A two-level distributed architecture for Web content adaptation and delivery

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The evolving Web scenario

- Heterogeneous clients
  - Different display, CPU, network
- Heterogeneous user behavior
  - Request for sophisticated, personalized services

Content adaptation
  (transcoding, personalization)
Content adaptation

- Possible approaches:
  - Server-based
  - Client-based
  - Intermediary-based

- Issue:
  - Content adaptation is computationally expensive

- Typical solutions
  - Caching → reduce adaptation operations
  - Replication → load sharing
Issues for efficient content adaptation

- Caching issue
  - multiple version of every resource → working set size grows
  - locality improves caching effectiveness

- Replication issue
  - provide adequate load sharing

**Contribution:**
We propose a novel architecture for distributed content adaptation that *preserves locality* and *provides load sharing*.
Functions in content adaptation

- Main functions:
  - Gateway
  - Location
  - Adaptation
  - Fetch
  - Cache

Architectures differ in the mapping of these functions.
Two-level content adaptation architecture

Origin server

Internal nodes

Client

Hash(URL)
**Benefit of hashing**

- Hash computed **only on URL** (no version)
  - every version of the same resource is on the same node (simplify lookup)
  - improve **locality**
- **URL-space partitioned**
  - no cache duplicates (**efficient use of cache**)
- **Hash-based request distribution**
  - evenly distributed requests (**load sharing**)
Two-level content adaptation architecture

- Few powerful internal nodes:
  - Improves security (easy to control)
  - Improves privacy (sensitive information)
  - Solves management issues (few nodes)
  - Solves data consistency issues (hashing)
  - Internal nodes can be locally replicated to further increase computational power (cluster)
Two-level content adaptation architecture

- Many simple edge nodes
  - no management required
  - no computational power required
  - can be highly distributed

- Drawback of having two levels
  - Two steps for every request
  - We compare the two-level architecture with a flat architecture
Flat content adaptation architecture

Origin server

Client

Edge node

G,F

Query-based lookup
Flat content adaptation architecture

- **Pros:**
  - Highly distributed
  - No need for two steps

- **Cons:**
  - Privacy issues
  - Data consistency issues
  - Does not guarantee load sharing
Performance evaluation

- Workload models:
  - Working set with heavy impact on adaptation
  - Synthetically generated traces

- We compare:
  - Two-level architecture
  - Flat architecture
  - No cooperation architecture

- Two network scenario:
  - Real network scenario
  - WAN-emulated scenario
Real network scenario
### Hit rate

<table>
<thead>
<tr>
<th></th>
<th>local</th>
<th></th>
<th>remote</th>
<th></th>
<th>global</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>exact</td>
<td>useful</td>
<td>exact</td>
<td>useful</td>
<td></td>
</tr>
<tr>
<td>No_Coop</td>
<td>8.3%</td>
<td>6.4%</td>
<td>n/a</td>
<td>n/a</td>
<td>14.7%</td>
</tr>
<tr>
<td>Flat</td>
<td>8.0%</td>
<td>7.0%</td>
<td>25.1%</td>
<td>26.8%</td>
<td>66.9%</td>
</tr>
<tr>
<td>Two-level</td>
<td>n/a</td>
<td>n/a</td>
<td>60.2%</td>
<td>21.0%</td>
<td>81.2%</td>
</tr>
</tbody>
</table>

- Two-level provides the highest hit rate
- Hash-based partition is effective in optimizing cache usage
Summary of findings

- Two-level architecture:
  - Hashing avoids duplicates → efficient cache space usage, high hit rate
  - High cache hit rate → load is reduced

- Focus on two-step penalty: sensitivity to network
Two-step penalty
Sensitivity to network parameters

- **Two-level:**
  - High hit rate → less sensitive to delay to origin server
  - Two steps → sensitivity to delay between edge and internal nodes
Two-level architecture constantly outperforms other architecture in our experiments.

Two-level architecture is sensitive to network delays between the nodes of the intermediate infrastructure.

Two-level architecture is less sensitive than flat architecture to delay to origin server.
Future work

- Flat architecture and two-level are two extreme cases
  - Flat: every node provides every function
  - Two-level: node functions partitioned
- *In medio stat virtus*
  - Intermediate hybrid architectures are a whole new space of investigation
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