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

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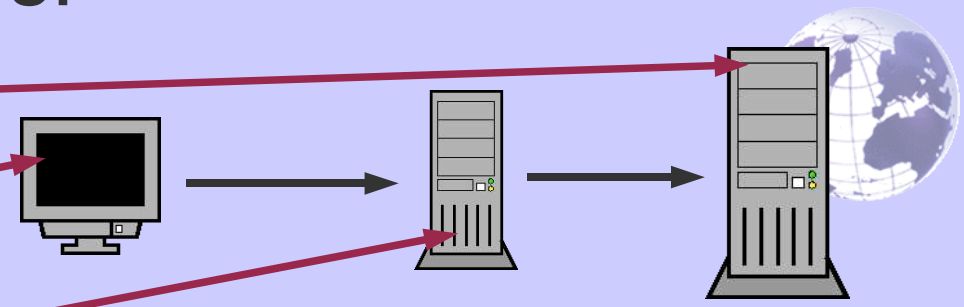
The evolving Web scenario

- 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:

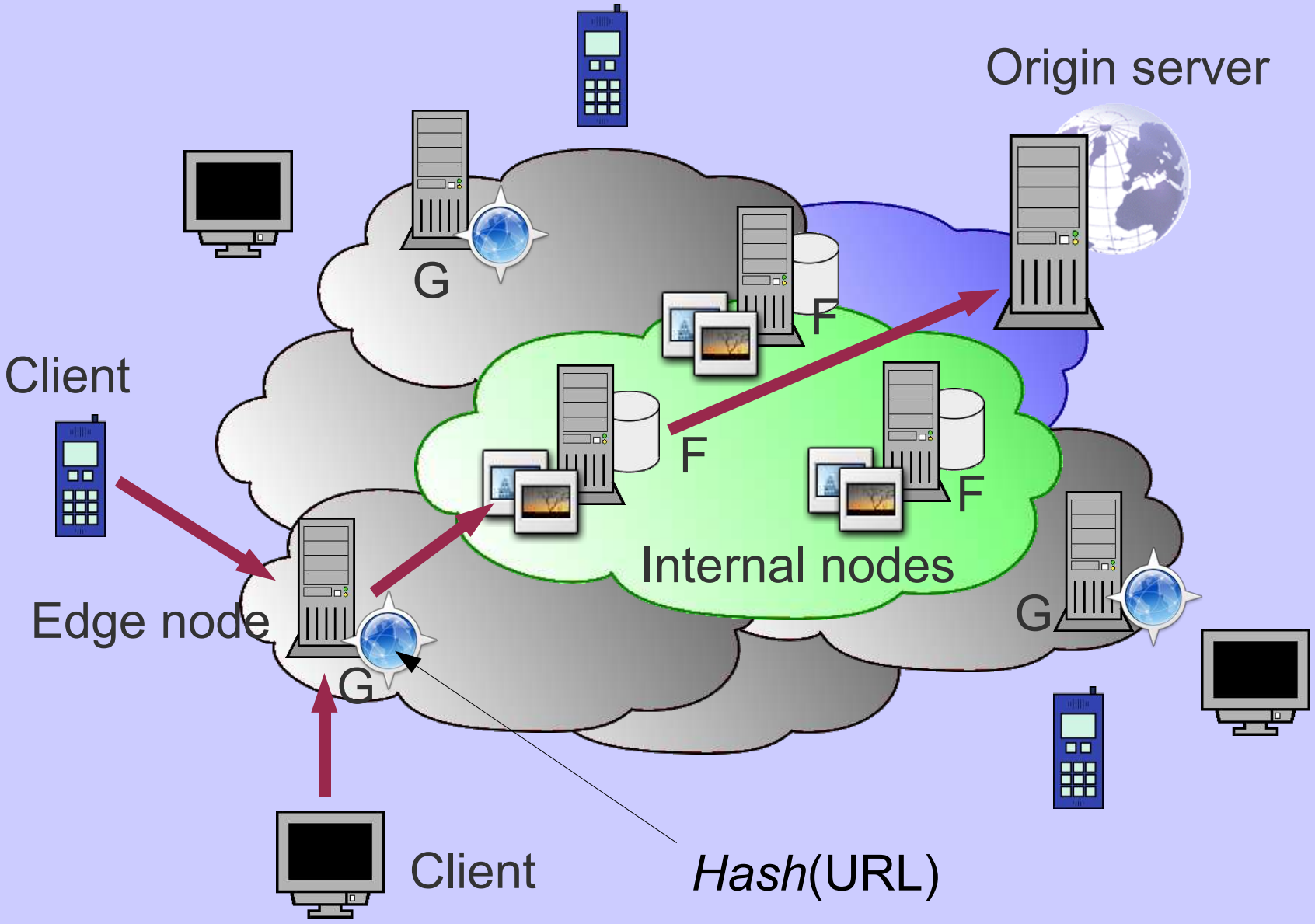
We propose a novel architecture for distributed content adaptation that preserves locality and provides load sharing

