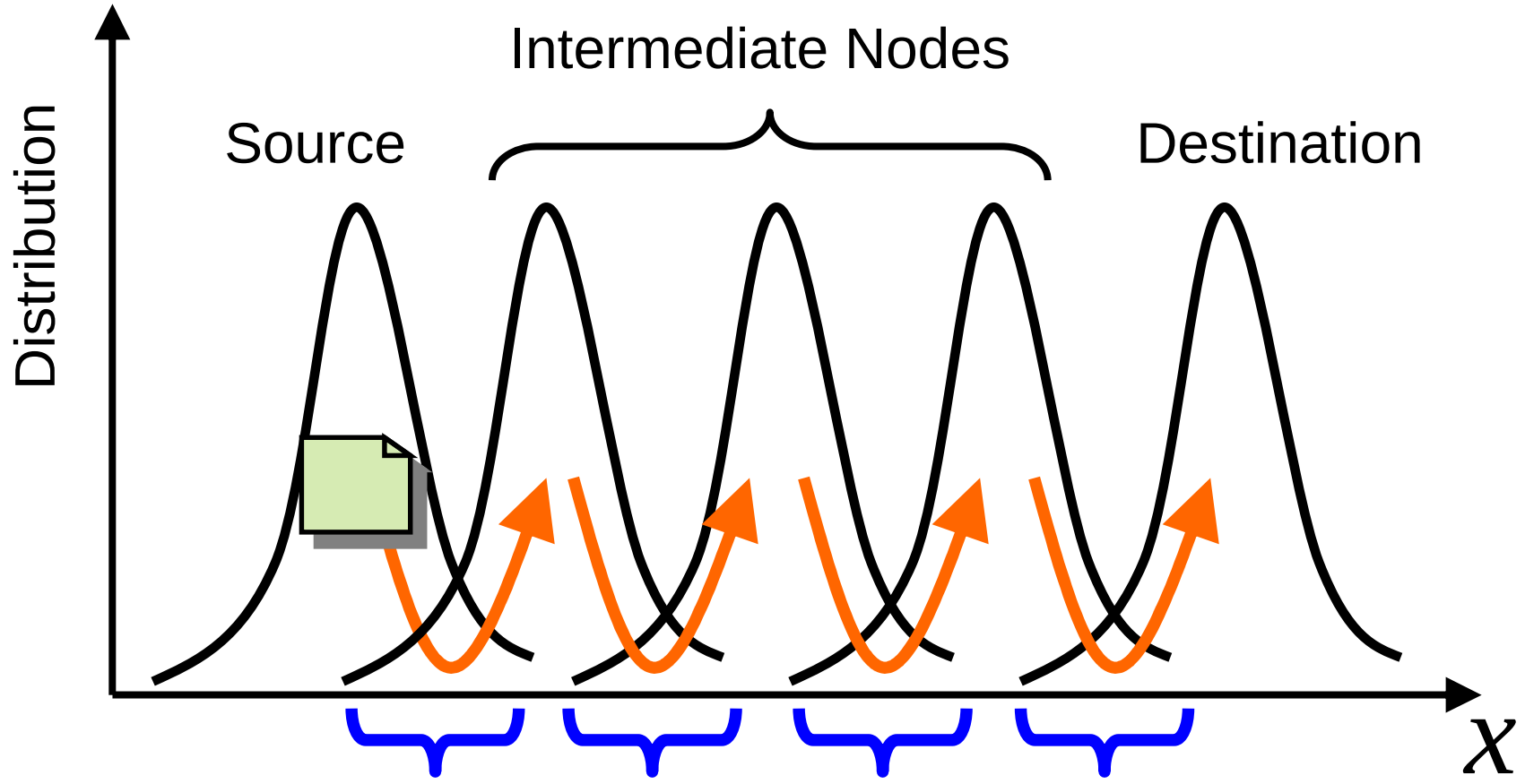
Large Entropy Case

- Long overlapping of node distribution

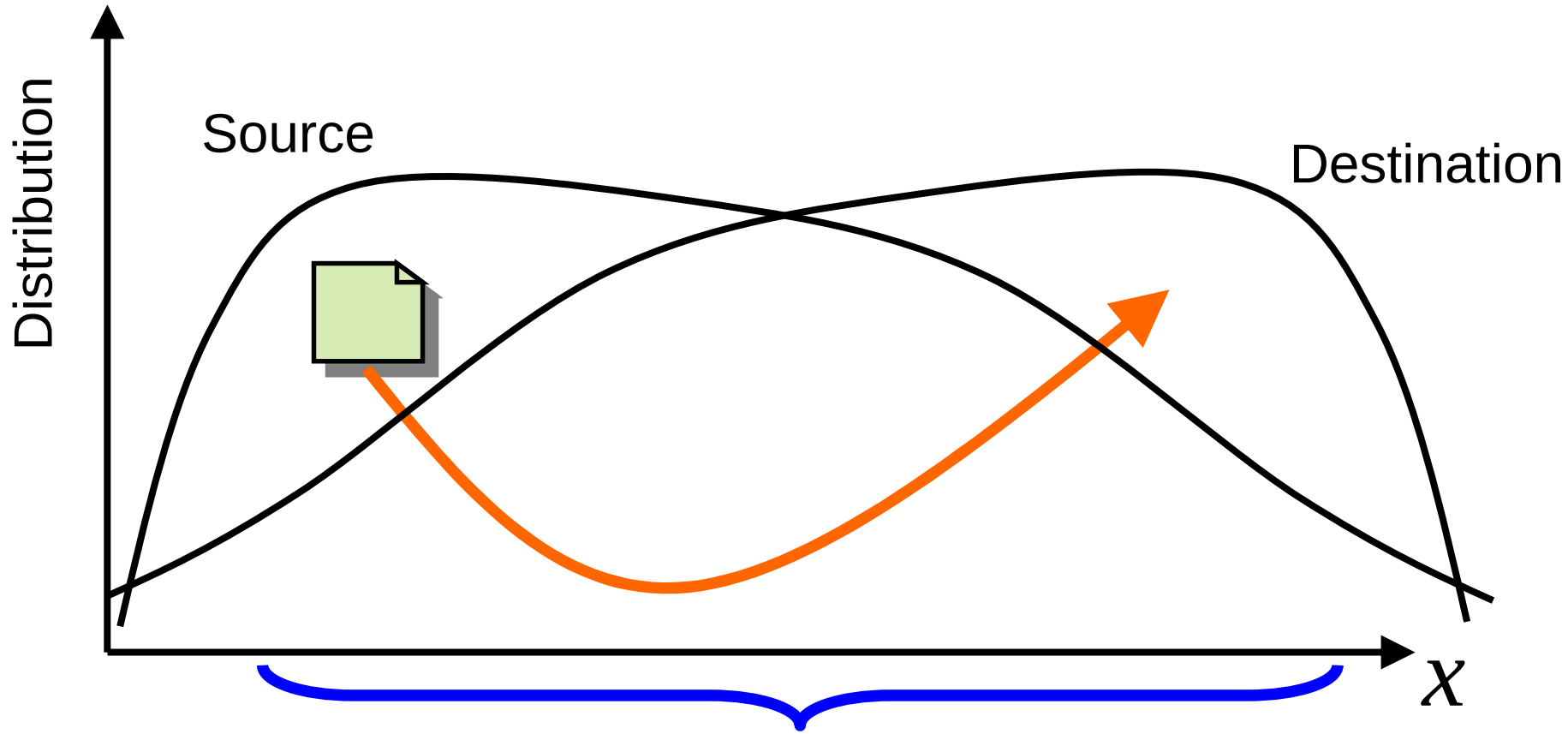
  ➔ Large Contact Areas



Message Delivery
Small Entropy Case



Message Delivery
Large Entropy Case

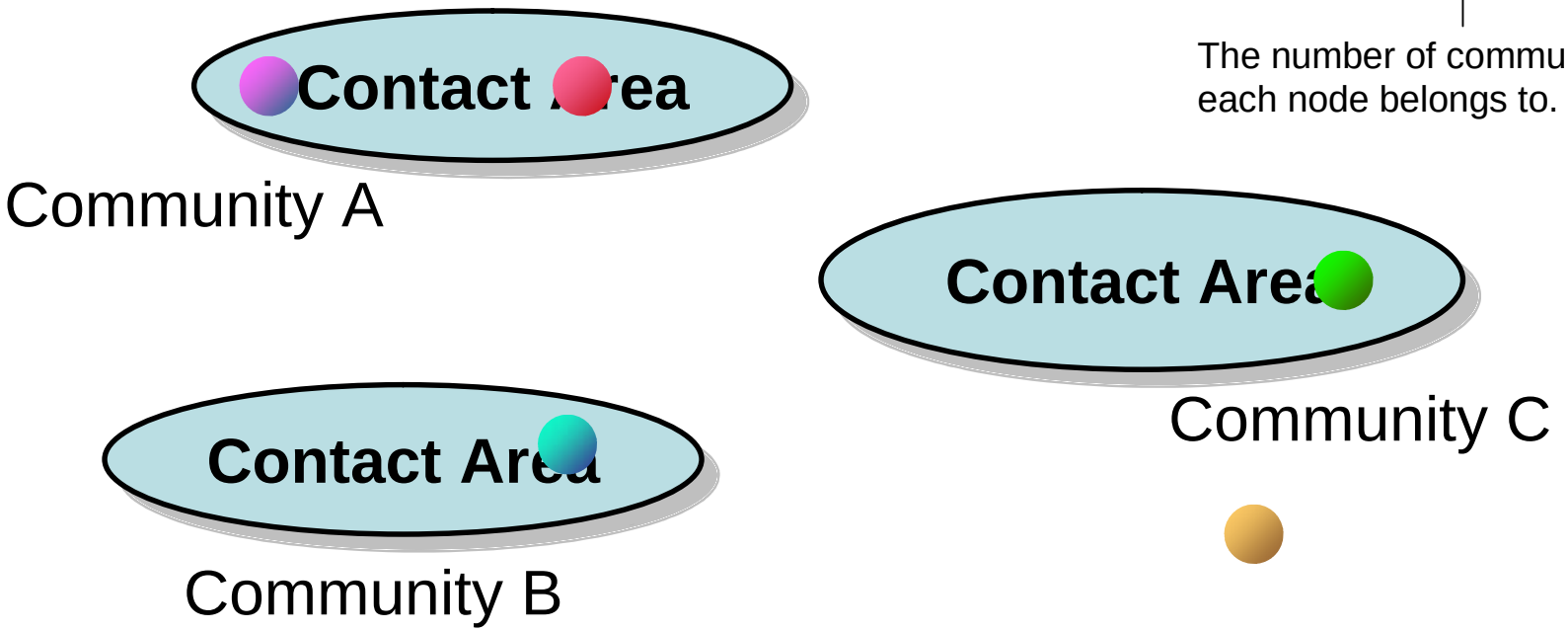


Community-Structured Environment (CSE)

1. Nodes can communicate with each other when they are in the same community.
