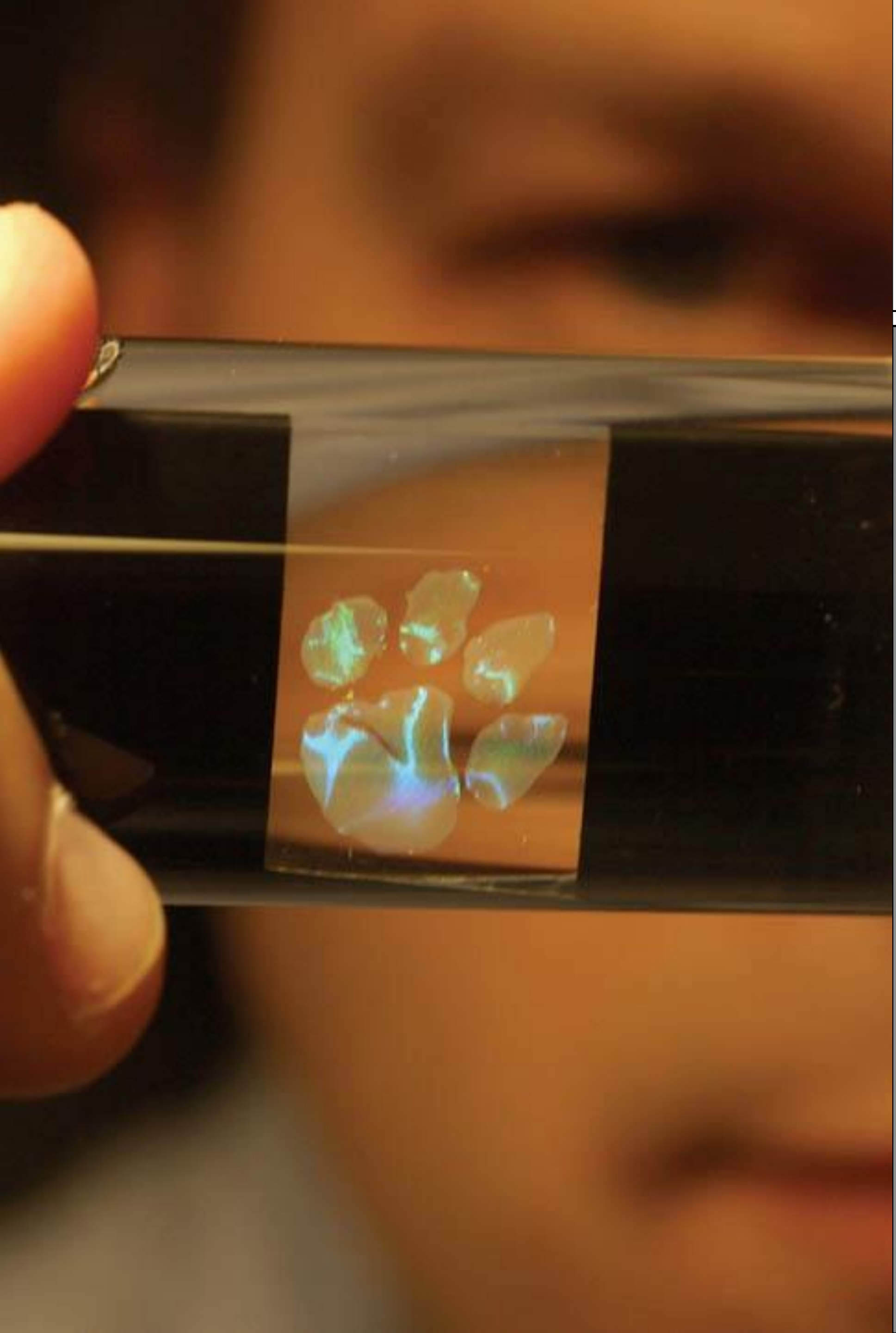

CLEMSON UNIVERSITY

Measuring and Evaluating Live Content Consistency in a Large-Scale CDN

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Outline

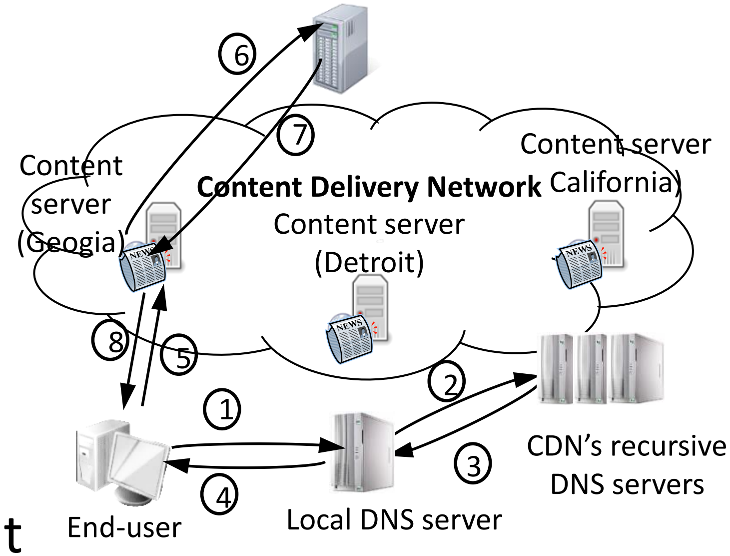
- Introduction
- Related work
- Inconsistency analysis
- Performance evaluation
- Conclusion

Introduction

- Content Delivery Networks (CDNs)
  - Cache/replicate contents to surrogate servers near the network edge
  - Optimize the end user experience with short access latency
- Trends:
  - Increased number of enterprises (28 commercial CDNs)
    - Akamai, Limelight, Level 3, Turner, ChinaCache, …
  - Scale up rapidly, as Akamai:
    - 85,800 servers in 1800 districts over 79 countries
    - Growing scale: 50% servers due to 100% increases of traffic per year

Introduction

- Architecture of CDNs
  - (1)-(4) recursively resolve the hostname
    - (2)-(3) for load balancing with Locality awareness
  - (5)-(8) get the requested content
    - Acting as a proxy



- Dynamic contents: (live game statistics)
  - Non-trivial for consistency maintenance: Large amount & widely scattered replicas
  - Introduce two requirements**: Scalable and consistency guarantee**

Introduction

- Our contribution:
