Performance comparison of distributed architectures for content adaptation and delivery of Web resources

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Current Web scenario

- Heterogeneity:
  - Client devices range from smartphones to high-end workstations
- Critical Web-based services
  - Web is a critical communication channel
  - **Need** for system to enable ubiquitous Web access.

Web content adaptation *on-the- fly*

Functions in a distributed Web content adaptation system

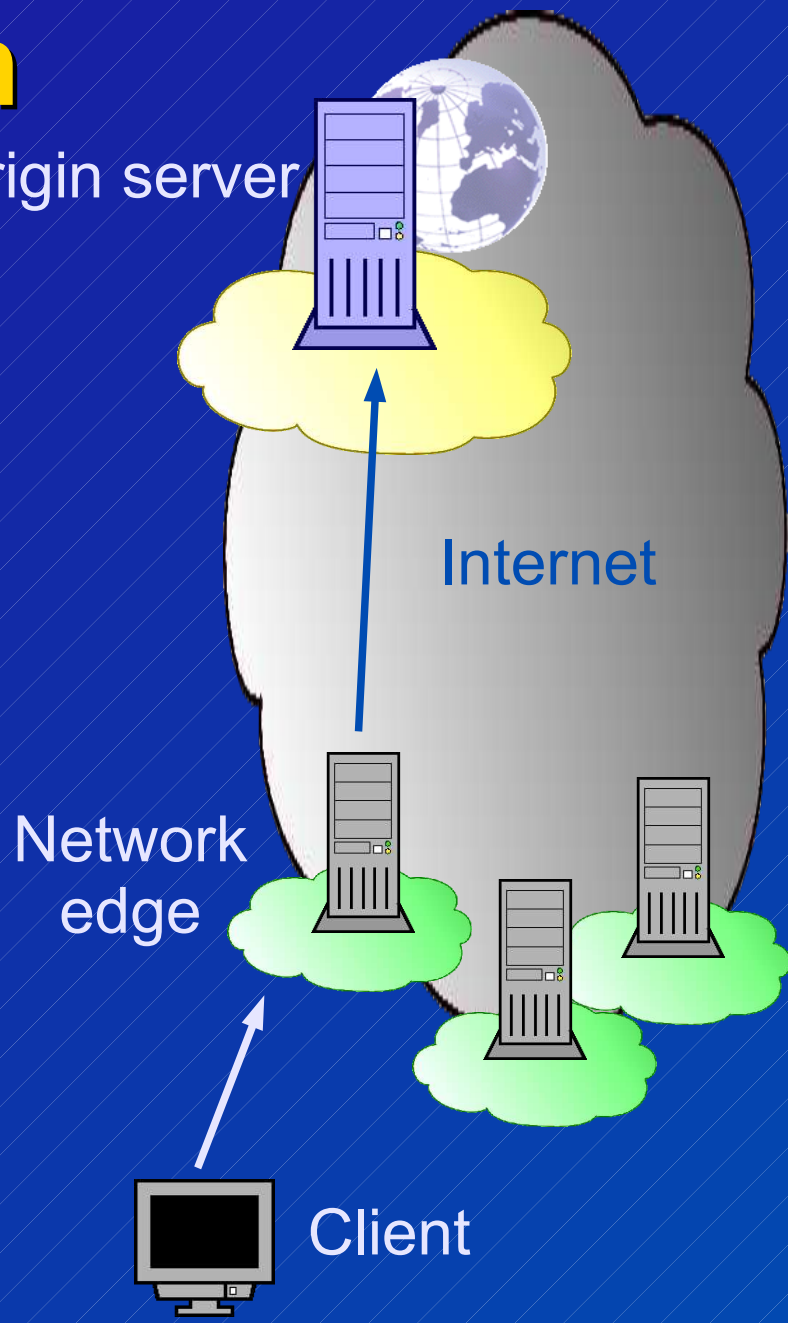
- Content adaptation
  - Computationally expensive (on-the-fly adaptation)
- Client capability/User preferences identification
- Caching
  - Multi-version caching
- Location of (possibly adapted) resources
  - Multi-version lookup process: Exact hit, Useful hit and Miss
- Interaction with Origin server

On which nodes to place these functions?