Functions in content adaptation

- Main functions:
  - Gateway → G
  - Location 
  - Adaptation 
  - Fetch → F
  - Cache 

Architectures differ in the mapping of these functions

Two-level content adaptation architecture

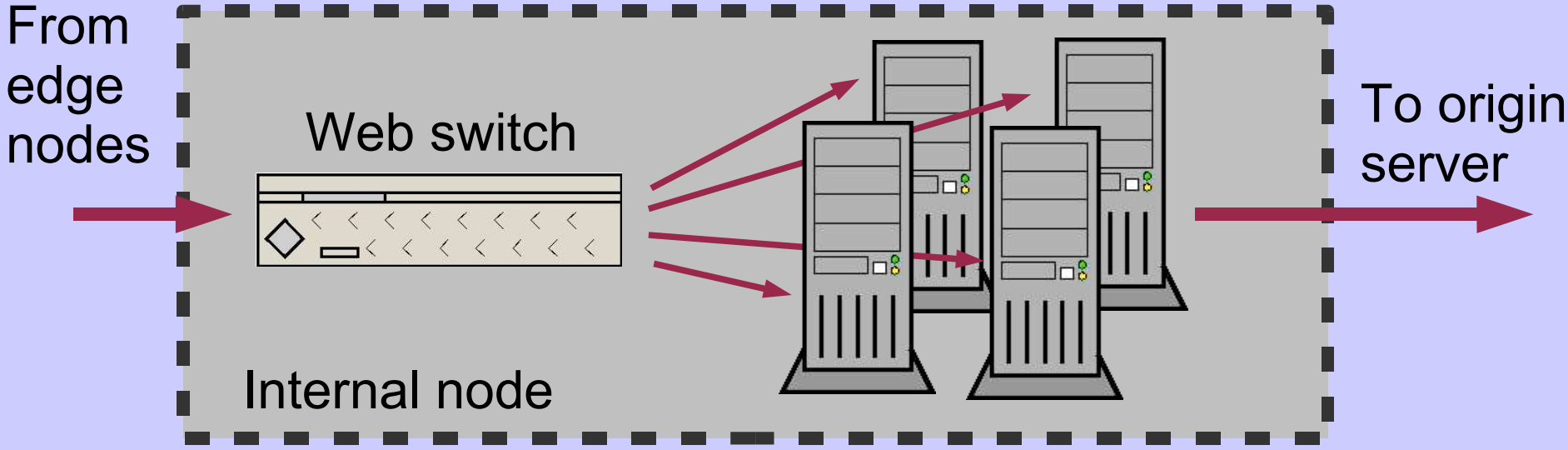


Benefit of hashing

- 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 fur-ther increase computational power (cluster)