  - To help develop consistency maintenance approaches for CDNs by answering
    - Can the current update method used in the CDN provide high consistency for dynamic contents?
      - Measuring the inconsistency of a major CDN
    - What are the reasons for the content inconsistency?
      - Breaking down the inconsistency reasons
    - What are the advantages and disadvantages of employing previously proposed consistency maintenance approaches in the CDN environment?
      - Trace-driven experiments show the performance

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Related work

- Update infrastructures:
  - Unicast: Low scalability
  - Broadcast: High overload
  - Multicast: Not dynamism resilient
- Update method:
  - Time To Live (TTL): high scalability vs. low consistency
  - Push: high consistency vs. unnecessary traffic
  - Invalidation: traffic saving vs. long access latency
- Problem:
  - None of current update infrastructures together with update methods can achieve both scalability and consistency guarantee with traffic cost minimization.

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  - Trace crawl
  - Inconsistency breakdown
- Performance evaluation
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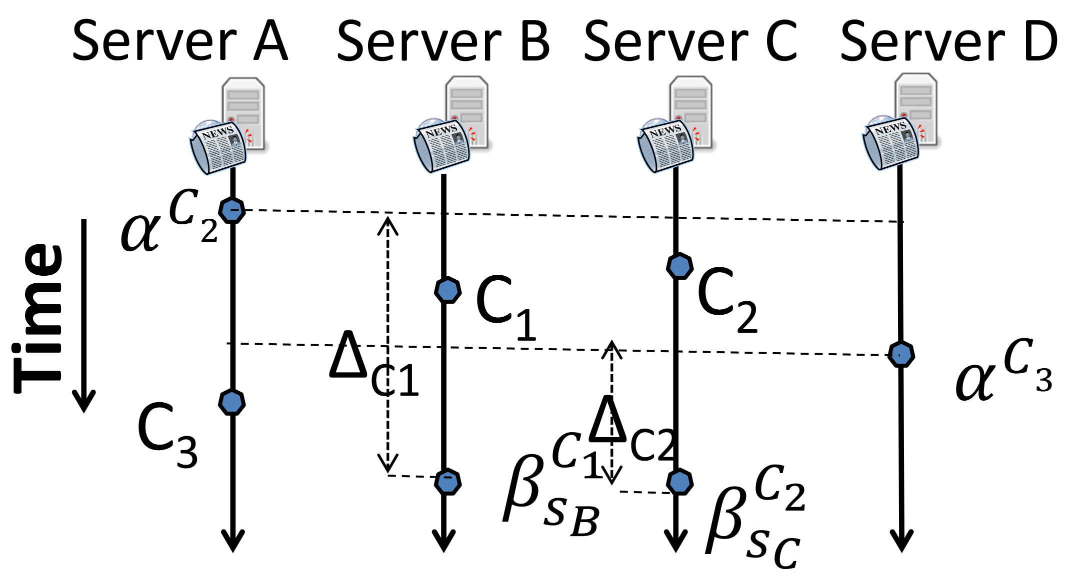
Trace crawl

