Dynamic Layer Management in Superpeer Architectures

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Outline

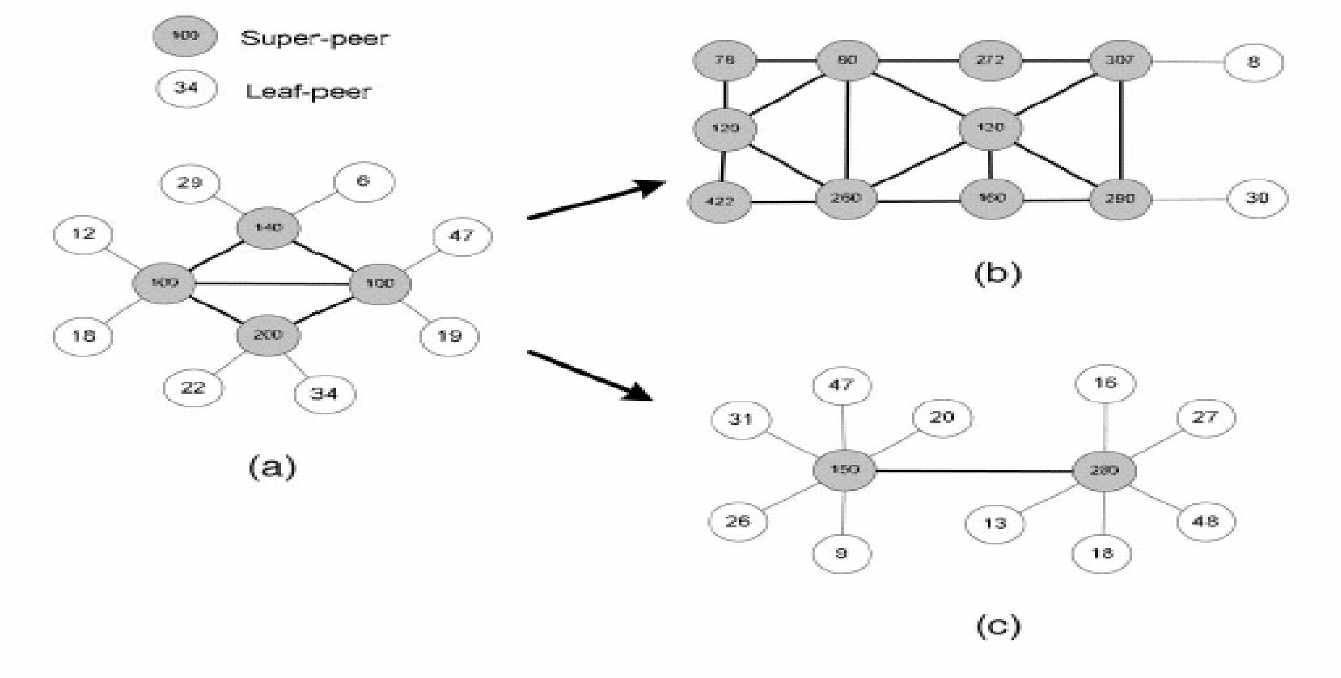
- Introduction
- Workload Model
- Dynamic Layer Management Algorithm (DLM)
- Performance Evaluation
- Conclusion

Introduction

- Superpeer unstructured P2P systems have been found to be very effective by dividing the peers into two layers, super-layer and leaf-layer.
  - Message flooding is only conducted among superpeer.

Problems

- What is the optimal size ratio of leaf-layer to super-layer?
  - Too many superpeers – pure P2P systems
  - Too few superpeers – centralized P2P systems



Problems(2)

- How can the optimal ratio be maintained ?
- What types of peers should be elected to super-layer?

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Workload Model

- n peers, n_l peers are leaf-peers
  n_s peers are superpeers
- Each leaf-peer connects to m superpeers.
- Each superpeer connects to k_s other superpeers and k_l leaf-peers.
- $\eta = n_l / n_s$ (layer size ratio)

- W_{on}- the workload on the overall network

  W_{sp}- the workload on a superpeer
- The workloads can be divided into three parts:
  - Connection Workload
  - Query Workload
  - Relay Workload

Connection Workload (CW)

- CW is defined as the traffic overhead incurred to maintain the connections to the neighboring peers.
- CW is related to the size and stability of the neighboring peer set.

