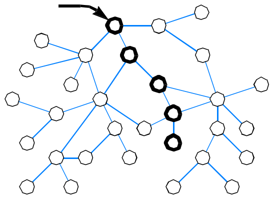
INF5070 – Media Servers and Distribution Systems:

Distribution – Part II

24/10 – 2005

Type IV – Distribution Systems

- Combine
  - Types I, II or III
  - Network of servers
- Server hierarchy
  - Autonomous servers
  - Cooperative servers
  - Coordinated servers
- "Proxy caches"
  - Not accurate ...
  - Cache servers
    - Keep copies on behalf of a remote server
  - Proxy servers
    - Perform actions on behalf of their clients



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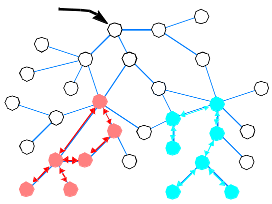

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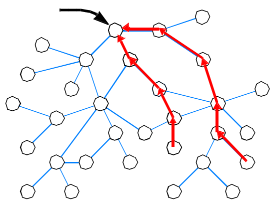


Type IV – Distribution Systems

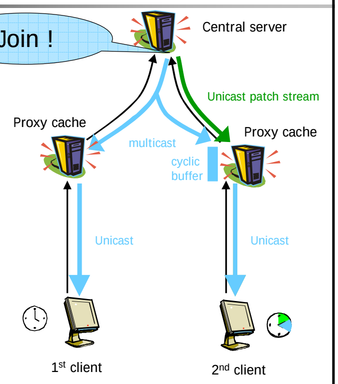
- Variations
  - Gleaning
    - Autonomous, coordinated possible
    - In komssys
  - Proxy prefix caching
    - Coordinated, autonomous possible
    - In Blue Coat (which was formerly Cacheflow, which was formerly Entera)
  - Periodic multicasting with pre-storage
    - Coordinated
    - The theoretical optimum

Gleaning

- *Webster's Dictionary: from Late Latin glennare, of Celtic origin*
  1. *to gather grain or other produce left by reapers*
  2. *to gather information or material bit by bit*
- Combine *patching* with *caching* ideas
  - non-conflicting benefits of caching and patching
- Caching
  - reduce number of end-to-end transmissions
  - distribute service access points
  - no single point of failure
  - true on-demand capabilities
- Patching
  - shorten average streaming time per client
  - true on-demand capabilities

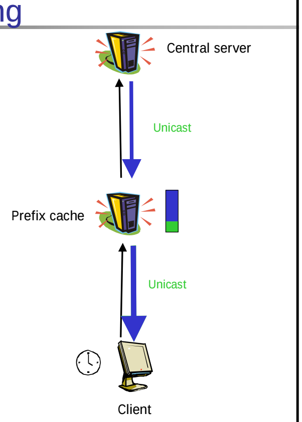
Gleaning

- Combines Patching & Caching ideas
  - Wide-area scalable
  - Reduced server load
  - Reduced network load
  - Can support standard clients



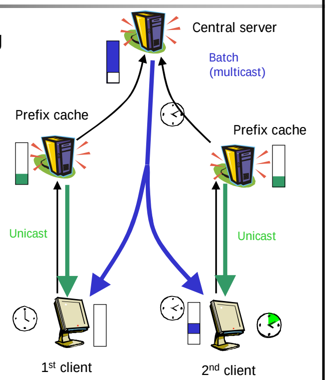
Proxy Prefix Caching

- Split movie
  - Prefix
  - Suffix
- Operation
  - Store prefix in prefix cache
    - Coordination necessary!
  - On demand
    - Deliver prefix immediately
    - Prefetch suffix from central server
- Goal
  - Reduce startup latency
  - Hide bandwidth limitations, delay and/or jitter in backbone
  - Reduce load in backbone



MCache

- One of several Prefix Caching variations
- Combines Batching and Prefix Caching
  - Can be optimized per movie
    - server bandwidth
    - network bandwidth
    - cache space
  - Uses multicast
  - Needs non-standard clients