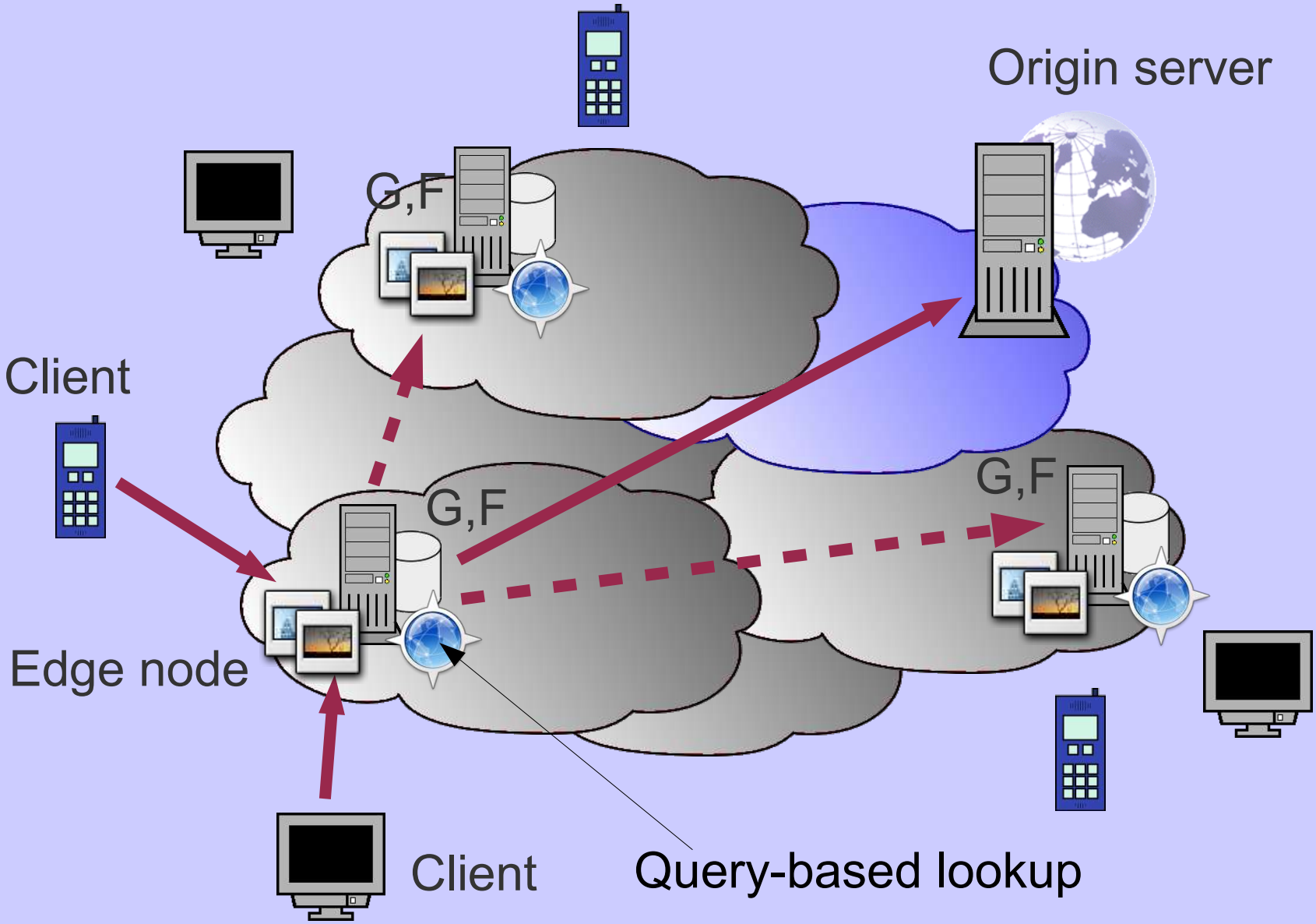


Two-level content adaptation architecture

- 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