Providing Web content adaptation

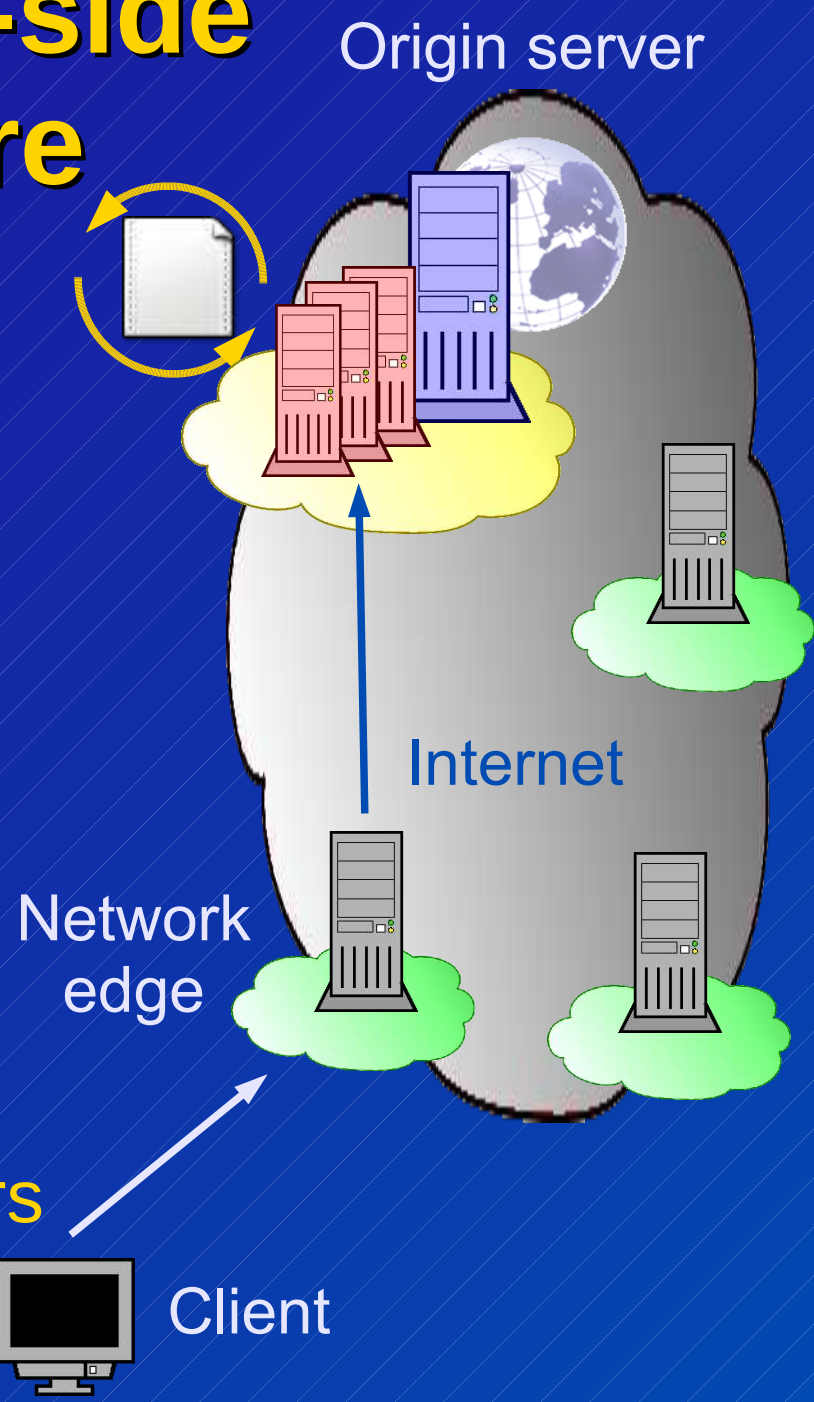
Different approaches for mapping content adaptation functions on the nodes:

- "Keep every function in the origin server area"
- "Move most functions towards the network edge nodes"
  - → Non cooperative edge server-side architecture
  - "Exploit potential of distributed architectures by allowing cooperation among edge nodes"



Origin server-side architecture

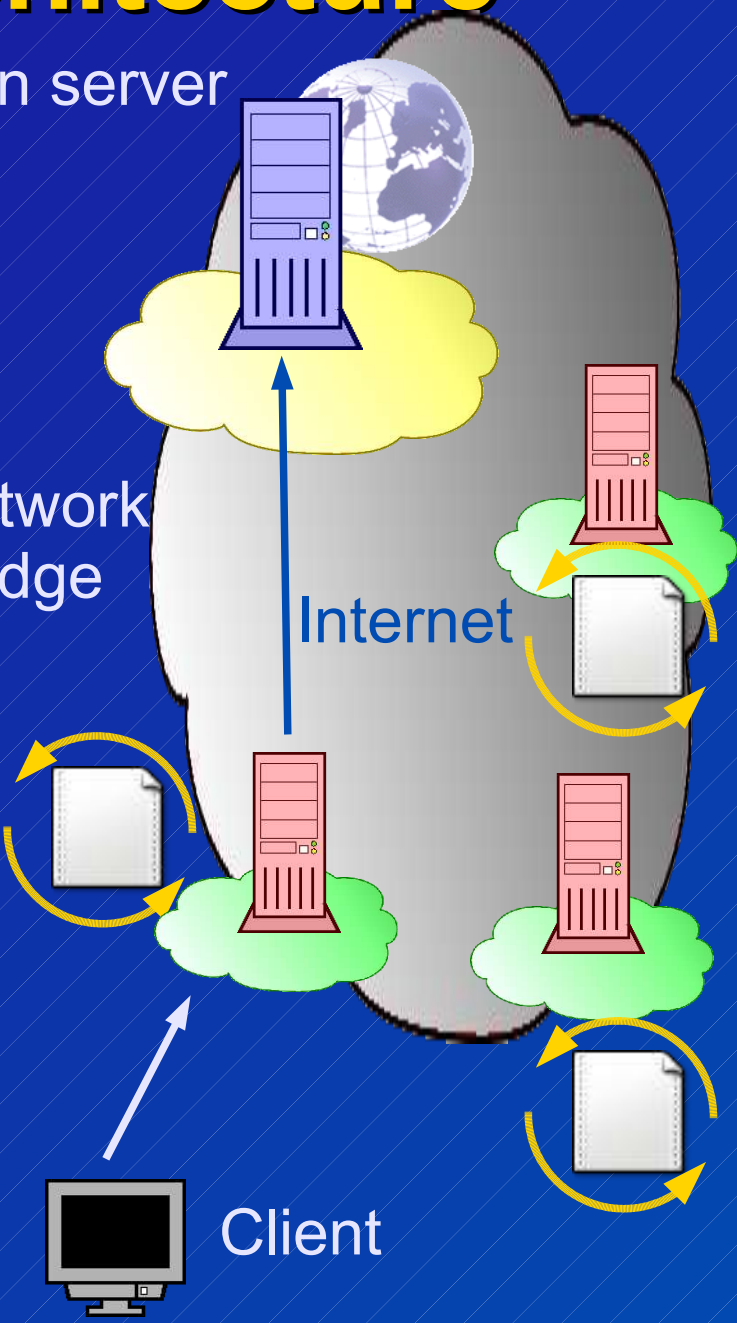
- "Keep every function in the origin server area"
- Potential advantages
  - Simplify interaction with origin server (security / privacy / sophisticated services)
  - Can exploit clusters
- Possible drawbacks
  - Sensitive to network parameters
  - High latency