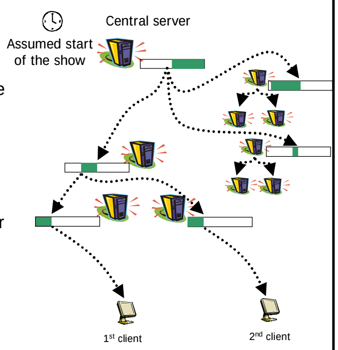


Proxy Prefix Caching

- Basic version
  - Practical
  - No multicast
  - Not optimized
  - Aimed at large ISPs
  - Wide-area scalable
  - Reduced server load
  - Reduced network load
  - Can support standard clients
  - Can partially hide jitter
- Optimized versions
  - Theoretical
  - Multicast
  - Optimized
  - Optimum is constantly unstable
    - jitter and loss is experienced for each client !

Periodic Multicasting with Pre–Storage

- Optimize storage and network
  - Wide-area scalable
  - Minimal server load achievable
  - Reduced network load
  - Can support standard clients
- Specials
  - Can optimize network load per subtree
- Negative
  - Bad error behaviour



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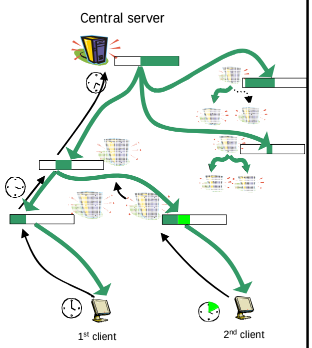


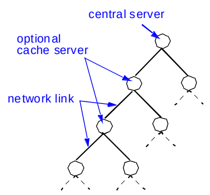
Type IV – Distribution Systems

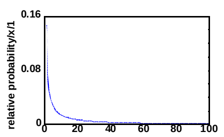
- Autonomous servers
  - Requires decision making on each proxy
  - Some content must be discarded
  - Caching strategies
- Coordinated servers
  - Requires central decision making
  - Global optimization of the system
- Cooperative servers
  - No quantitative research yet

Autonomous servers

Simulation

- Binary tree model allows
  - Allows analytical comparison of
    - Caching
    - Patching
    - Gleaning
- Considering
  - optimal cache placement per movie
  - basic server cost
  - per-stream costs of storage, interface card, network link
  - movie popularity according to Zipf distribution





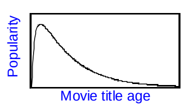
Simulation

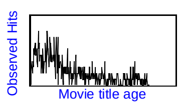
- Example
  - 500 different movies
  - 220 active users
  - basic server: $25000
  - interface cost: $100/stream
  - network link cost: $350/stream
  - storage cost: $1000/stream
- Analytical comparison
  - demonstrates potential of the approach
  - very simplified

Caching	Caching Unicast transmission	4664 Mio $
Patching	No caching Multicast Client side buffer	375 Mio $
Gleaning	Caching Multicast	276 Mio $

Simulation

- Modeling
  - User behaviour
  - Movie popularity development
  - Limited resources
  - Hierarchical topology
- Individual user's
  - Intention
    - depends on user's time (model randomly)
  - Selection
    - depends on movies' popularity
- Popularity development





Caching Strategies

- Strategies
  - FIFO
    - First-in-first-out
      - Remove the oldest object in the cache in favor of new objects
  - LRU
    - Least recently used strategy
      - Maintain a list of objects
      - Move to head of the list whenever accessed
      - Remove the tail of the list in favor of new objects
  - LFU
    - Least frequently used
      - Maintain a list distance between last two requests per object
      - Distance can be time or number of requests to other objects
      - Sort list: shortest distance first
      - Remove the tail of the list in favor of new objects

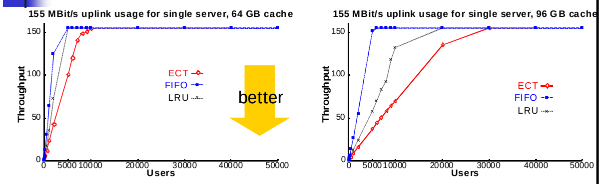
Caching Strategies

- Considerations
  - conditional overwrite strategies
    - can be highly efficient
  - limited uplink bandwidth
    - quickly exhausted
    - performance degrades immediately when working set is too large for storage space