- CDN and content publisher server crawl process:
  - Retrieval all domain names after crawling all webpages of a sport game portal
  - 300 geo-distributed PlanetLab nodes to get IPs through local DNS service
    - Domain -> CNAMEs -> Edge server URL-> IPs
  - 10 IPs of the provider and 50064 IPs of the CDN
- Content crawl process:
  - 200 globally distributed PlanetLab nodes.
    - Towards 3000 random selected IPs
  - Live statistical webpages served by a major CDN
    - 15 day trace between May 15, 2012 and June 4, 2012.

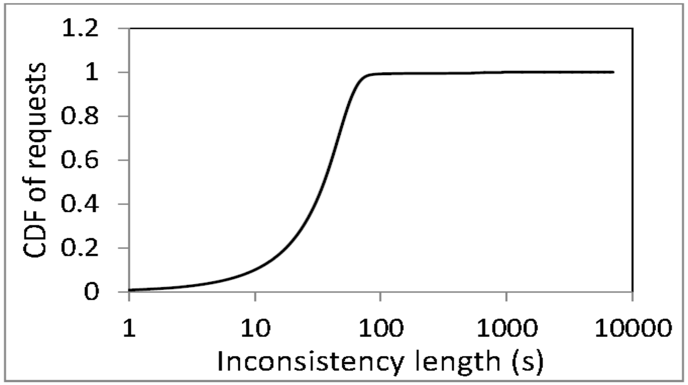
Inconsistency breakdown

- Inconsistency measurement method
  - C_i: The i^{th} update
  - α^{C_i}: The first time when C_i shows up among all servers
  - $\beta_{s_B}^{C_{i-1}}$: The last time when C_{i-1} shows up
  - $\Delta_{C_{i-1}} = Max\{\beta_{s_B}^{C_{i-1}} - \alpha^{C_i}\}$

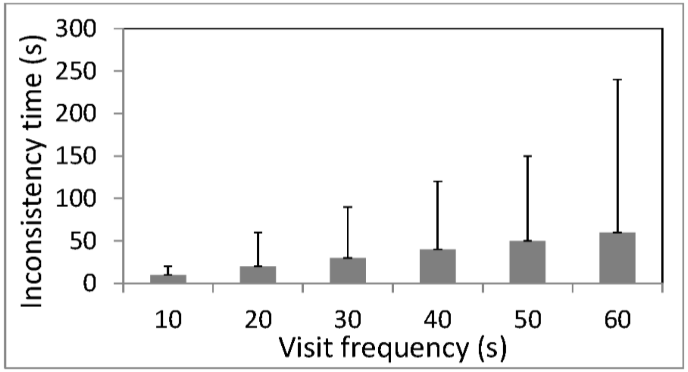


Inconsistency breakdown

- Is there any inconsistency?
  - 10.1% having inconsistency < 10s
  - 20.3% having inconsistency > 50s