Edge server-side architecture

- "Move most functions towards the network edge nodes"
- Potential advantages
  - Caching is more effective
  - Reduce bandwidth usage
- Possible drawbacks
  - Higher complexity than origin server-side approach

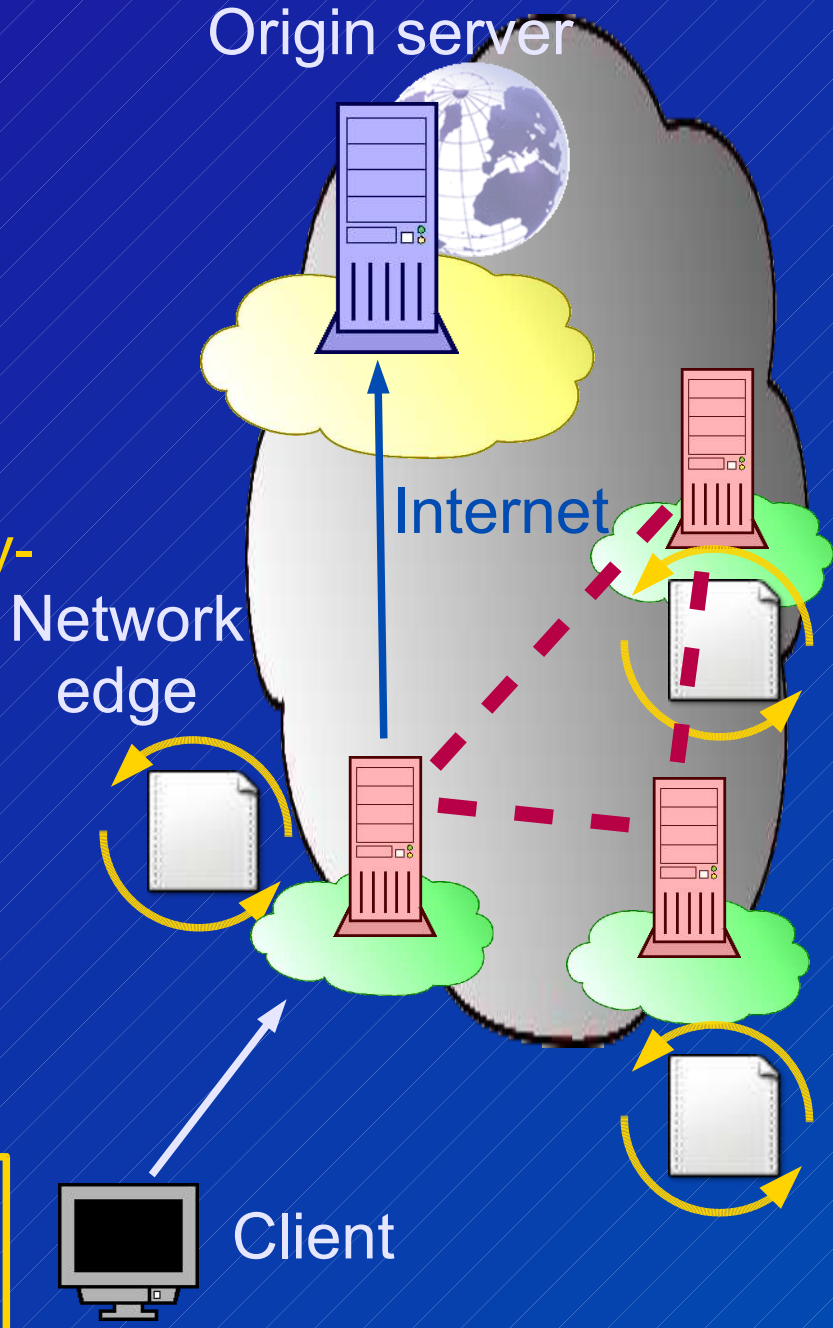
What is the performance gain from pushing services on the network edge?