2. Nodes move among predefined community set repeatedly.
3. Mobility entropy is given by the number of communities a node belongs to.

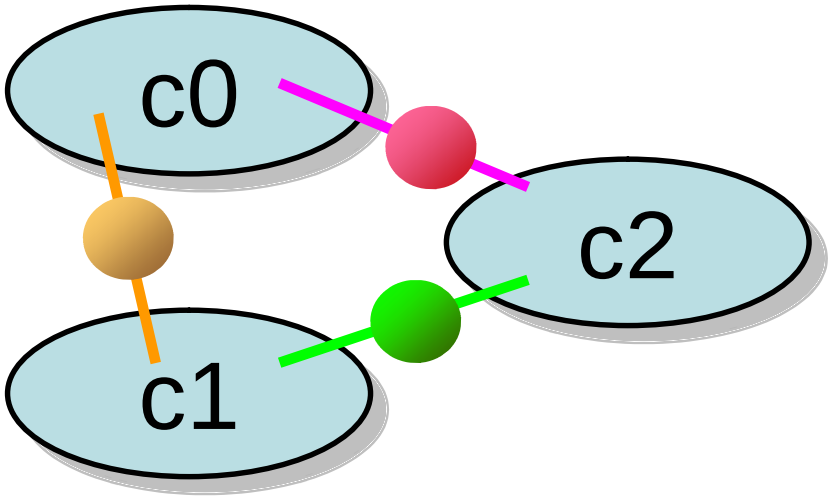
$$\text{Mobility Entropy} = \log_2 \Omega$$

Ω: The number of communities each node belongs to.



CSE and Mobility Entropy

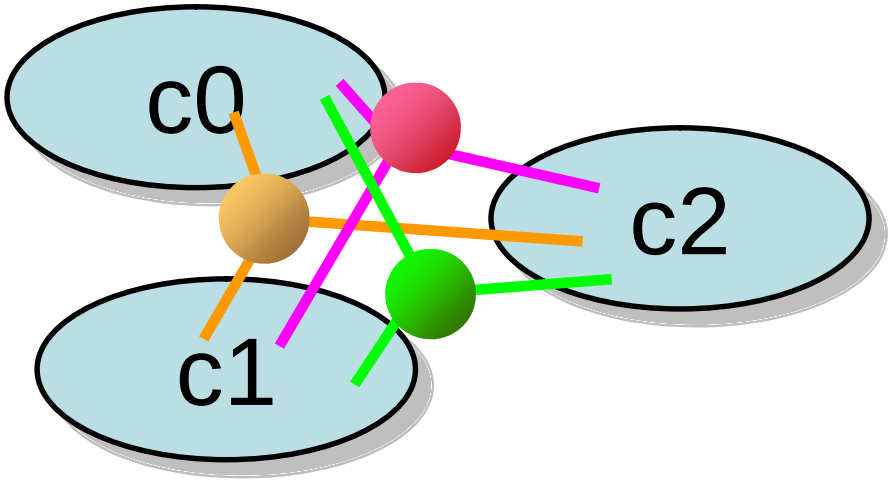
If every node belongs to 2 communities.