Connection Workload

$$W_{sp\_cw} = \frac{k_l}{t_l} + \frac{k_s}{t_s} = \frac{m\eta}{t_l} + \frac{k_s}{t_s}$$

$$W_{on\_cw} = \frac{n_l m}{t_l} + \frac{n_s}{t_s}(k_l + k_s) = \frac{mn\eta}{(1+\eta)t_l} + \frac{n(m\eta + k_s)}{(1+\eta)t_s}$$

- W_{sp_cw} and W_{on_cw} : the portions of connection workload in W_{sp} and W_{on}
- t_l and t_s : the average lifetimes of neighboring leaf-peers and superpeers

Query Workload (QW)

- QW is defined as the traffic overhead incurred for a peer to process the queries generated by its leaf neighbors and itself.
- QW is proportional to the number of leaf neighbors and the query frequency.

Query Workload

$$W_{sp\_qw} = k_l f = m\eta f$$

$$W_{on\_qw} = \frac{nm\eta f}{1+\eta}$$

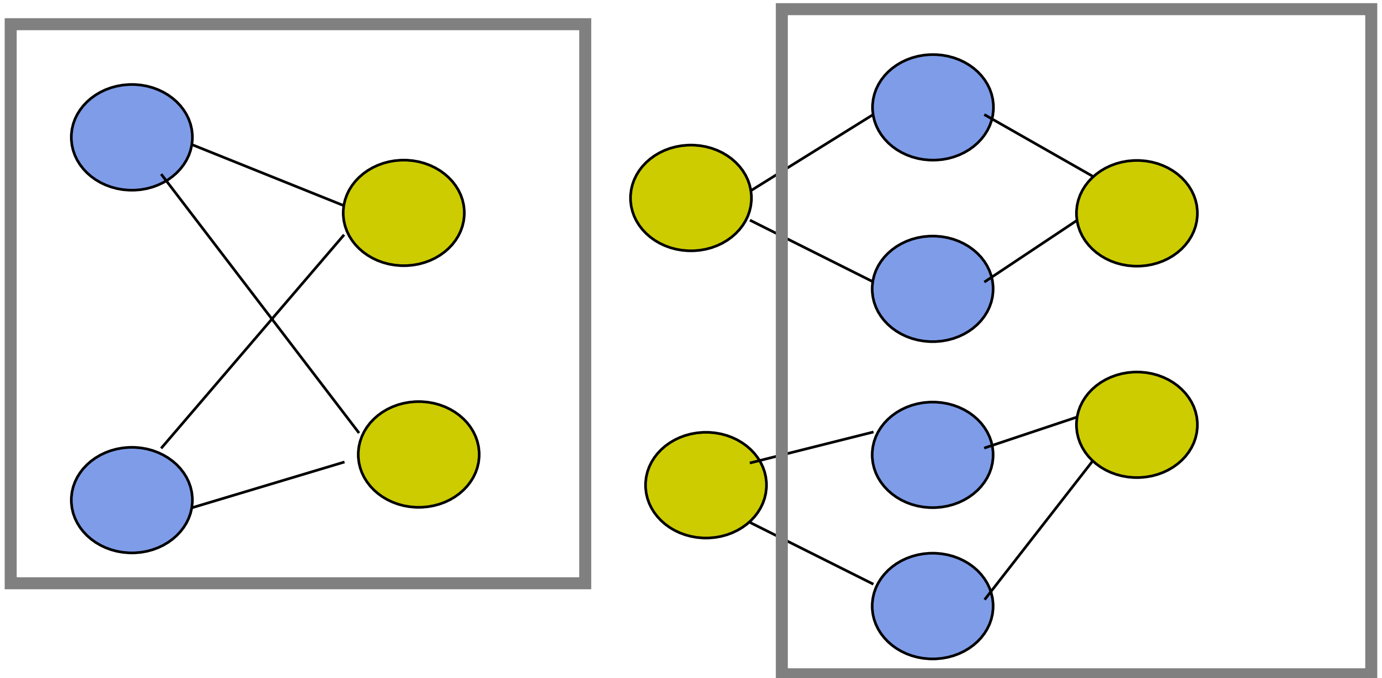
- W_{sp_qw} and W_{on_qw} : the portions of query workload in W_{sp} and W_{on}
- f : the query frequency of a peer

Relay Workload (RW)

- RW is defined as the traffic overhead incurred to process queries relayed form the superpeer neighbors.