LFU	ECT
Forget object statistics when removed →	Remember object statistics forever
Cache all requested objects →	Compare requested object and replacement candidate
Log # requests or time between hits →	Log times between hits

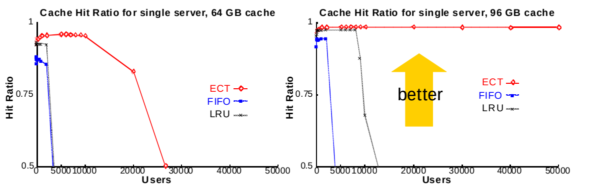
- ECT
  - Eternal, Conditional, Temporal

Effects of caching strategies on throughput



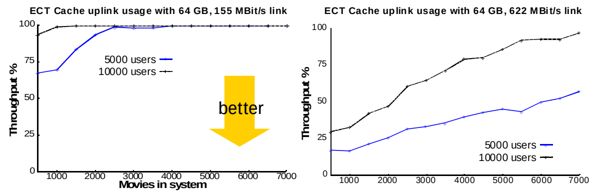
- Movies
  - 500 movies, Zipf-distributed popularity
  - 1.5 MBit/s, 5400 sec, size ~7.9 GB
- Uplink usage
  - profits from small cache increase greatly ...
  - ... if there is a strategy
- Conditional overwrite
  - reduces uplink usage

Effects of caching strategies on user hit rates



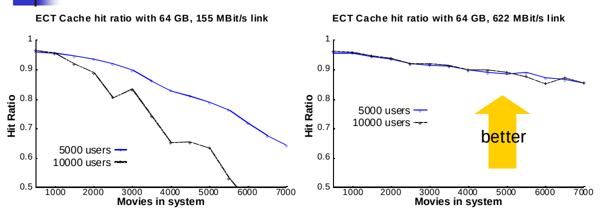
- Hit ratio
  - dumb strategies do not profit from cache size increases
  - intelligent strategies profit hugely from cache size increases
  - strategies that use conditional overwrite outperform other strategies massively
    - doesn't have to be ECT

Effects of number of movies on uplink usage



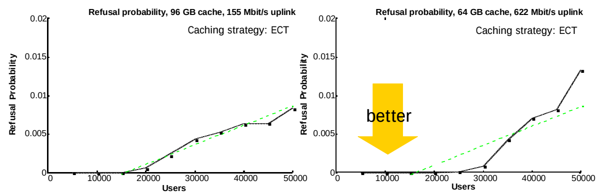
- In spite of 99% hit rates
  - Increasing the number of users will congest the uplink
  - Note
    - scheduling techniques provide no savings on low-popularity movies
    - identical to unicast scenario with minimally larger caches

Effects of number of movies on hit ratio



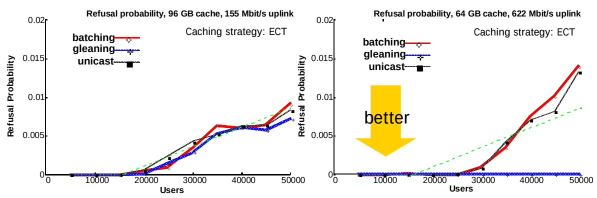
- Limited uplink bandwidth
  - Prevents the exchange of titles with medium popularity
  - Unproportional drop of efficiency for more users
  - Strategy can not recognize medium popularity titles

Effects of user numbers on refusal probabilities



- Refusal in this simulation
  - Equivalent to "renegance"
  - Network is admission controlled – users have to wait for their turn
  - Users wait up to 5 minutes – afterwards count one refusal
- Scenarios
  - Left: cache ~12 movies, uplink capacity ~103 streams
  - Right: cache ~8 movies, uplink capacity ~415 streams
- Uplink-bound scenario
  - No bottleneck between cache server and clients
  - Moderately popular movies can exhausted uplink bandwidth quickly
  - Unicast gains a lot from large caches