Mobility Entropy

$= \log_2 2$

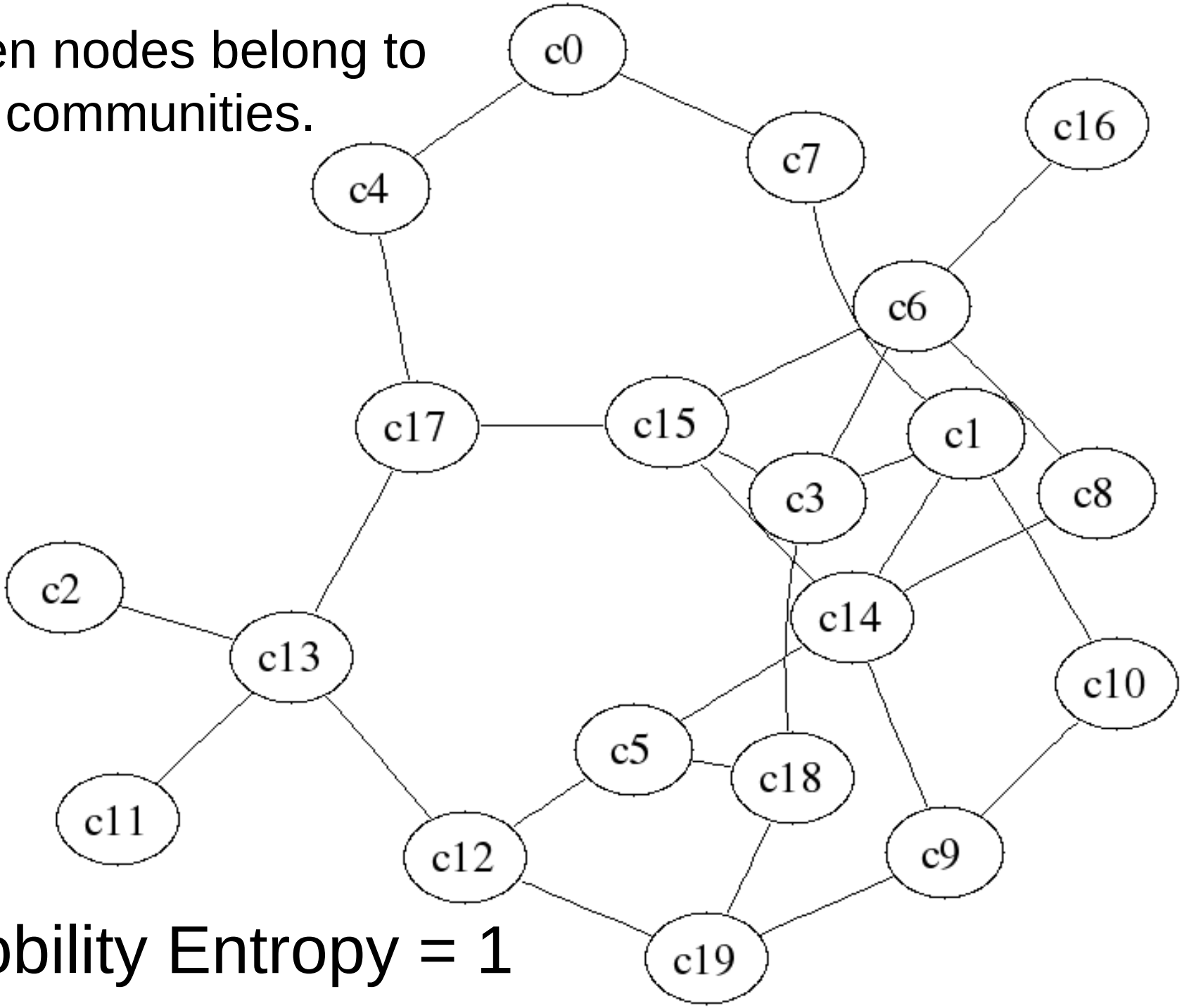
If every node belongs to 3 communities.



Mobility Entropy

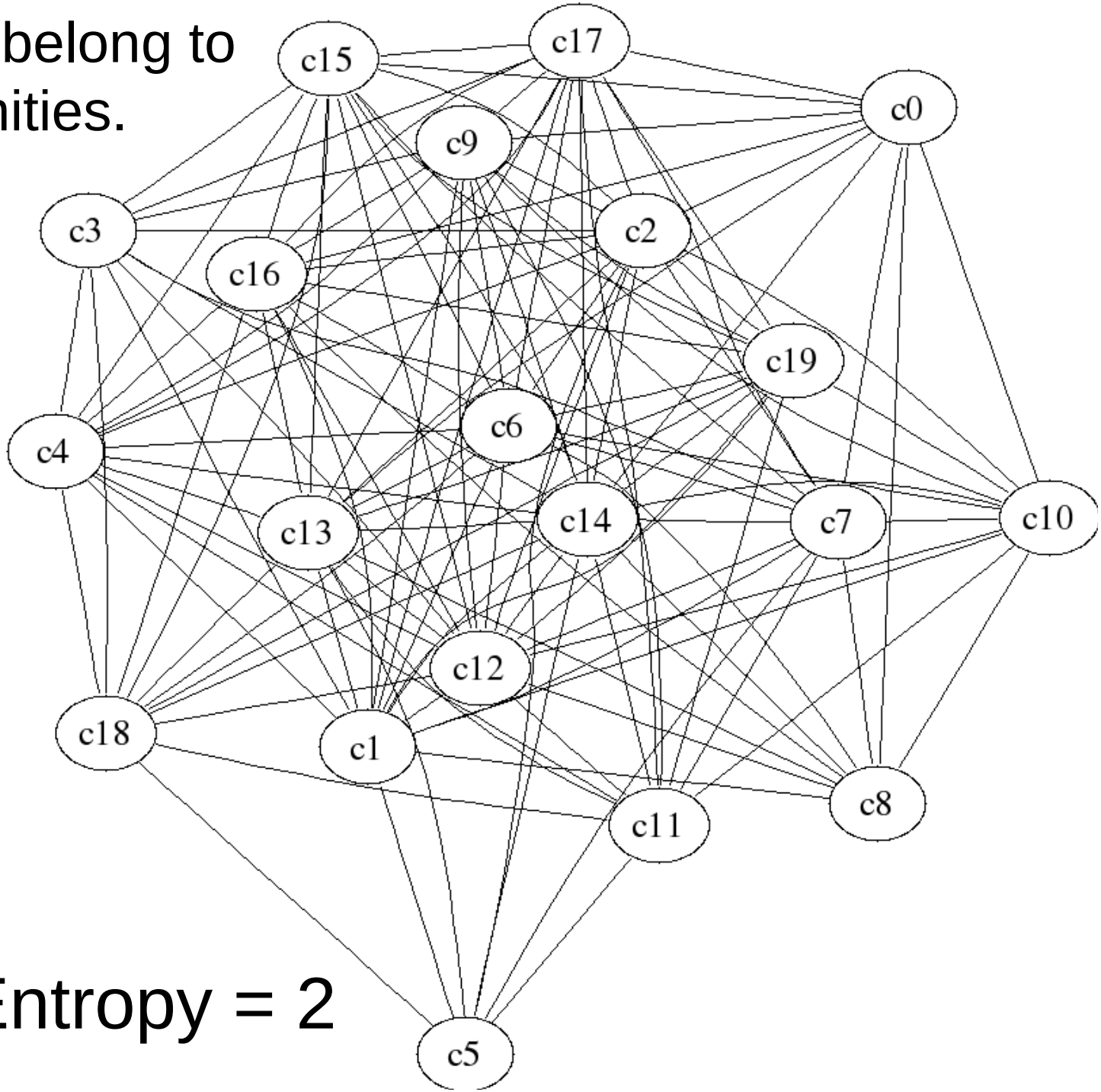
$< \log_2 3$

When nodes belong to **two** communities.



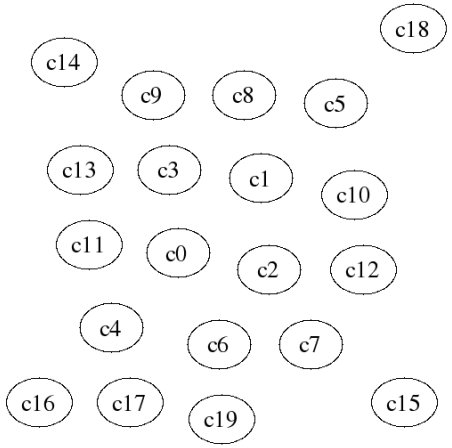
Mobility Entropy = 1

When nodes belong to **four** communities.