Cooperative Edge server-side architecture

- "Exploit potential of distributed architectures by allowing cooperation among edge nodes"
- We focus on the best performing algorithm for cooperative lookup (query-based)
- Potential advantages
  - Increased efficiency
- Potential drawbacks
  - Higher complexity

What is the advantage from cooperation?

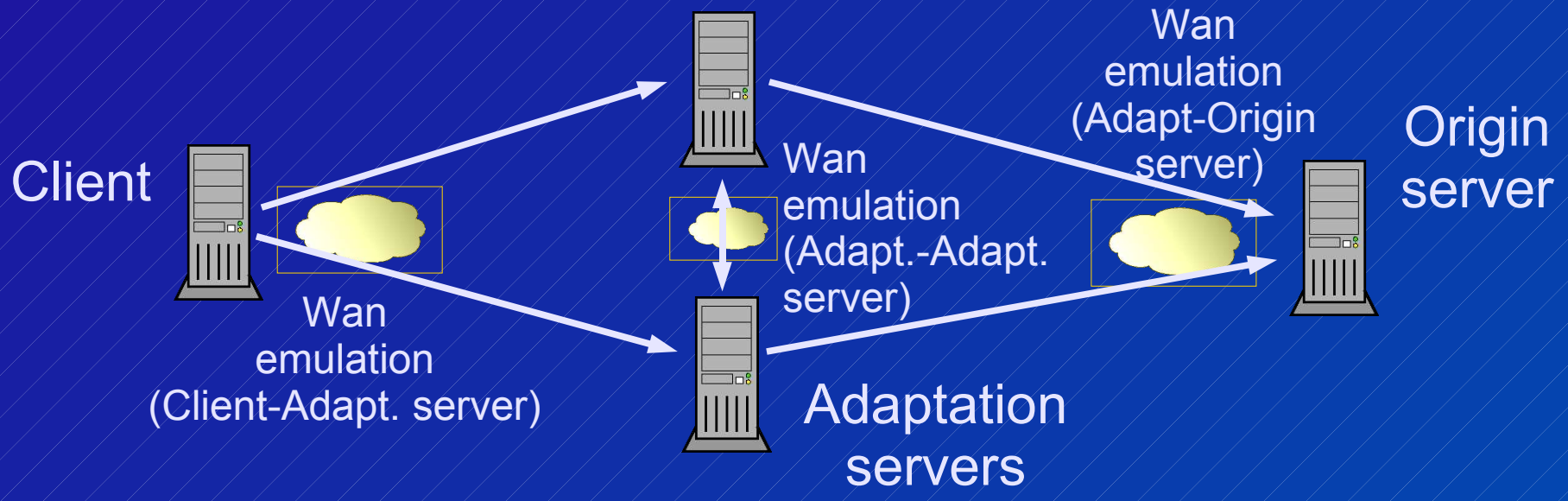


Main goals:

- Comparison of leading solutions for content adaptation
  - What is the gain from pushing content adaptation on the network edge? Under which circumstances this performance gain is more evident?
  - What is the advantage achieved through cooperation?
- Performance evaluation with real prototypes in a controlled environment
  - Different workloads
  - WAN emulation with multiple network scenarios

Performance evaluation

- Experimental setup
  - 16 nodes with content adaptation capabilities (adaptation servers)
  - 1 Web server (Origin server) + 1 client emulator
  - WAN emulation (*NetEm* network scheduler: delay, packet loss, bandwidth limitation



Performance evaluation

- Two workload models (prevalent static resources)
  - IRcache (from IRcache logs)
  - Photo album (heavy content adaptation tasks)
- Multiple WAN setups, we report the most significant results (sensitivity to bandwidth)

Architecture	WAN-emulated links	Bandwidth [Mbit/s]	Delay [ms]	Loss
Origin server-side	Client-Adapt. server	8, 16, 32	100	1,00%
Edge server-side	Adapt.-Origin server	8, 16, 32	100	1,00%
Cooperative edge server-side	Adapt.-Origin server	8, 16, 32	100	1,00%
	Adapt.-Adapt. server	8, 16, 32	25	1,00%