Effects of user numbers on refusal probabilities

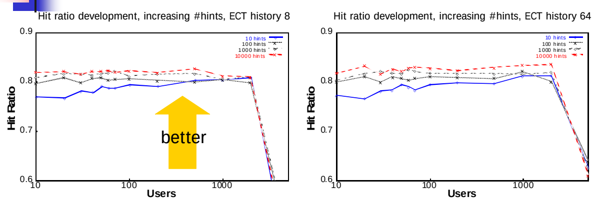


- Uplink-bound scenario
  - Shows that low–popularity movies are accessed like unicast by all techniques
  - Patching techniques with infinite window can exploit multicast
  - Collecting requests does not work
- Cache size
  - Is *not very relevant for patching techniques*
  - Is very relevant for full–title techniques

Bandwidth effect of daytime variations

- Change popularity according to time-of-day
- Two tests
  - Popularity peaks and valleys uniformly distributed
    - Complete exchange of all titles
    - Spread over the whole day
  - Popularity peaks and valleys either at 10:00 or at 20:00
    - Complete exchange of all titles
    - Within a short time-frame around peak-time
- Astonishing results
  - For ECT with all mechanisms
  - Hardly any influence on
    - hit rate
    - uplink congestion
  - Traffic is hidden by delivery of low-popularity titles

Hint–based Caching



- Idea
  - Caches consider requests to neighbour caches in their removal decisions
- Conclusion
  - Instability due to uplink congestion can not be prevented
  - Advantage exists and is logarithmic as expected
    - Larger hint numbers maintain the advantage to the point of instability
  - Intensity of instability is due to ECT problem
    - ECT inherits IRG drawback of fixed–size histograms

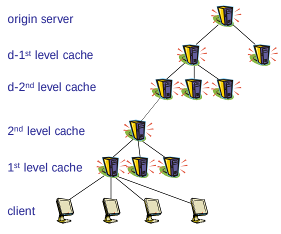
Simulation

- High relevance of population sizes
  - complex strategies require large customer bases
- Efficiency of small caches
  - 90:10 rule–of–thumb reasonable
  - unlike web caching
- Efficiency of distribution mechanisms
  - considerable bandwidth savings for uncached titles
- Effects of removal strategies
  - relevance of conditional overwrite
  - unlike web caching, paging, swapping, ...
- Irrelevance of popularity changes on short timescales
  - few cache updates compared to many direct deliveries

Coordinated servers

Distribution Architectures

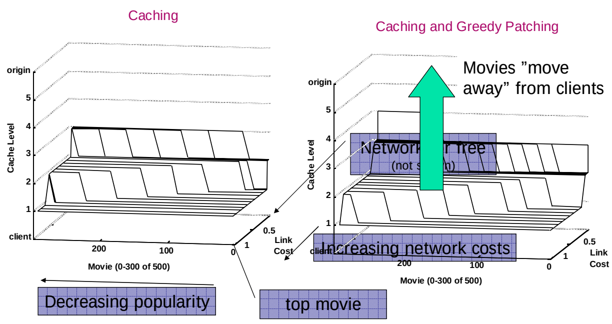
- Combined optimization
  - Scheduling algorithm
  - Proxy placement and dimensioning



Distribution Architectures

- Combined optimization
  - Scheduling algorithm
  - Proxy placement and dimensioning
- No problems with simple scheduling mechanisms
- Examples
  - Caching with unicast communication
  - Caching with greedy patching
    - Patching window in greedy patching is the movie length