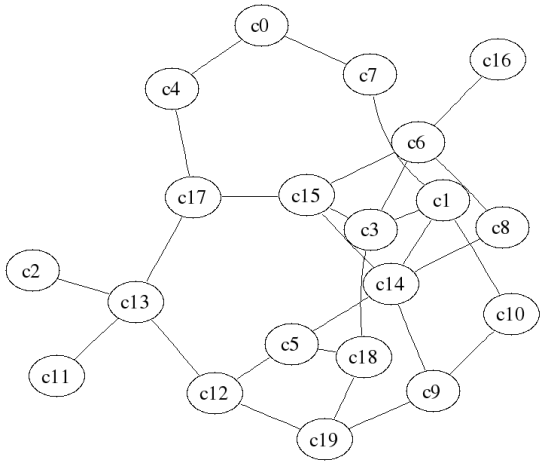


Mobility Entropy = 2

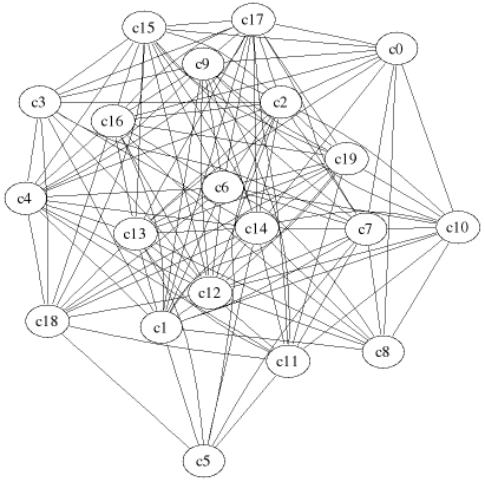
CSE and Mobility Entropy



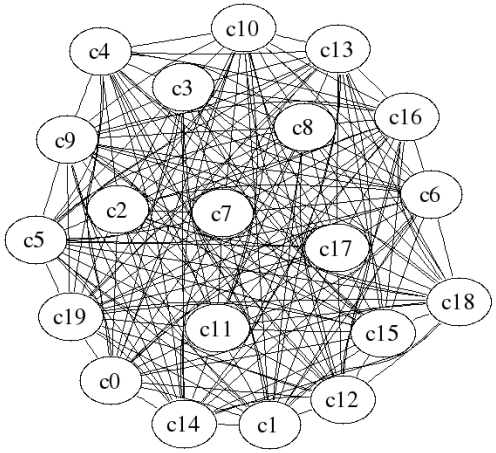
Mobility Entropy = 0



Mobility Entropy = 1



Mobility Entropy = 2



Mobility Entropy = 3

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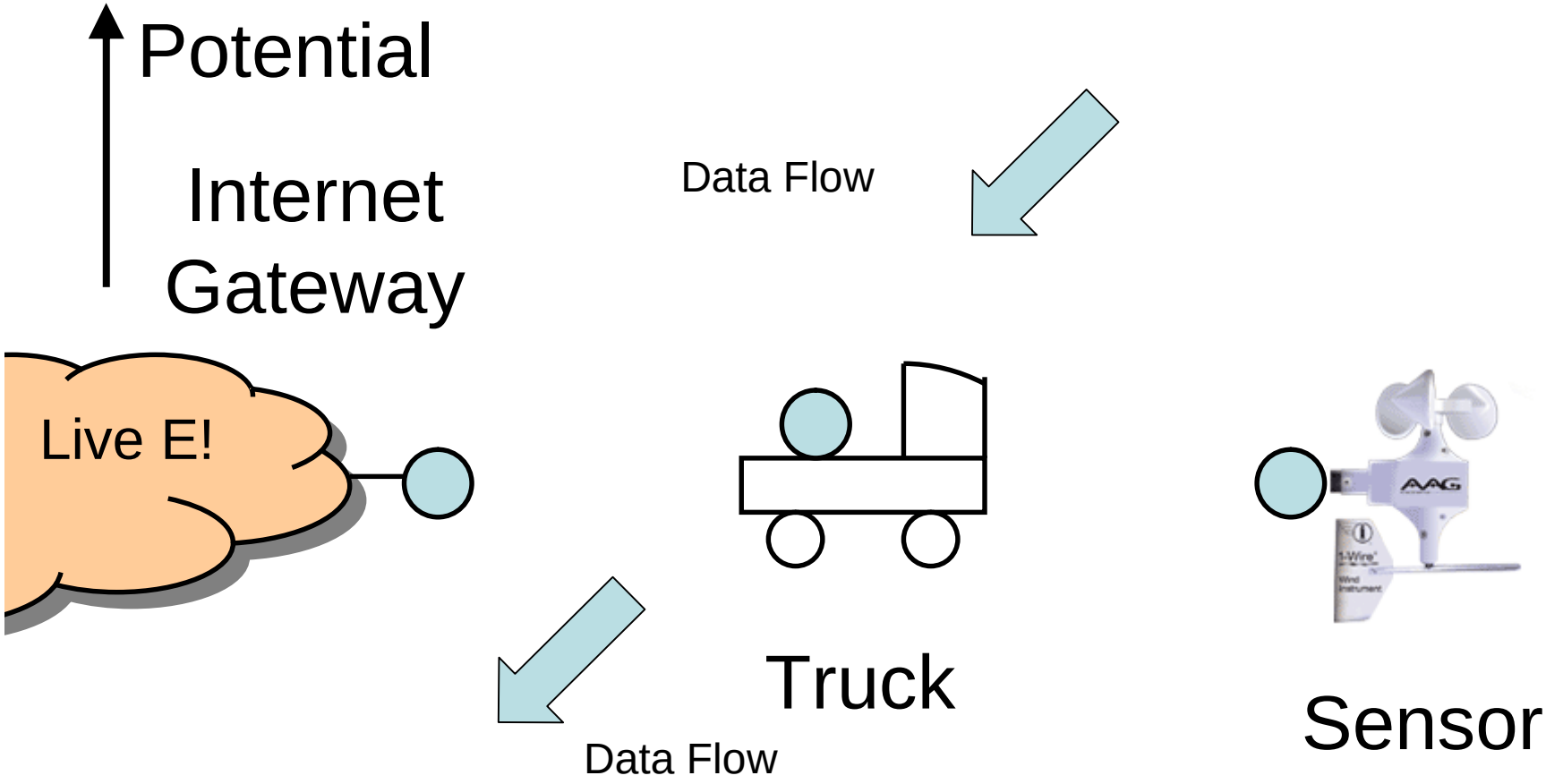
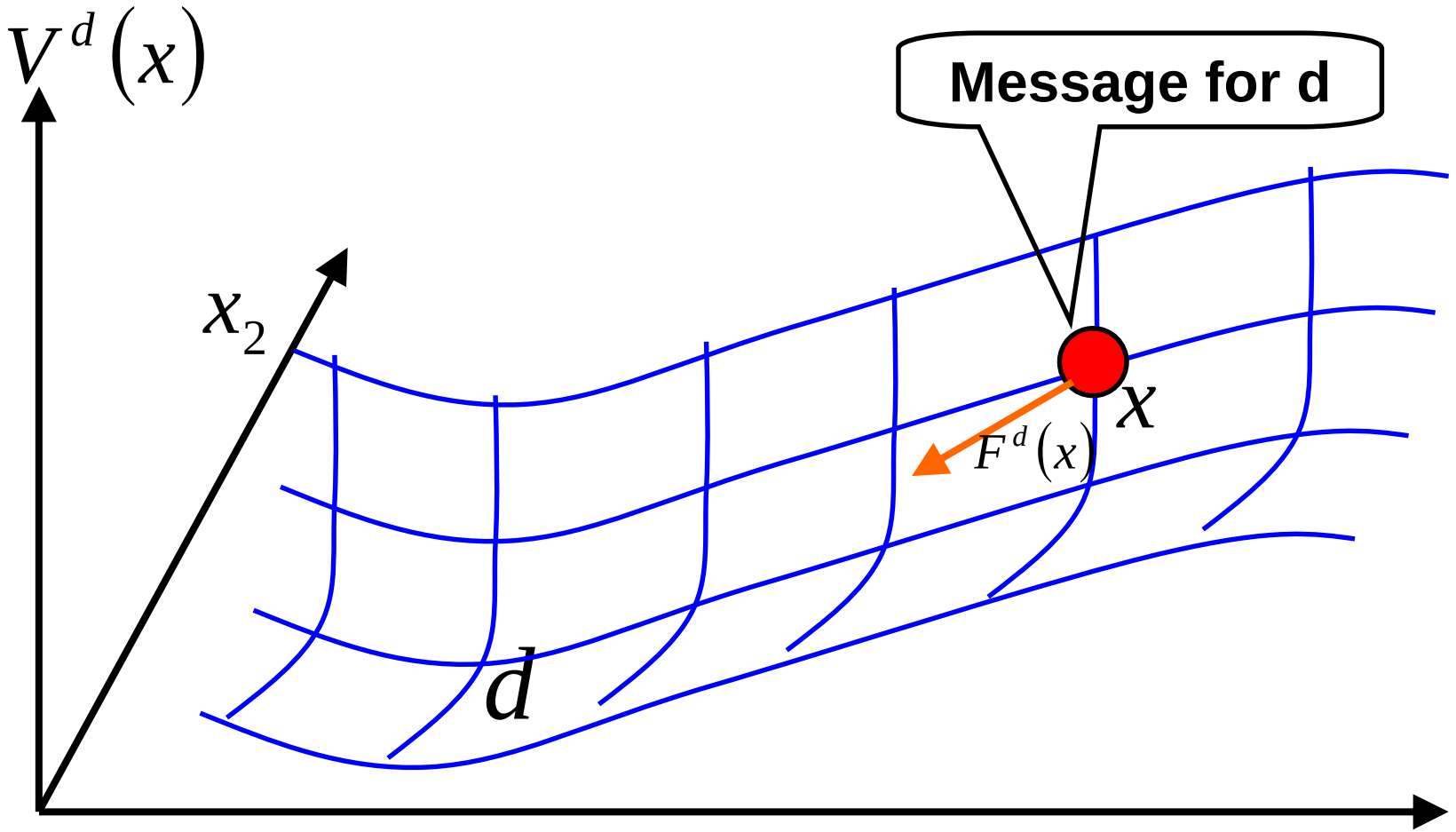
Potential-Based Routing