Architecture comparison: Origin server *vs.* Edge server-side

IRcache workload

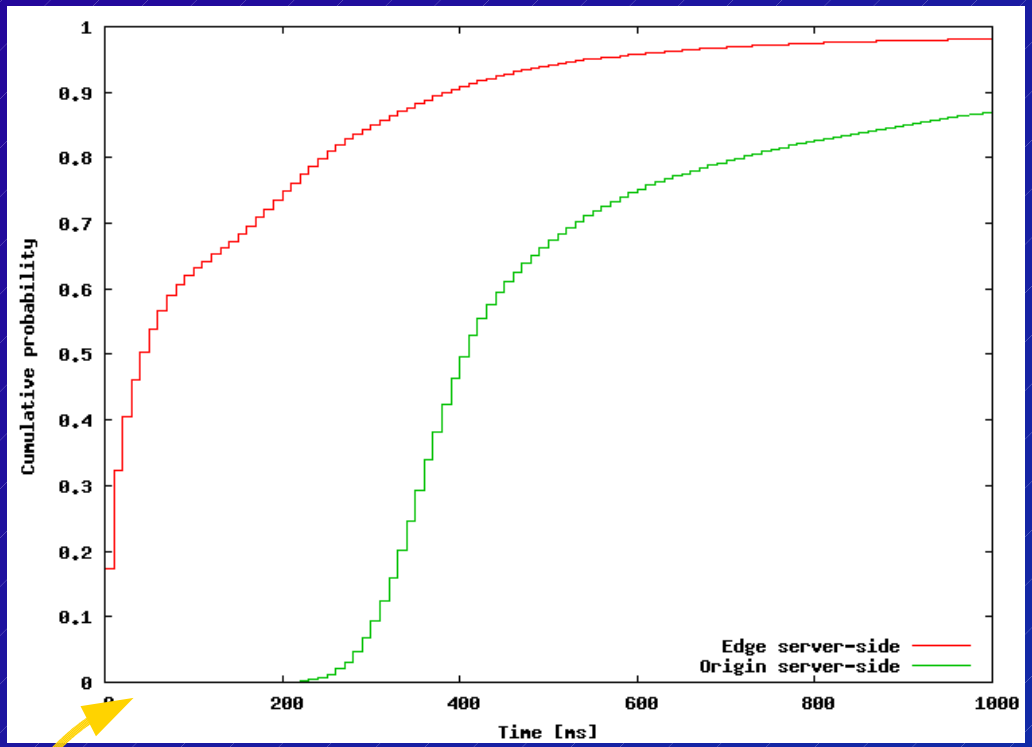
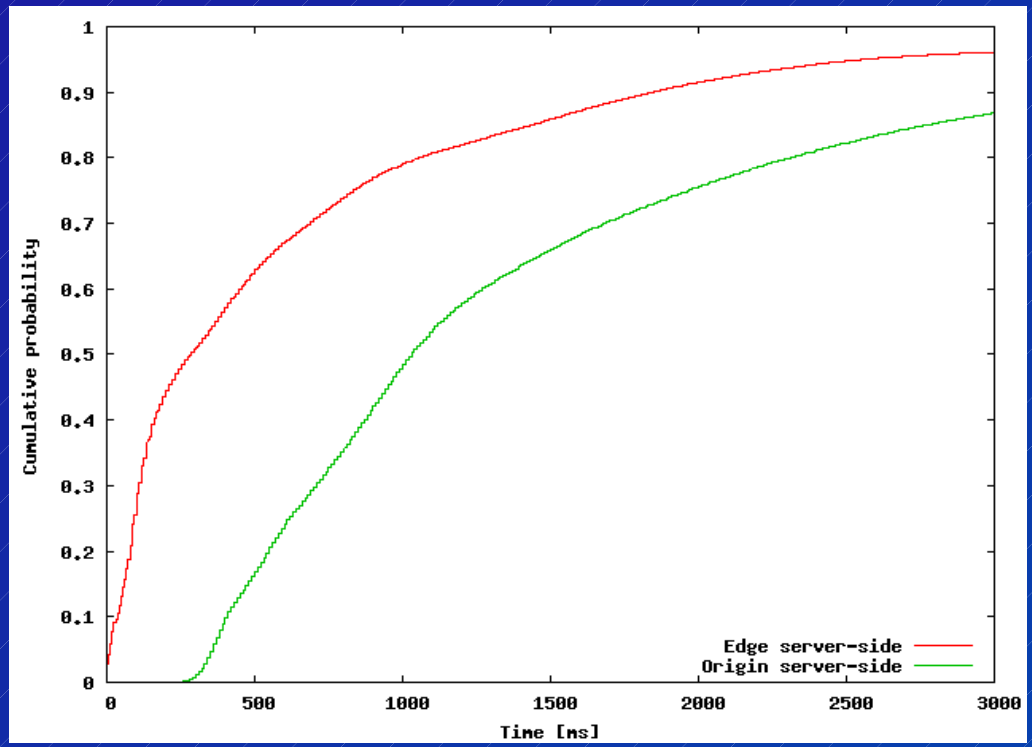


Photo album workload



- Edge server-side always outperforms Origin server-side
- Performance gain is more significant in the case of light workload (IRcache)