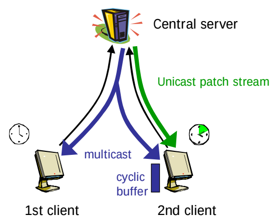
Distribution Architectures

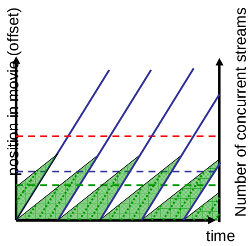


Distribution Architectures

- Combined optimization
  - Scheduling algorithm
  - Proxy placement and dimensioning
- Problems with complex scheduling mechanisms
- Examples
  - Caching with λ–patching
    - Patching window is optimized for minimal server load
  - Caching with gleaning
    - A 1st level proxy cache maintains the "client buffer" for several clients
  - Caching with MPatch
    - The initial portion of the movie is cached in a 1st level proxy cache

λ–Patching

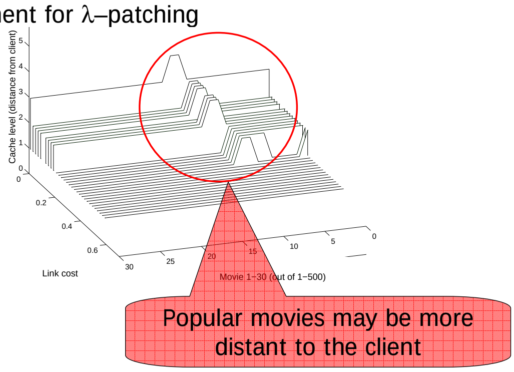




$$\Delta_M = \sqrt{2 \cdot F \cdot \Delta_U}$$

Distribution Architectures

- Placement for λ–patching



Distribution Architectures

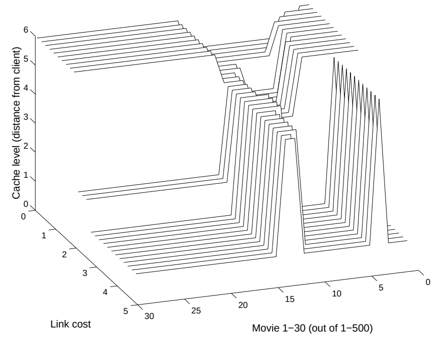
- Failure of the optimization
  - Implicitly assumes perfect delivery
  - Has no notion of quality
  - User satisfaction is ignored
- Disadvantage
  - Popular movies further away from clients
    - Longer distance
    - Higher startup latency
    - Higher loss rate
    - More jitter
  - Popular movies are requested more frequently
  - ***Average*** delivery quality is lower

Distribution Architectures

- Placement for gleaning
  - Combines
    - Caching of the full movie
    - Optimized patching
    - Mandatory proxy cache
  - 2 degrees of freedom
    - Caching level
    - Patch length

Distribution Architectures

- Placement for gleaning

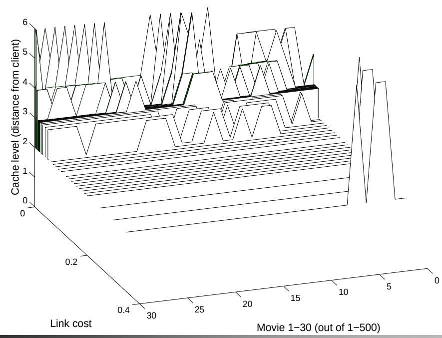


Distribution Architectures

- Placement for MPatch
  - Combines
    - Caching of the full movie
    - Partial caching in proxy servers
    - Multicast in access networks
    - Patching from the full copy
  - 3 degrees of freedom
    - Caching level
    - Patch length
    - Prefix length

Distribution Architectures

- Placement for MPatch



Approaches

- Consider quality
  - Penalize distance in optimality calculation
  - Sort
- Penalty approach ☹
  - Low penalties
    - Doesn't achieve order because actual cost is higher
  - High penalties
    - Doesn't achieve order because optimizer gets confused
- Sorting ☺
  - Trivial
  - Very low resource waste

Distribution Architectures

- Combined optimization
  - Scheduling algorithm
  - Proxy placement and dimensioning
  - Impossible to achieve optimum with autonomous caching
- Solution for complex scheduling mechanisms
- A simple solution exists:
  - Enforce order according to priorities
    - (simple sorting)
  - Increase in resource use is marginal

References

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