To deliver sensor readings to the Internet GW

: Wireless Device

Message Forwarding in Potential-Based Routing



A message goes down the curve until it reaches the destination.

How to develop potential-field in PEAR

Potential-Field Construction

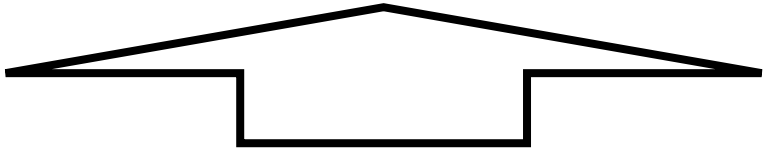
$$V^d(n,t+1) = V^d(n,t) + D \min_{k \in nbr(n)} \left\{ V^d(k,t) - V^d(n,t) \right\} + \rho$$

Boundary Condition

$$\forall n \in N, \left(V^d(n,0) = 0 \right)$$

$$\forall t, \left(V^d(d,t) = 0 \right)$$

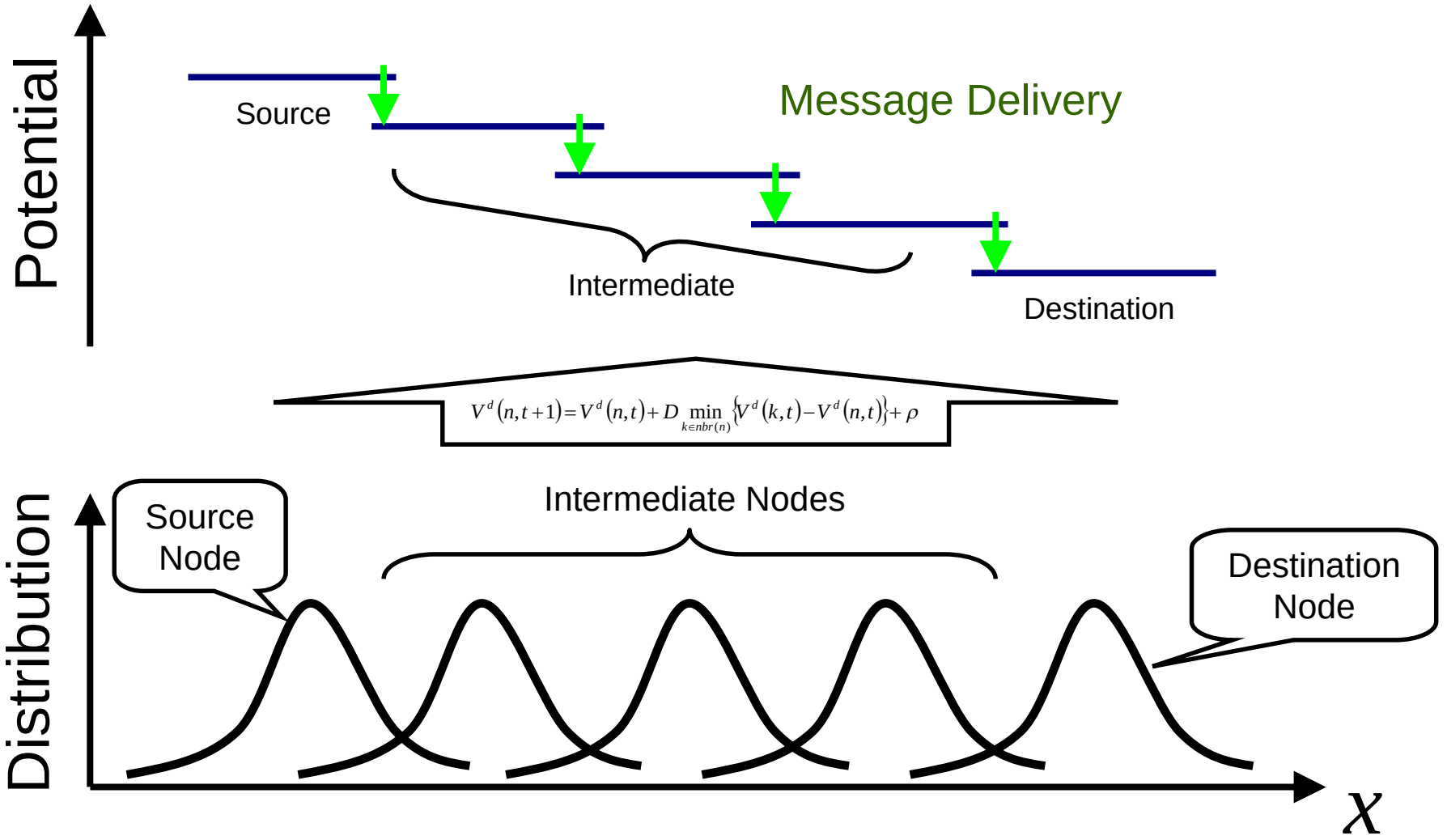
$$D(>0), \rho(>0) \quad const.$$



Diffusion Equation

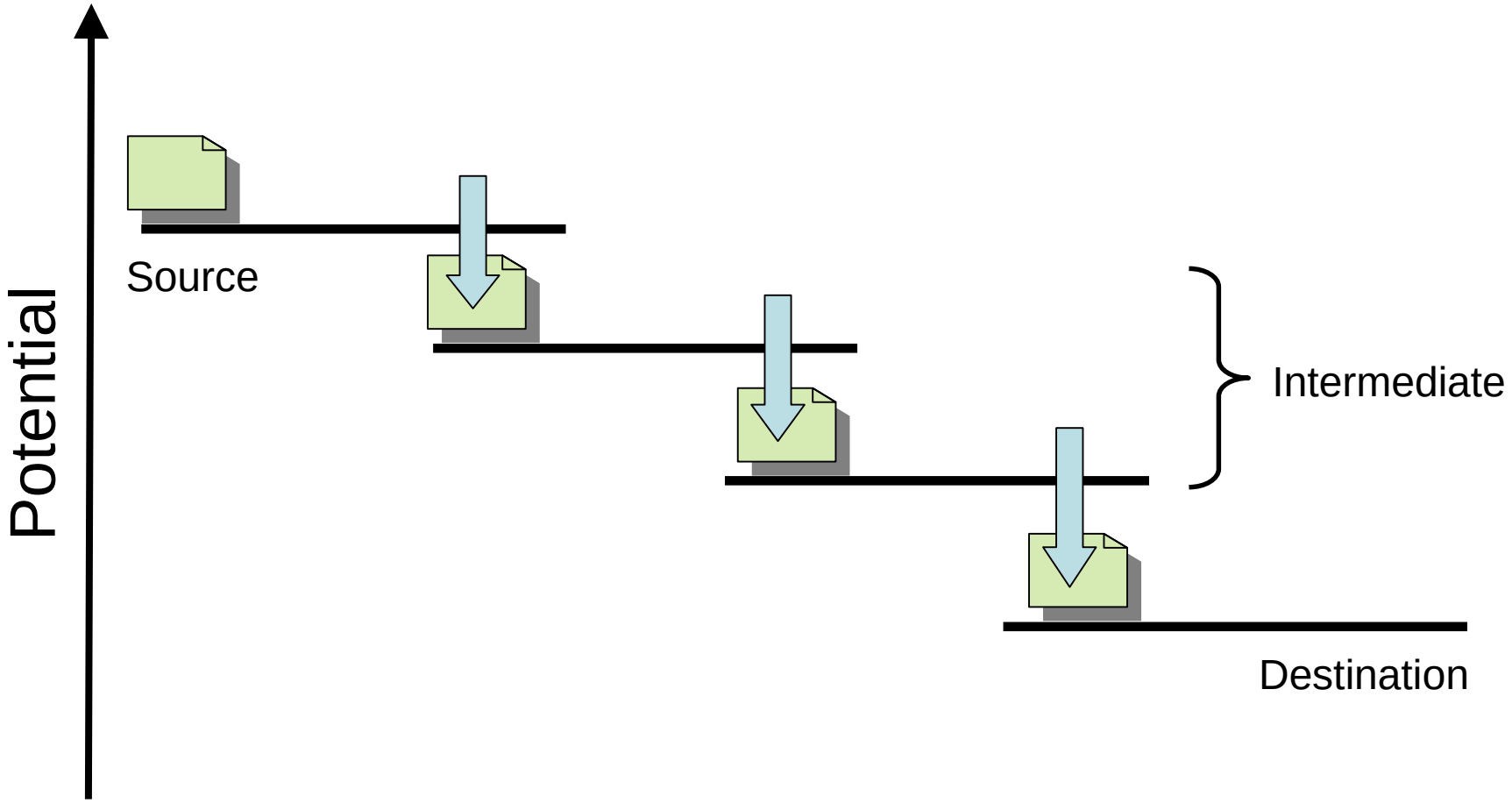
$$V^d(n,t+1) = V^d(n,t) + D \sum_{k \in nbr(n)} \left\{ V^d(k,t) - V^d(n,t) \right\}$$