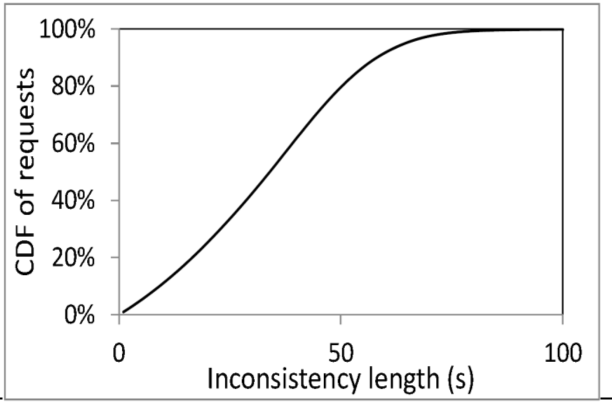


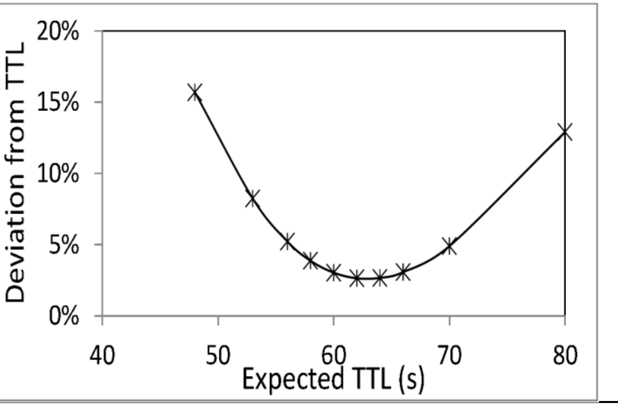
- Does a user can observe inconsistency?
  - Inconsistency: Continuous inconsistency time is proportional to TTL of a user's browser
  - Cause: Switching between CDN edge servers
  - Conclusion: The edge servers have inconsistencies



Inconsistency breakdown

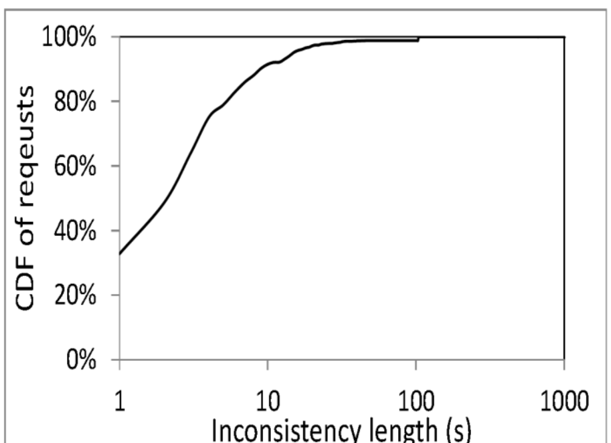
- Effect of TTL of CDN servers
  - Measure the inner cluster inconsistency (by location)
    - Exclude the propagation delay effect
    - TTL = 80s = 2* Average inconsistency = 2 * 40s
  - TTL refinement
    - Exclude the other factors' affection
    - Calculate the standard deviation
      - Expected distribution VS. Actual distribution within expected TTL
      - TTL=60s (with smallest deviation) = 75% of 80s

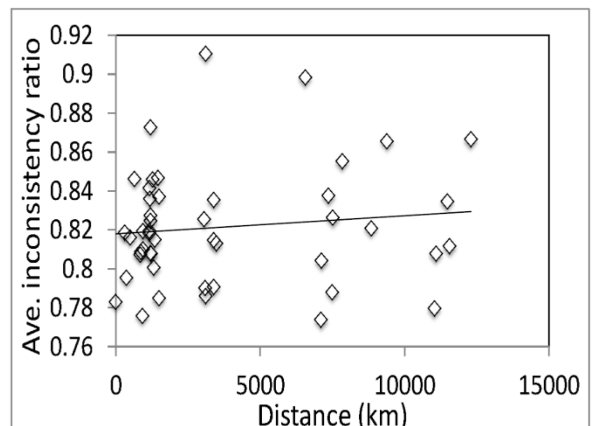




Inconsistency breakdown

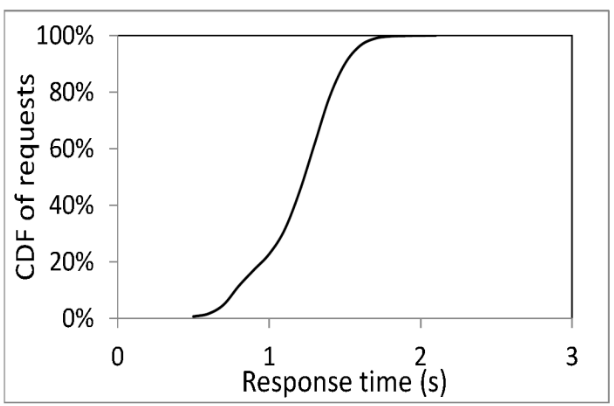
- Effect of content provider's inconsistency
  - 90.2% of served requests have inconsistency < 10s
  - Average inconsistency = 3.43s = **4.3%***80s
- Effect of provider-server propagation delay
  - Average consistency ratio VS. provider-server distance
  - Correlation between two factors = 0.11
    - Little effect on inconsistency