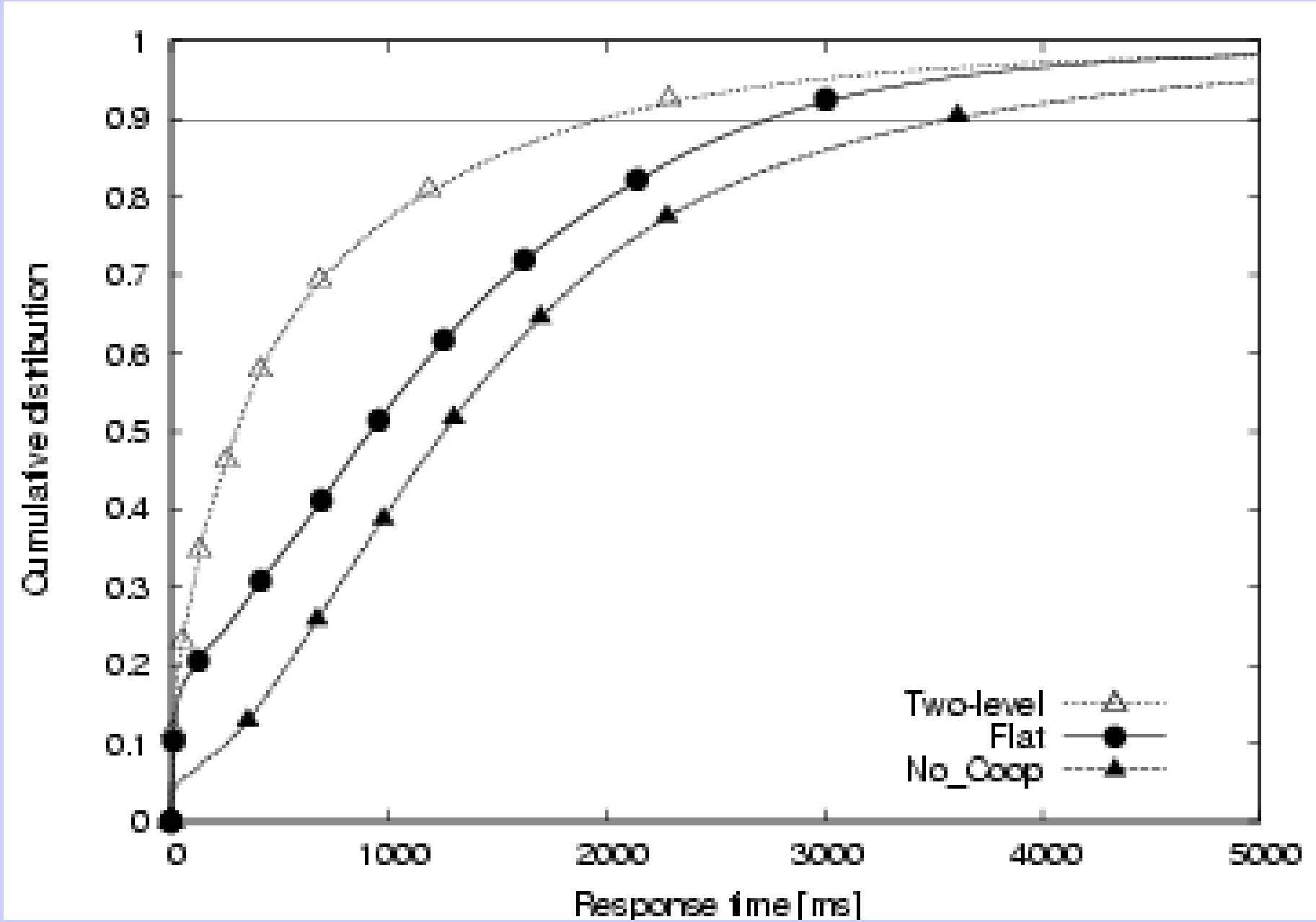
Flat content adaptation architecture

- 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

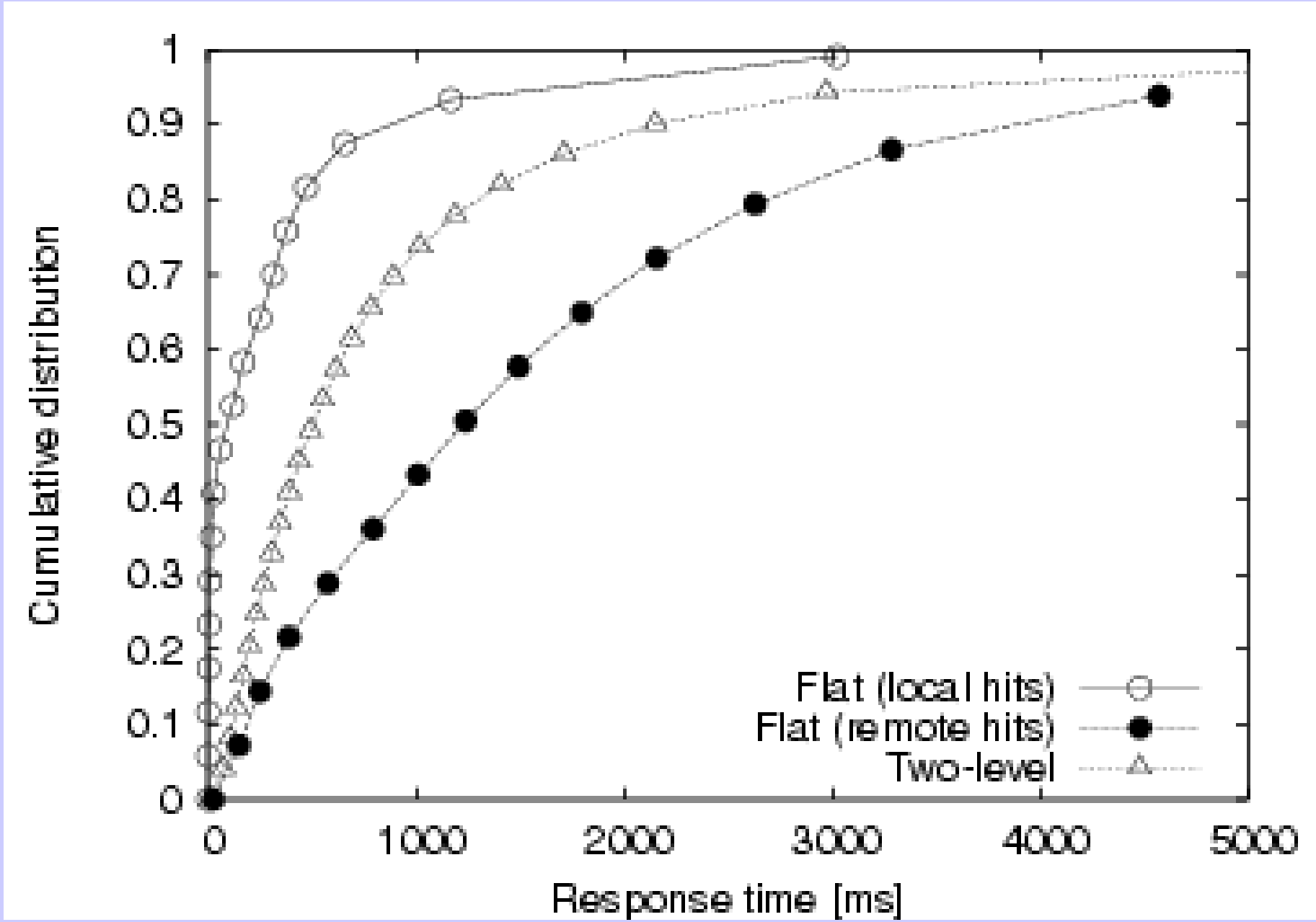
	local		remote		global
	exact	**useful**	**exact**	**useful**	
No_Coop	8.3%	6.4%	n/a	n/a	14.7%
Flat	8.0%	7.0%	25.1%	26.8%	66.9%
Two-level	n/a	n/a	60.2%	21.0%	81.2%

