Dominating Set Based and Power-aware Hierarchical Epidemics in P2P Systems

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Introduction

- Epidemic (gossip-based) principles: highly popular in large scale distributed systems
  - Reliable multicast
  - Aggregation
  - P2P Streaming
  - Topology construction
- Peer-to-Peer Energy Consumption
  - Among the total internet traffic, 70% is accounted as peer-to-peer
  - Need to reduce cost and overhead of P2P principles
- Significance of energy efficient epidemic protocols
  - Lack of studies on energy consumption and modeling of epidemic protocols

Background

Types of Epidemic Algorithms

- **Basic**
  - Requires global knowledge
  - Uniform gossiping
  - Not practical
- **Neighborhood**
  - Uses local knowledge
  - Gossiping with neighbors
  - Redundant communication

Flat → No structure is used; Redundant communication

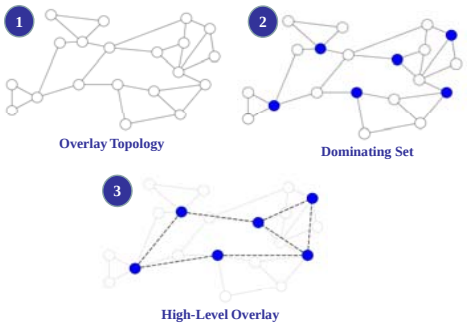
- **Hierarchical**
  - Makes use of a structure among peers
  - Aims to reduce communication overhead
  - Possibility of active/passive peers

Objective

- Considering power awareness features of flat and hierarchical epidemics in P2P systems
- A novel dominating-set based and power-aware hierarchical epidemic approach that eliminates significant number of peers from gossiping
- Only a subset of peer population is active in gossiping by forming an overlay consisting of dominating set peers, so that the other peers can switch to idle state.

Dominating Set Based and Power-aware Hierarchical Gossip Model

Dominating Set is a subset S of a graph G=(V,E) such that every vertex in G is either in S or adjacent to a vertex in S.



Idea: *Only dominating set peers are active in gossiping*

Contributions

- Hierarchical gossip-based model using dominating set
  - Uses local knowledge only
  - Gossiping on the high level overlay
  - Uses new neighborhood definition among DS peers
- Active/passive peers
  - Reduces convergence time
  - Reduces message overhead
  - Reduces energy cost
- Developing a cost model for hierarchical gossip
- Comparison of flat and hierarchical cost models

Flat Epidemics: Energy Cost Model

$$E_{i,j} = E_{send,j} + E_{receive,j} + E_{comp,i} + c$$

$$E_{P_i} \le R_F \cdot mms \cdot \sum_{j \in V \cup W} E_{i,j}$$

Energy consumed during gossip operation

$$R_F \approx \frac{1}{\log \varepsilon} . \log N_F . convLimit . \frac{1}{fanout} . \frac{1}{mms}$$

Hierarchical Epidemics: Energy Cost Model

Energy Model for NDS Peer:

$$E_{P_i,NDS} \le \sum_{j \in K} (E_{i,j,1} + E_{i,j,2})$$

Energy consumed while receiving the result

Energy consumed while receiving request, sending LSI and DS ID set

Energy Model for DS Peer:

$$E_{P_i,DS} \le \sum_{j \in X} E_{i,j,1} + R_H \cdot mms \cdot \sum_{j \in Y \cup Z} E_{i,j,2} + \sum_{j \in X} E_{i,j,3}$$

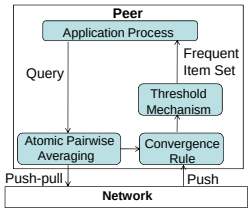
Energy consumed while sending request, receiving LSI and DS ID set

Energy consumed during gossip operation

Energy consumed while sending the result

Simulation Model

- PeerSim Simulator: http://peersim.sf.net
- ProFID Protocol [4] on PeerSim
- Frequent Item Set Discovery in P2P Networks
- Flat and Hierarchical Implementations



Default parameter values

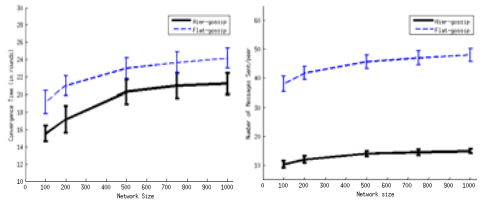
Parameter	Value	Parameter	Value
N	1000	*convLimit*	10
M	N/10	*ε*	10
mms	M	*fanout*	1
T	500		

Simulation settings

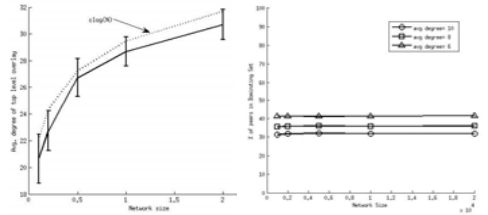
Parameter	Value
Topology	Barabasi-Albert (k=5)
Frequencies of each item	[1,N] (Zipf Distribution ρ=0.271)
Distribution of items	PowerLaw(p=4)

- **Performance Metrics**
  - Convergence Time
  - Number of messages sent per peer
  - Relative Error

Experimental Results



Decrease in convergence time — Decrease in total message sent per peer



Average degree increases logarithmically — Significant reduction in # of gossiping peers

Conclusion

- Address the aspect of energy efficiency in epidemic protocols
- Propose a distributed hierarchical gossip-based approach
  - Uses dominating set (active/passive peers)
  - Uses local knowledge
  - Gossiping on the high level overlay
  - Uses new neighborhood definition among DS peers
- Develop and compare cost models for flat and hierarchical approaches
- Conducted experiments to study energy efficiency

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Supported by the COST (European Cooperation in Science and Technology) framework under Action IC0804, and by TUBITAK (The Scientific and Technical Research Council of Turkey) under Grant 109M761.