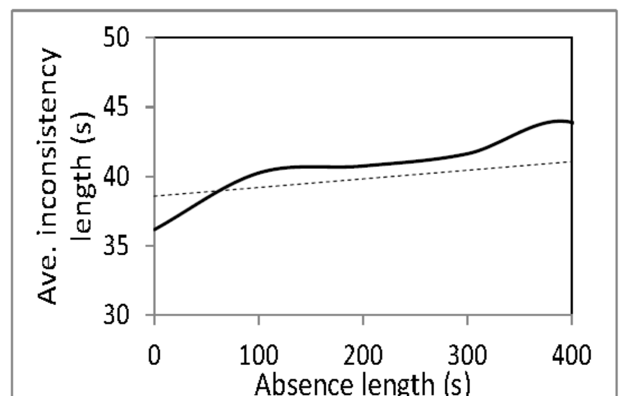




Inconsistency breakdown

- Effect of content provider's bandwidth
  - Measure the response time for querying contents
  - [0.5, 2.1]s and 90% requests < 1.5
  - Inconsistency effect: 0.5s = **0.6%** * 80s (negligible)
- Effect of CDN server failure and overload
  - Measure the inconsistency after the absence with certain length
  - Effect < 8s = **10%** *80s





Inconsistency breakdown

- Possible causes:
  - TTL of CDN servers
  - Provider-server propagation delay
  - Content provider servers' inconsistency
  - Content providers' bandwidth
  - CDN server overload and failure
- Influence:
  - TTL contributes around 75% of average inconsistency
    - Easy to solve by changing update methods
  - Other factors contribute significantly less than TTL
    - Expensive to solve compared to TTL

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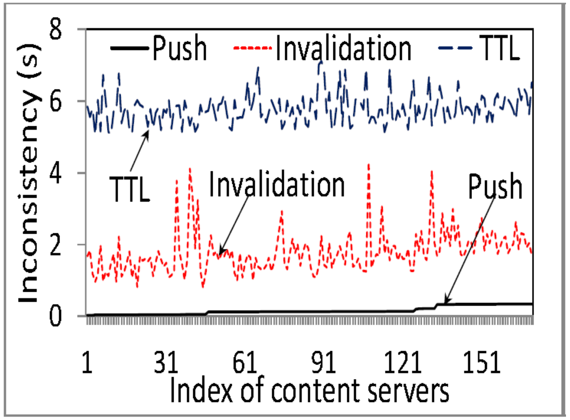
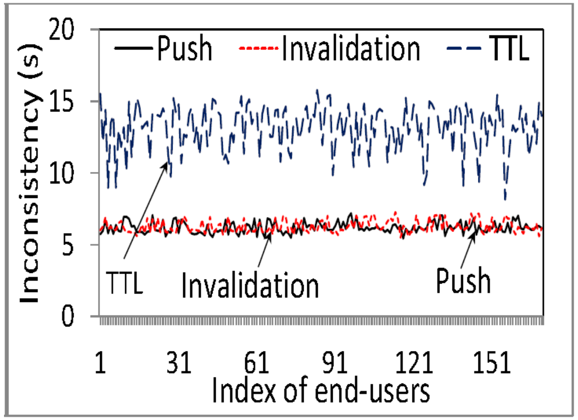
Performance evaluation

- Experimental settings:
  - CDN servers: 170 PlanetLab nodes with high performance and light load in the U.S., Europe, and Asia.
  - Content provider server: One PlanetLab node in Atlanta
  - Trace: Live game events on Jun. 2nd, 2012
    - 306 different snapshots
    - 2 hours and 26 minutes long
  - Users: Each PlanetLab node simulates five browsers

Performance evaluation

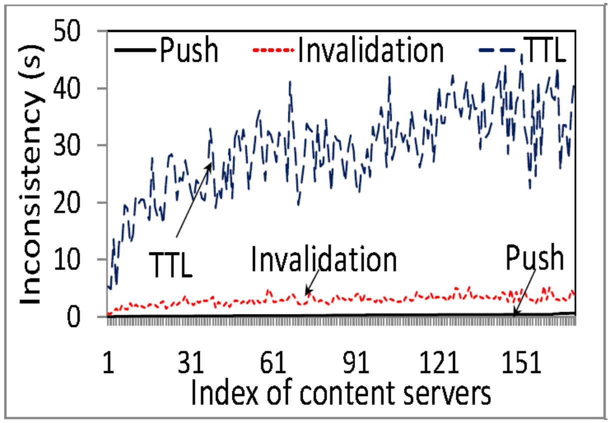
- Inconsistency under unicast
  - Inconsistency among CDN servers
    - Push < Invalidation < TTL
    - Push needs a long time to update (central server bottleneck)
  - Inconsistency among users
    - Push ≈ Invalidation < TTL