To cover p peers, the number of superpeers that should be queried has a lower bound of $p/(1+k_l)$ and an upper bound of $mp/(m+k_l)$

- A superpeer can be viewed to represent k_l+1peers.



$p_s * k_l = p_l * m$ $\qquad$ $p_s * k_l = p_l$

Theorem 1

$(p_s * k_l) / m \leqq p_l \leqq p_s * k_l$

$\Rightarrow p - p_s \leqq p_s * k_l \leqq (p - p_s) m$

$\Rightarrow p/(1+k_l) \leqq p_s \leqq mp/(m+k_l)$

When $p_s \ll n_s$, p_s is very close to $p/(1+k_l)$

To cover $p_s = p/(1+k_l)$ superpeers, the number of query message range from $(p/(1+k_l))-1$ to $pk_s/(1+k_l)$

- The ideal search algorithm should only query each per once. Therefore, it can only use p_s-1 message.
- For an inefficient search algorithm, each link relays the same query at most twice.

The maximum number of links is $p_s*k_s/2$, so the maximum number of messages is p_sk_s

Theorem 2

Relay Workload

- Each peer initiates *f* queries per time unit and each superpeer receives $(1+k_l)f$ queries from itself and its leaf neighbors.

  the query frequency of the total network $(1+k_l)n_s f$

- From theorem 2, the number of messages used by a query ranges from

  $(p/(1+k_l))-1$ to $pk_s/(1+k_l)$

Relay Workload

$$W_{on\_rw(\min)} = (1+k_l)n_s f\left(\frac{p}{1+k_l} - 1\right) = n_s f(p-1-k_l)$$
$$= \frac{nf}{1+\eta}(p-1-m\eta)$$

$$W_{on\_rw(\max)} = n_s f p k_s = \frac{f p k_s n}{1+\eta}.$$

$$W_{sp\_rw(\min)} = (p-1-m\eta)f \text{ and } W_{sp\_rw(\max)} = f p k_s.$$

Wsp_rw is $\frac{1}{n_s}$ of W_{on_rw}

Optimal Layer Size Ratio

- W = W_{cw} + W_{qw}+ W_{rw}

$$\begin{aligned} W_{sp(min)} &= \frac{m\eta}{t_l} + \frac{k_s}{t_s} + m\eta f + (p - 1 - m\eta) f \\ &= \frac{m\eta}{t_l} + \frac{k_s}{t_s} + (p-1) f \\ W_{on}(min) &= \frac{mn\eta}{(1+\eta)t_l} + \frac{n(m\eta + k_s)}{(1+\eta)t_s} + \frac{nm\eta f}{1+\eta} \\ &\quad + \frac{nf}{1+\eta}(p - 1 - m\eta) \\ &= \frac{n}{1+\eta}\left(\frac{m\eta}{t_l} + \frac{m\eta + k_s}{t_s} + fp - f\right). \end{aligned}$$

$$\begin{aligned} W_{sp(max)} &= \frac{m\eta}{t_l} + \frac{k_s}{t_s} + m\eta f + fpk_s \\ &= \left(\frac{1}{t_l} + f\right) m\eta + \frac{k_s}{t_s} + fpk_s, \\ W_{on(max)} &= \frac{mn\eta}{(1+\eta)t_l} + \frac{n(m\eta + k_s)}{(1+\eta)t_s} + \frac{nm\eta f}{1+\eta} + \frac{fpk_s n}{1+\eta} \\ &= \frac{n}{1+\eta}\left(\frac{m\eta}{t_l} + \frac{m\eta + k_s}{t_s} + m\eta f + fpk_s\right). \end{aligned}$$