Potential and Message Routing
Small Entropy Case



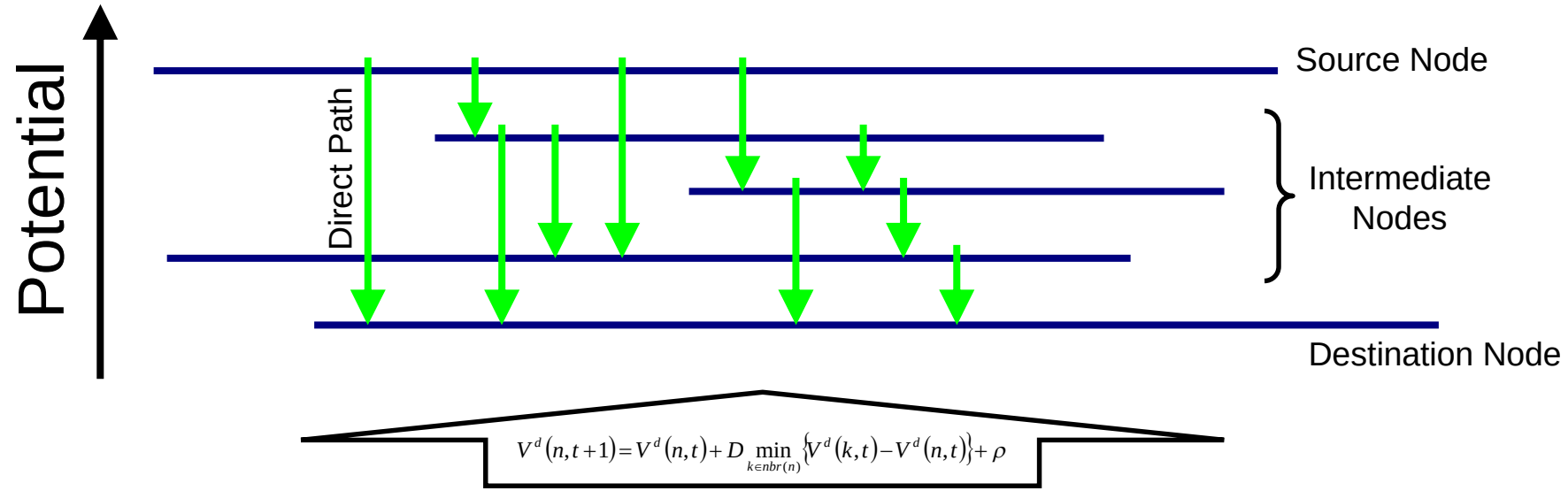
Message Delivery by PEAR

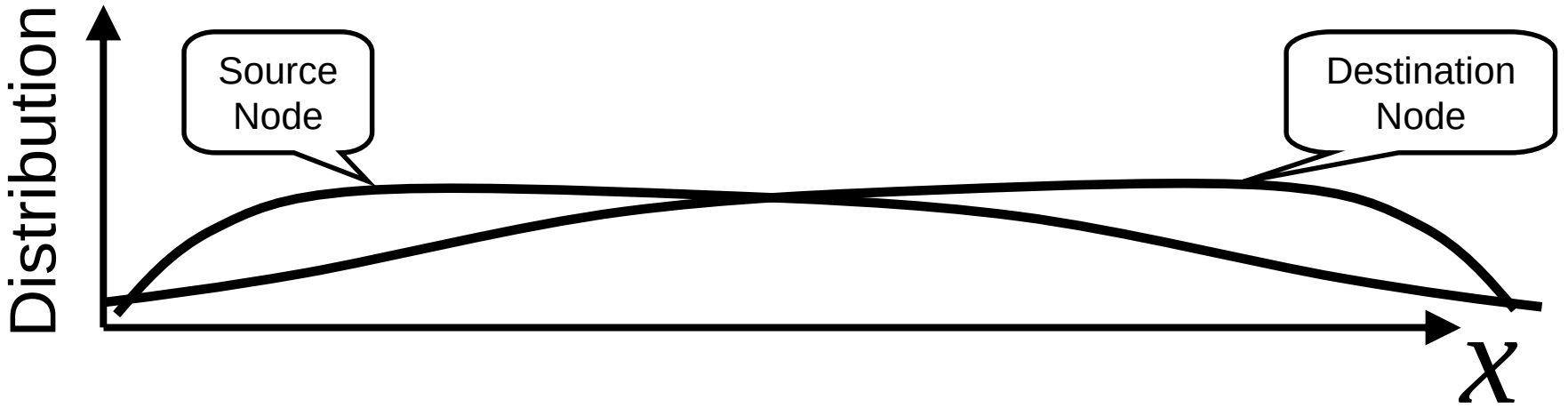
Small Entropy Case



Potential and Message Routing