Architecture comparison: Impact of cooperation

IRcache workload

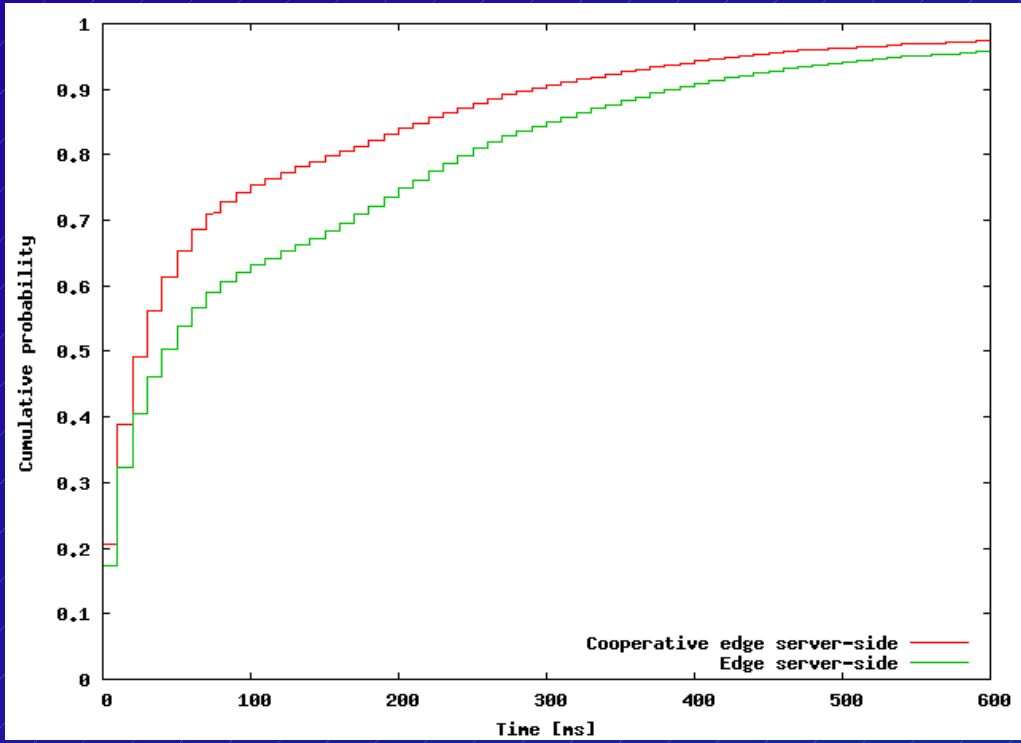
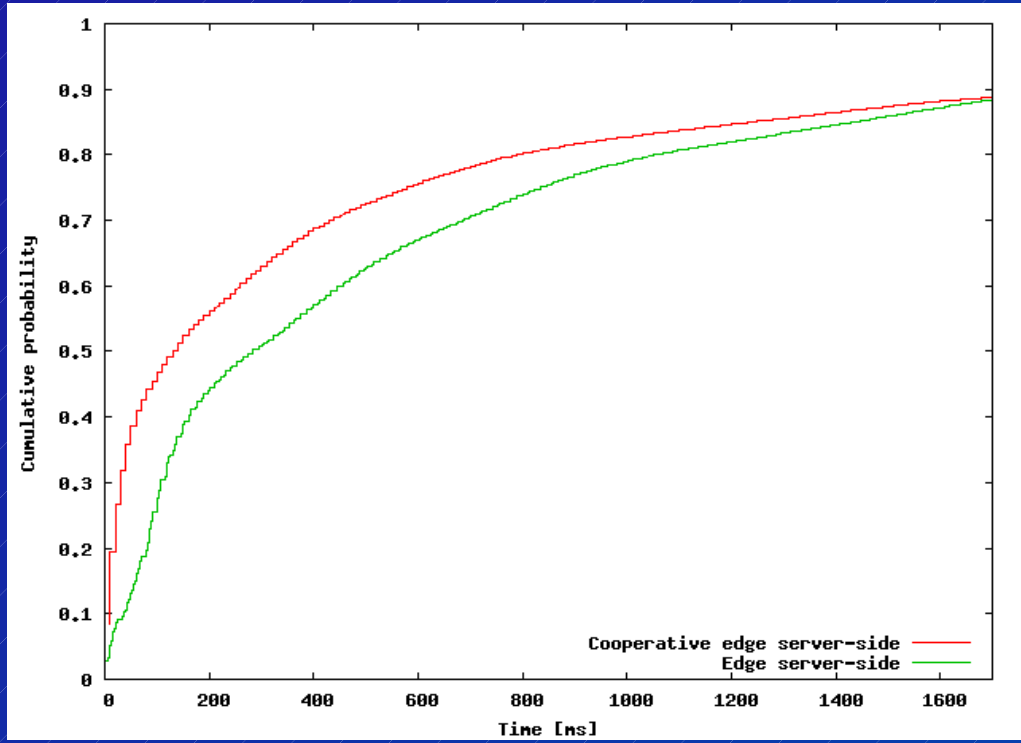