Optimal Layer Size Ratio

$$W = \alpha W_{sp} + \beta \frac{W_{on}}{n} \quad (1)$$

- Since both Wsp and Won are functions of η ,by differentiating we can obtain optimal value η as

$$\eta' = \sqrt{\frac{B - C}{A}} - 1,$$

where, for the most efficient search algorithm,

$$A = \frac{m\alpha}{t_l}, B = \left(\frac{k_s}{t_s} + fp - f\right)\beta, \text{ and } C = \left(\frac{1}{t_l} + \frac{1}{t_s}\right)m\beta,$$

while, for the most inefficient search algorithm,

$$A = \left(\frac{1}{t_l} + f\right)m\alpha, B = \left(\frac{1}{t_s} + fp\right)k_s\beta, \text{ and}$$

$$C = \left(\frac{1}{t_l} + \frac{1}{t_s} + f\right)m\beta.$$

Dynamic layer management algorithm

1. Information Collection
2. Maintaining Appropriate Layer-Size-Ratio
3. Scaled Comparisons of Capacity and Age
4. Promotion or Demotion

1.Information Collection

- Peers exchange information with their superpeers to know their leaf neighbor number.
- Peers report their *age* and *capacity* to their superpeers.

2. Maintaining Appropriate Layer-Size-Ratio

- Due to the randomness of the neighbor selection mechanism in superpeer systems, the current numbers of leaf neighbors of superpeers can reflect the current layer size ratio.
- l_{nn}: the leaf neighbors number
- $$\mu = log(l_{nn}/k_1).$$
- $\mu > 0$: too few superpeers
- $\mu < 0$: too many superpeers

3.Scaled Comparisons of Capacity and Age

- For each peer that runs DLM, it uses two counting variables,Y_{capa}, Y_{age} .

$$
\begin{array}{l}
\textbf{for} \text{ all peer } d_i \text{ in } G(d) \\
\quad \textbf{if } (capacity(d_i)^* X_{capa} > capacity(d)) \\
\quad\quad Y_{capa} += 1/(\text{size of } G(d)); \\
\quad \textbf{if } (age(d_i)^* X_{age} > age(d)) \\
\quad\quad Y_{age} += 1/(\text{size of } G(d));
\end{array}
$$