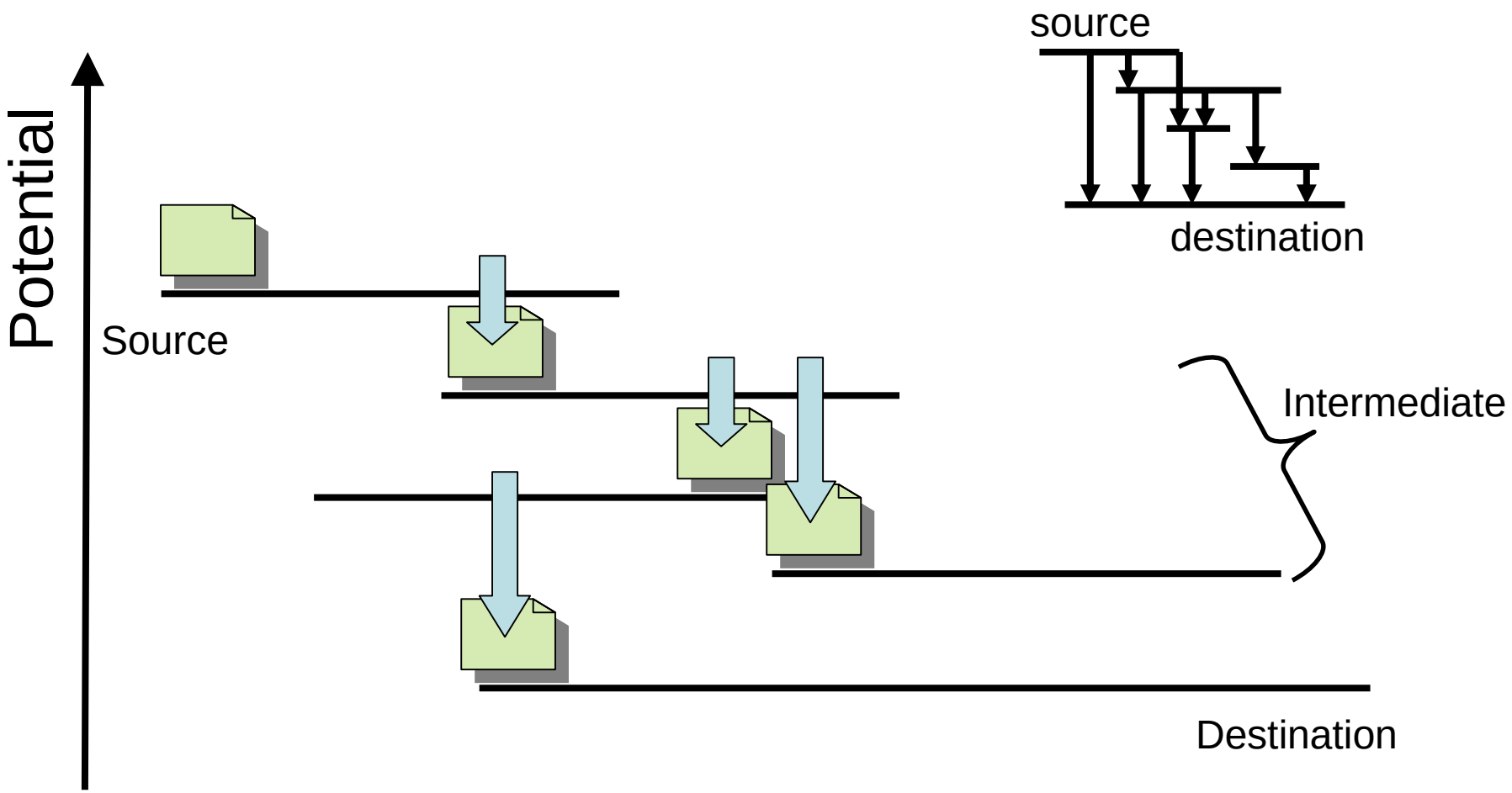
Large Entropy Case





Message Delivery by PEAR

Large Entropy Case



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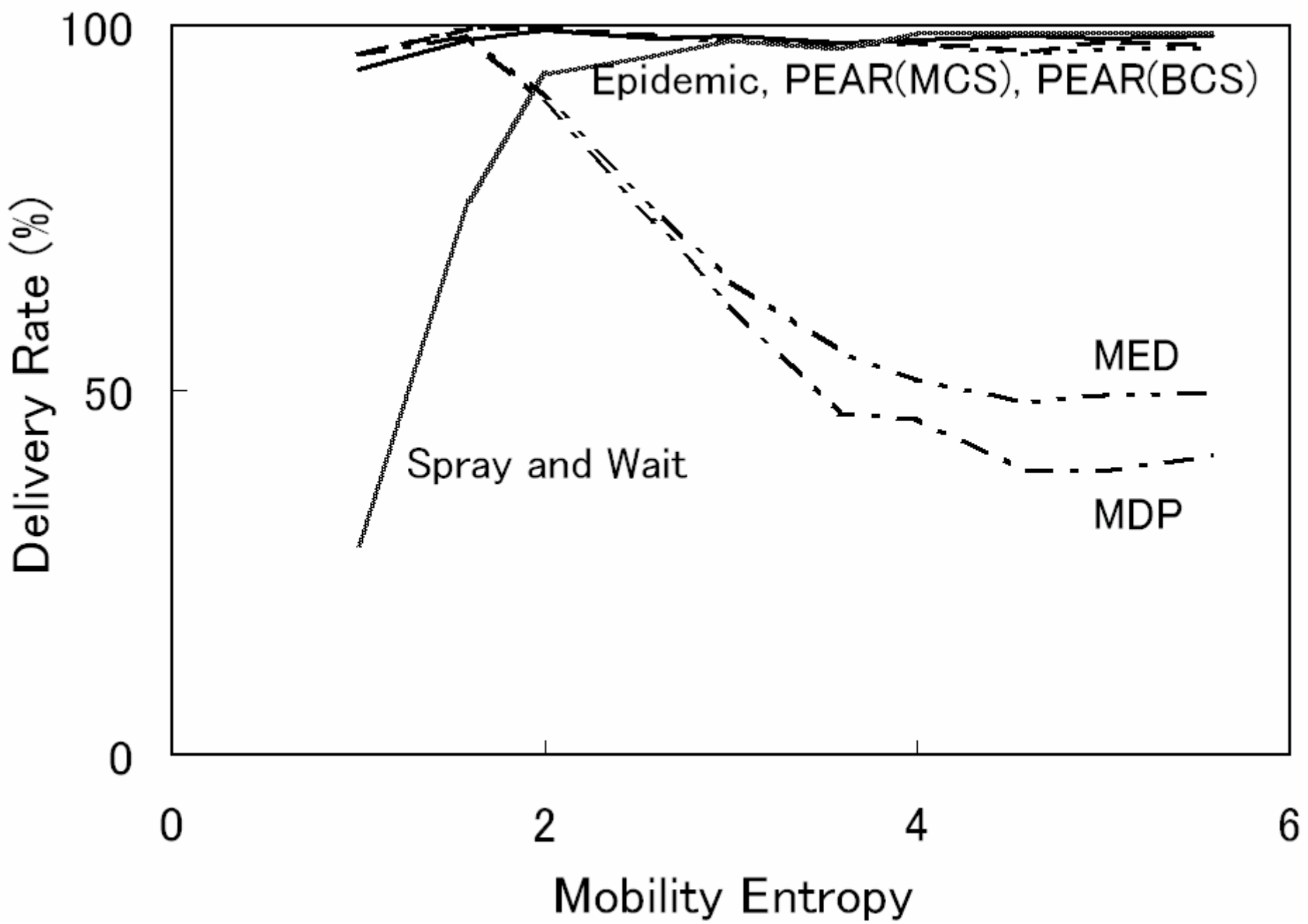
Evaluation