Photo album workload

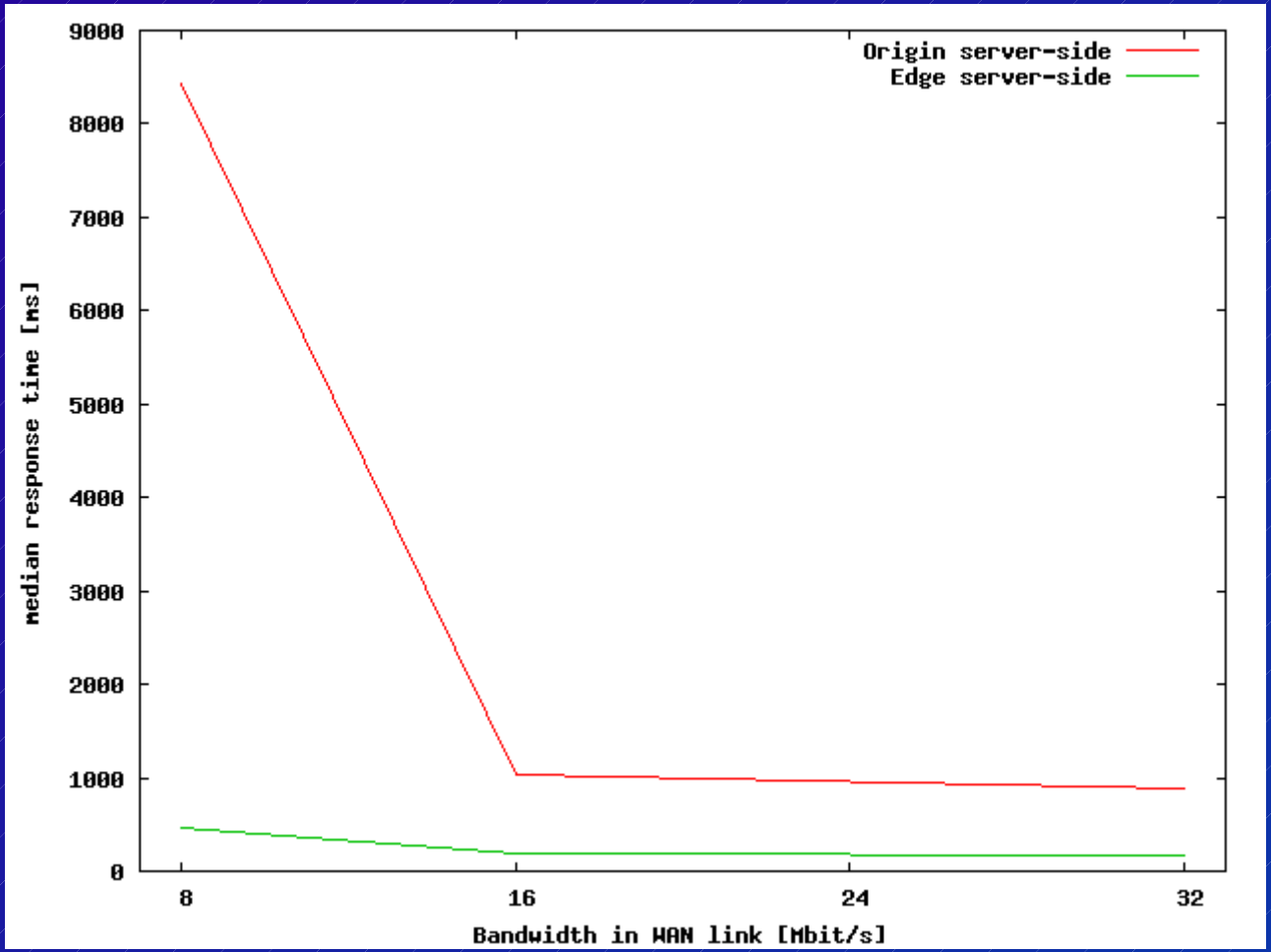


- Performance improvement on median response time (cooperation can improve cache hit rate)
- Less advantage for the 90-percentile (a miss is more expensive in the case of cooperation)

Summary (architecture comparison)

- Pushing content adaptation on the network edge has a significant performance gain in the case of “light” services
  - Network-related time is dominant
  - In the case of a cache hit we save a connection to the origin server
- Performance gain from cooperation is related to the effectiveness of cooperative caching. Limited global performance gain
  - Cooperation increases the hit rate
  - No gain in the case of cache miss

Sensitivity to network parameters: Origin vs. Edge server-side



Median response time
Photo album workload

- Edge server-side provides better performance
  - Lower response time
  - Reduced sensitivity to bandwidth
  - Reduced number of open sockets (less parallel requests)

Sensitivity to network parameters: impact of cooperation

- In the case of poor network bandwidth cooperation increases dramatically performance
- The cooperation reduces sensitivity to network effects

Bandwidth [Mbit/s]	Edge server-side architecture		Cooperative edge server-side architecture			
	Adapt.-Origin server		Adapt.-Origin server		Adapt.-Adapt. server	
	Response time		Response time		Response time	
	median	**90-perc.**	**median**	**90-perc.**	**median**	**90-perc.**
8	470	54680	170	2030	150	1960
16	180	1848	130	1870	130	1870
32	170	1630	110	1660	110	1790

Summary (sensitivity to network)

- Edge server-side architecture reduces network utilization with respect to the Origin server-side approach
  - Reduction in the sensitivity to network parameters
- Cooperation further reduces the load on the network links
- The real advantage from cooperation lies in the limited sensitivity to network parameters

Conclusions

- Gain from pushing content adaptation on the network edge
  - Edge server-side approach is always best
  - The performance gain is more evident in the case of services with lower computational complexity

→ We should move “light” services towards the edge

- Advantages achieved through cooperation
  - **Reduction in sensitivity to network parameters**