- The value of X_{capa} and X_{age} are adjusted according to the value of μ

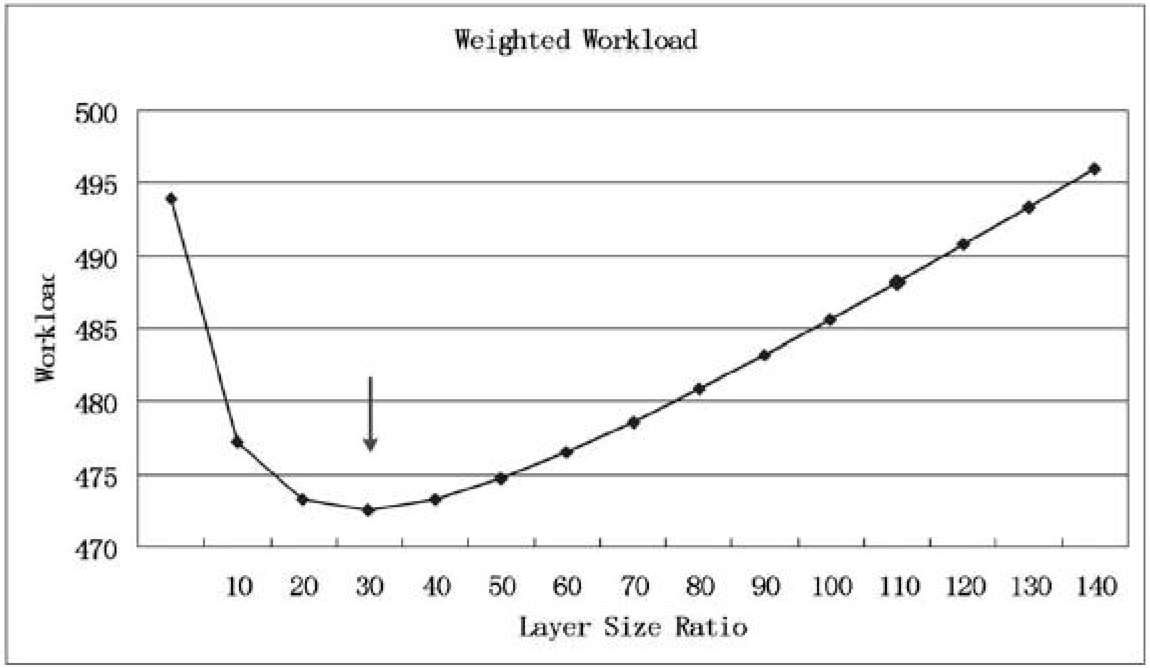
4.Promotion or Demotion

- We use tow threshold variable Z_{capa},Z_{age} in the determination.
- For a leaf-peer, if Y_{age} and Y_{capa} are smaller than Z_{capa} and Z_{age}, it will be promoted.
- For a superpeer, if Y_{age} and Y_{capa} are lareger than Z_{capa} and Z_{age}, it will be demoted.

Performance Evaluation

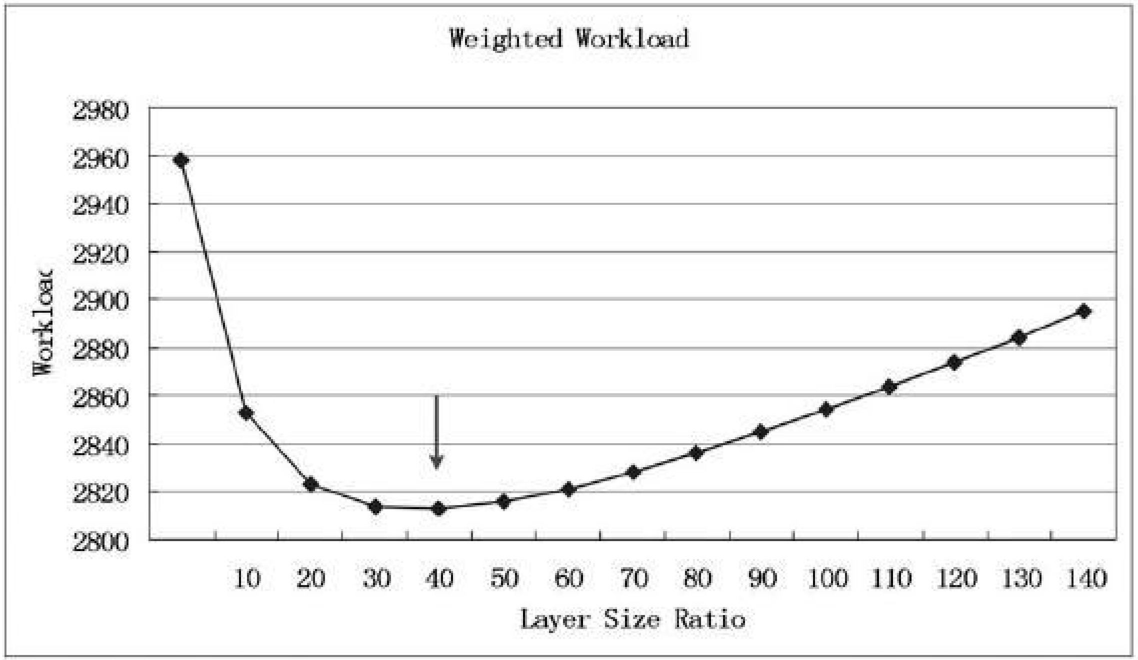
Simulation Parameters

Parameter	Value	Description
n	50,000	Number of peers in the network
n_l	48,780	Number of preferred leaf-peers
n_s	1,220	Number of preferred super-peers
η	40.0	Layer size ratio
m	2	Number of super-peer neighbors of a leaf-peer
k_l	80	Average number of leaf-peer neighbors of a super-peers
k_s	3	Average number of super-peer neighbors of a super-peers
t_l	3.5	Average duration time of leaf-peers
t_s	50	Average duration time of super-peers
f	0.3	Average number of queries of a peer per minute
p	3,000	Number of covered peers to ensure some fixed success rate