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

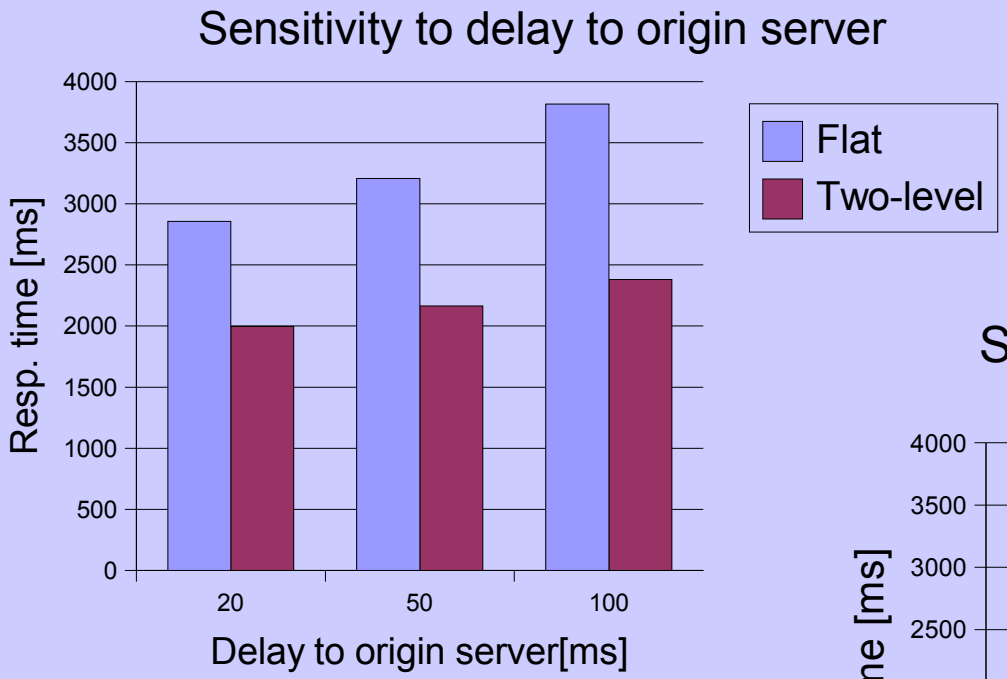
Summary of findings

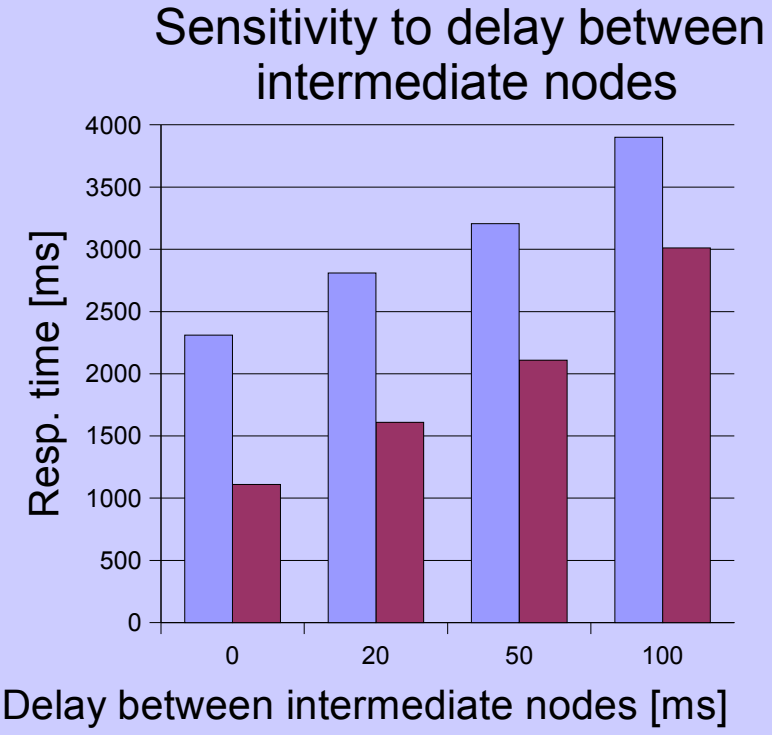
- Two-level architecture:
  - Hashing avoids duplicates $\rightarrow$ efficient cache space usage, high hit rate
  - High cache hit rate $\rightarrow$ load is reduced
- Focus on two-step penalty: sensitivity to network

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

Conclusion

- 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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