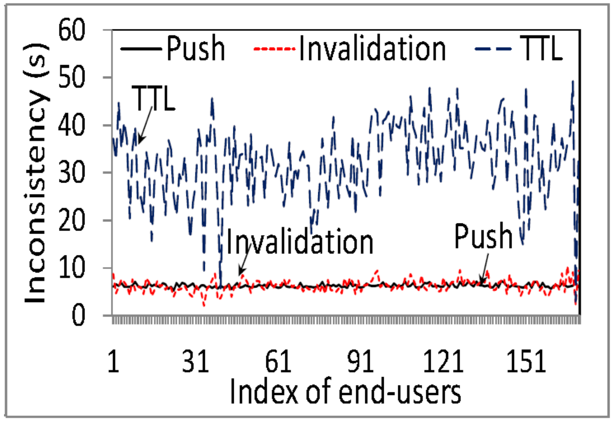




Performance evaluation

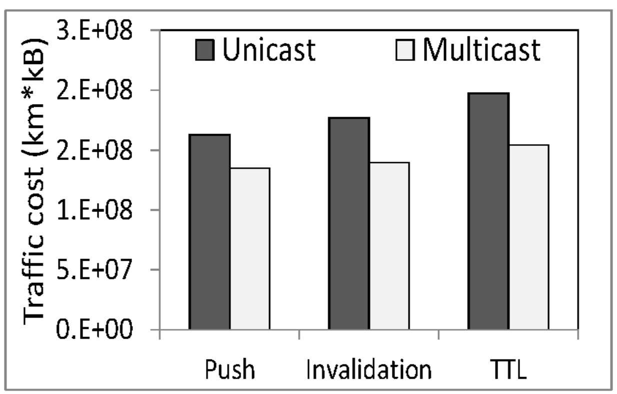
- Inconsistency under multicast
  - Inconsistency among CDN servers
    - Push < Invalidation < TTL (larger inconsistency for nodes at lower level in the tree)
    - Push needs a small time to update (scalable)
  - Inconsistency among users
    - Push ≈ Invalidation < TTL

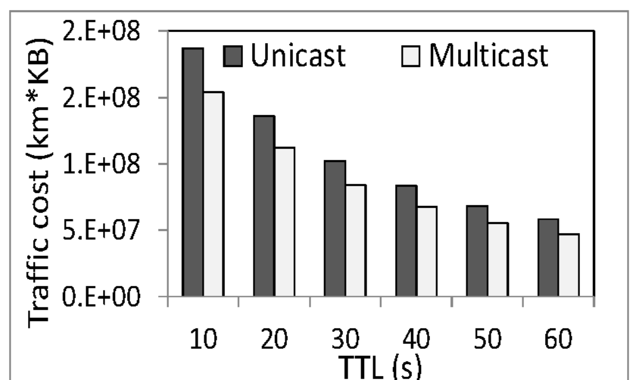




Performance evaluation

- Traffic cost
  - Multicast vs. Unicast
    - Unicast > Multicast (locality-aware)
  - Traffic cost for different methods
    - Scenario: Frequent & Rare updates and frequent visits
    - Push < invalidation < TTL
    - Different scenarios lead to different results -> Provide guidance for selecting or designing a CDN's consistency maintenance methods





Performance evaluation summary

- Update methods
  - Push:
    - Better consistency in a small-scale network
    - Lacks of scalability
  - Invalidation:
    - Similar consistency guarantee as Push to users with reduced traffic cost
    - Has heavy network burden for invalidation notification for frequently updated contents
  - TTL
    - Weak consistency
    - Better scalability
    - Waste cost by rarely updated contents
- Update infrastructures
  - Unicast
    - Little effect on inconsistency
    - Lacks of scalability
  - Multicast
    - Scalable (needs dynamism resilience)
    - Large effect on inconsistency when using TTL

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Conclustion

- Trace on thousands of CDN servers
  - Inconsistency does exist and users can observe it
  - Possible causes:
    - 1) TTL of CDN servers (major effect), 2) Provider-server propagation delay, 3) Content provider servers' inconsistency, 4) Content providers' bandwidth 5) CDN server overload and failure (large effect)

- Experiments (thousands of CDN servers)
  - Different infrastructures and methods
    - Effectiveness: consistency performance
    - Overhead: scalability

- Future work:
  - A hybrid and self-adapted consistency maintenance method
    - Scalable & Consistency& Cost minimization

Thank you!

Questions & Comments?

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