→ We should exploit cooperation in the case of poor network conditions (e.g., low bandwidth and/or network congestions)

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For more information:

http://weblab.ing.unimo.it/research/trans_caching.shtml

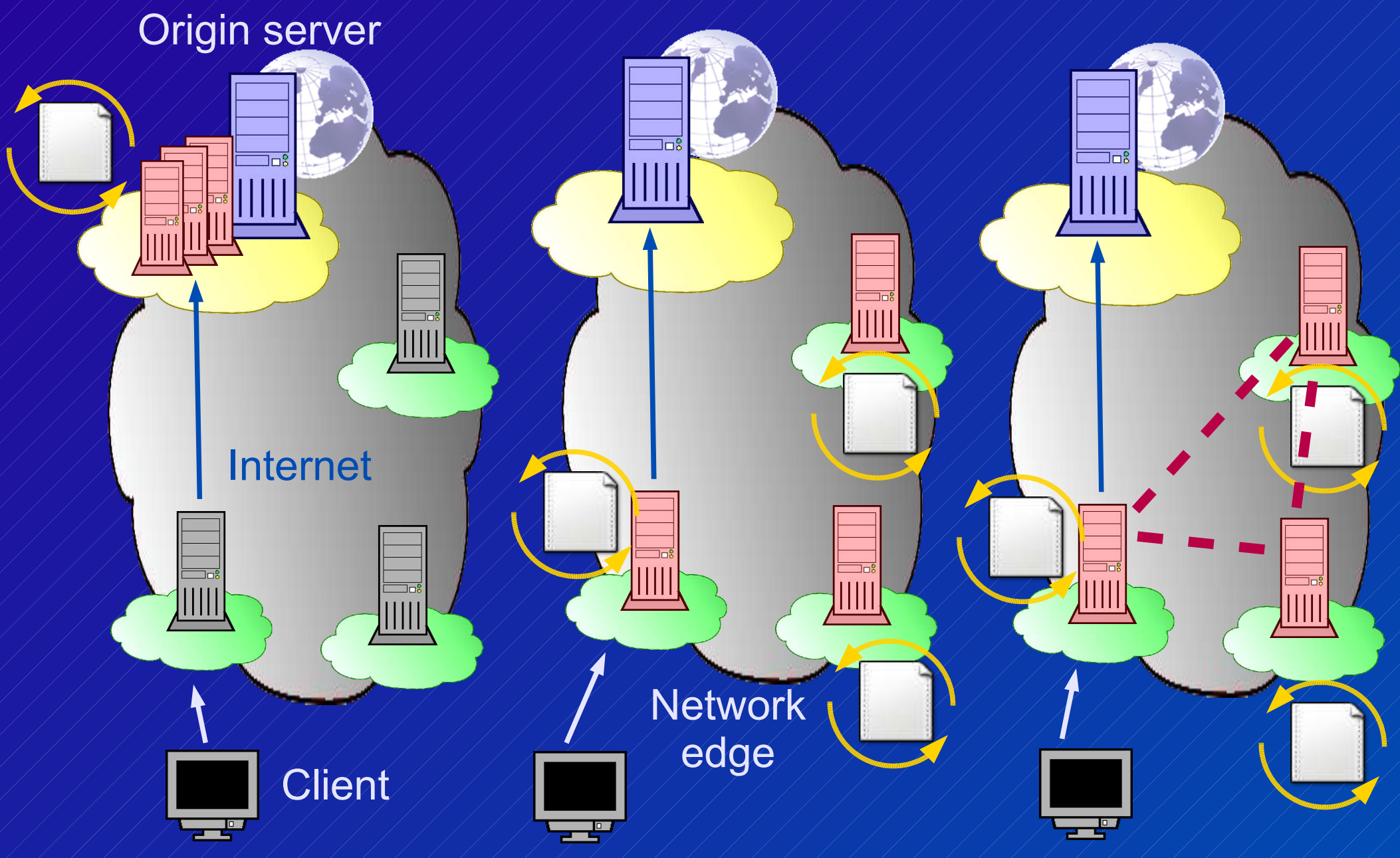
Conclusions

- Edge server-side architecture outperforms Origin server-side approach
  - Performance gain is more evident when content adaptation time is reduced
  - Performance gain increases dramatically in the case of low bandwidth links
- Cooperation in edge server-side architecture provides better performance
  - Performance gain less evident then in the case of origin-server side architecture
  - Cooperation reduces sensitivity to network parameters

Critical Issue

- Content adaptation is computationally expensive
  - Can take advantage from caching
  - We can reduce computational load by exploiting already-adapted resources
- Caching in a content adaptation system is more complex than traditional Web caching
  - Multiple versions of the same resource
  - We need multi-version lookup
  - We have a rich caching semantics: a lookup can result in Exact hit, Useful hit and Miss

Architectures



Providing Web content adaptation

- Three base approaches
  - ~~Client-side~~
  - Origin server-side
  - Edge-side (possibly cooperative)
- Drawbacks of the client-side approach
  - Limited computation power on edge nodes (not efficient)
  - Requires client-specific implementation (not general)
  - Does not save bandwidth (not effective)