- Evaluation of Delivery Rate and Total Transmissions on Mobility Entropy

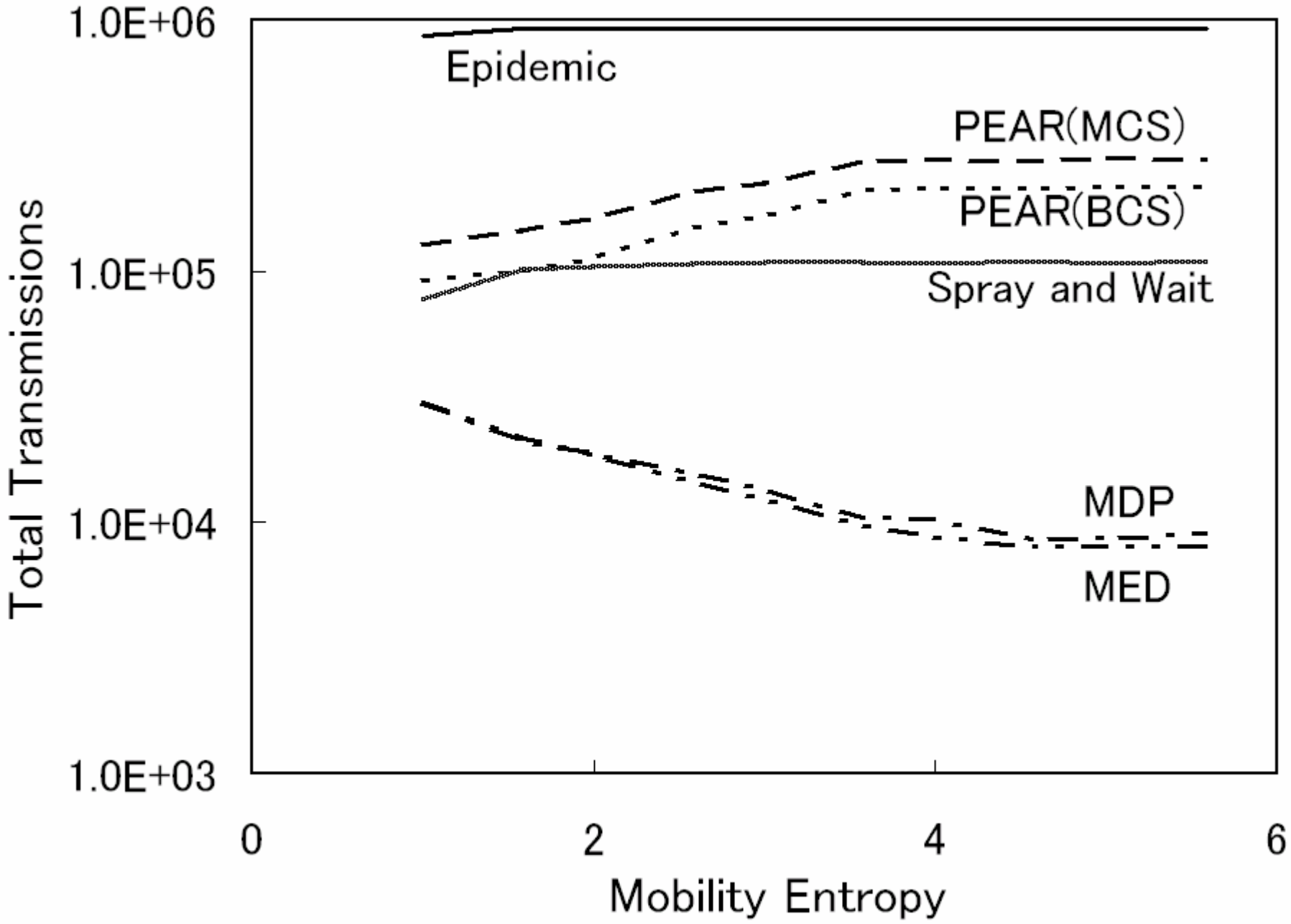
- PEAR in comparison with:
  - Epidemic Routing
  - Spray and Wait
  - Link-State Routing
    - Minimum Expected Delay (MED)
    - Maximum Delivery Probability (MDP)

- Java-based CSE simulator
  - Ignored: link-bandwidth, radio properties, message-partitioning, storage size, etc...

Delivery Rate



Total Message Transmissions



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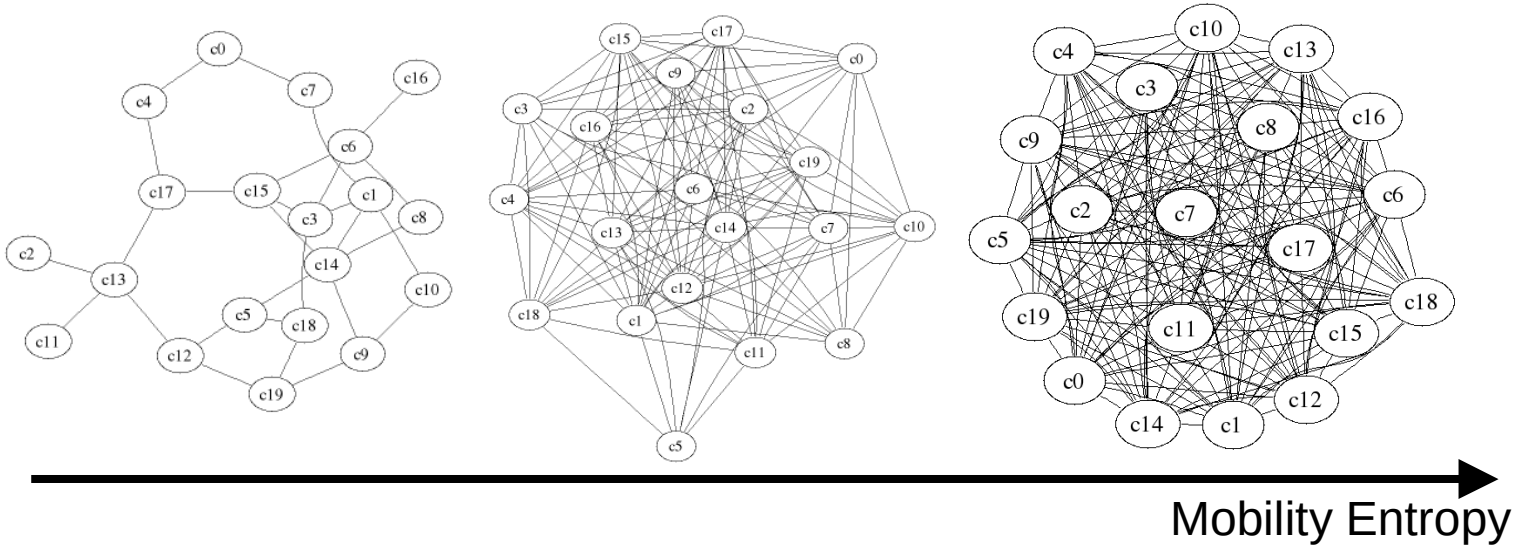
Conclusion

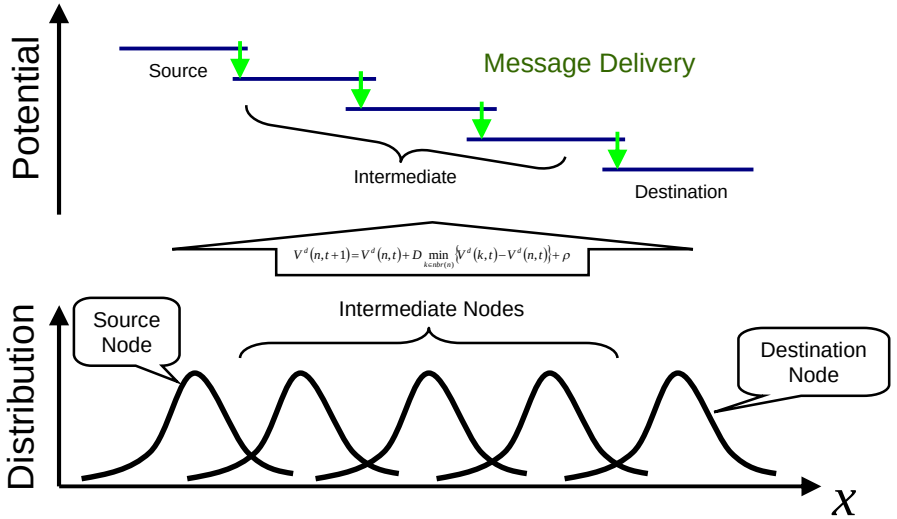
- Mobility Entropy
  - The new metrics that describes mobile environment.
    - Small entropy: Nodes are locally distributed.
    - Large entropy: Nodes are widely distributed.
  - Community-Structured Environment

- PEAR achieved high delivery probability
  - Small entropy: hop-by-hop routing
  - Large entropy: multiplying messages

Thank you..



Small Entropy Case



Large Entropy Case