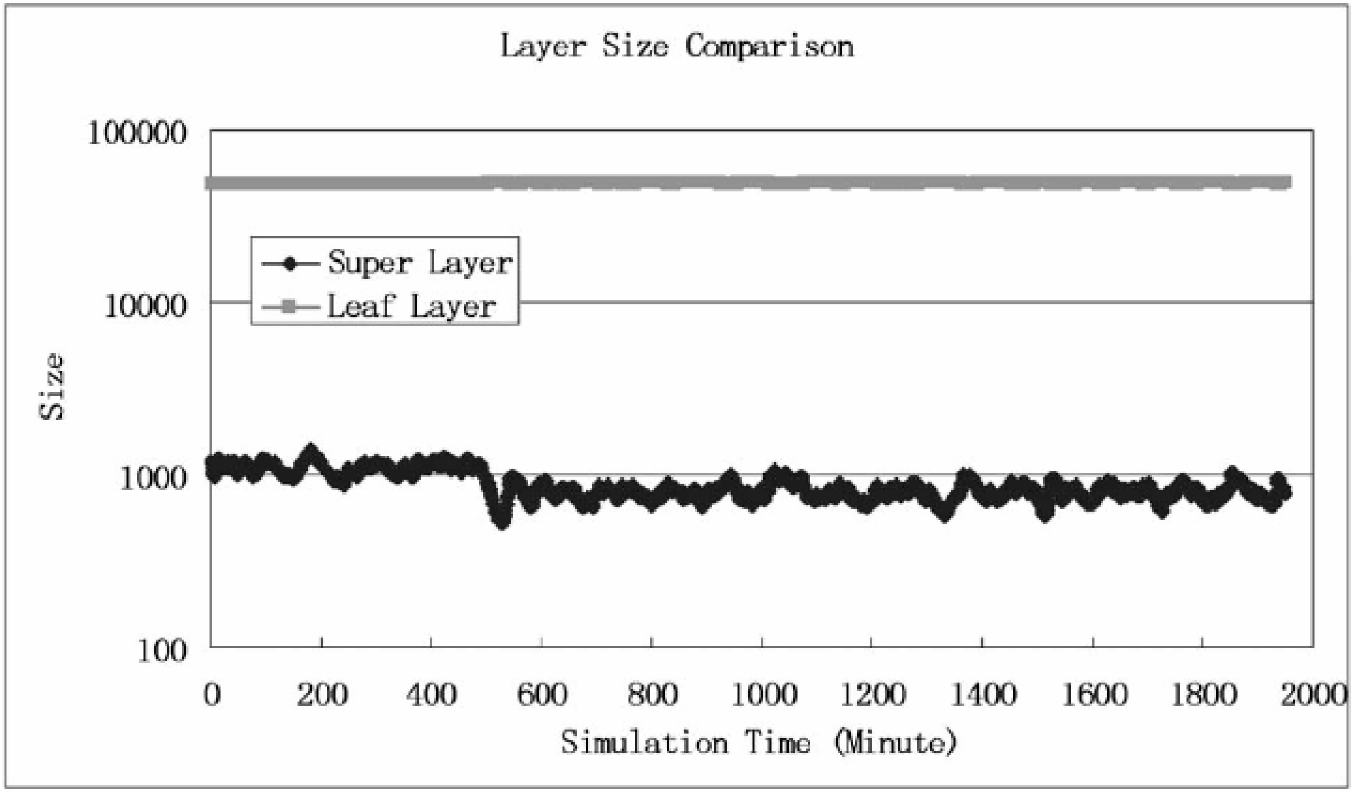
Weighted workload of most efficient search $(\alpha = 0.5, \beta = 0.5)$.

$$\eta_1' = \sqrt{\frac{B-C}{A}} - 1 \approx 38,$$



Weighted workload of most inefficient search $(\alpha = 0.5, \beta = 0.5)$.

$$\eta_1' = \sqrt{\frac{B-C}{A}} - 1 \approx 51.$$


Layer Size Comparison
100000
10000
1000
100
Size
Super Layer
Leaf Layer
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Simulation Time (Minute)

Conclusion

- In this paper, we purpose a workload model by analyzing the workload on one superpeer as well as on the total network.
- Based on this model , we can obtain an optimal layer size ratio.
- By DLM, we can adaptively elect peers and adjust them between superlayer and leaf-layer.

Thank you☺