Cooperative Cache Based Data Access in Ad Hoc Networks

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Motivation

- Data access issues in ad hoc networks:
  - Long query delay due to multi-hop links
  - Low data availability due to node/link failure
- Cooperative caching schemes
  - Share and coordinate cached data.
  - Reduce query delay, bandwidth/power consumption.
- Battle field:
  - Officer may have a powerful data center. Soldiers need to access the data center to get geographic info, enemy info, and new commands. Neighboring soldiers share these info.
- InfoStations
  - Infostations are deployed in cities to provide info, such as maps, attractive sites, or restaurant info to mobile users. Users may relay for each other to serve those not directly covered by the infostations.

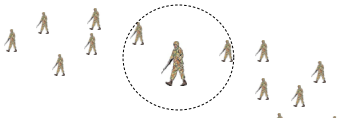

Fig. 1: Battle field example.

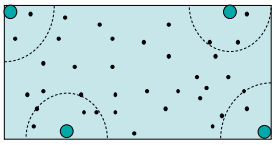

Fig 2: InfoStation Example

Green node: infostation; Black node: mobile node

Data Access Framework

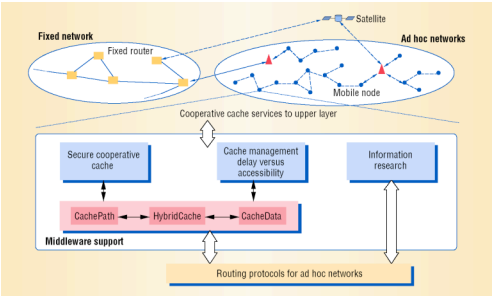

Fig. 3: Cooperative cache-based data access framework

- The cooperative cache-based data access framework stays on top of the routing protocol.
- It relies on several components such as
  - Secure cooperative caching,
  - Cache Management,
  - Information search

  to provide services to upper layer.

System Model

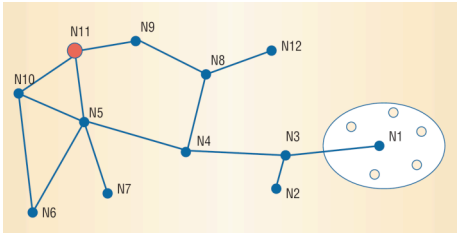

Fig. 4: Ad hoc networks. Node N_{11} is a data center and the blue nodes are router nodes. Node N_1 is a cluster header surrounded by cluster member nodes.

The Cache Protocols

The CacheData Scheme

- Router nodes caches frequently accessed passing-by data to serve future requests.
  - An example (using Fig. 4)
    - Suppose both N_6 and N_7 requested data item d_i through N_5.
    - N_5 might think that d_i is popular and cache it locally.
    - N_5 can then serve N_4's request directly.

The CachePath Scheme

- Cache the node *id* that requests the data when a data item passes by.
  - An example (using Fig. 4)
    - Suppose N_1 requests d_i from N_{11}.
    - When N_3 forwards d_i to N_1, it caches the id pair of N_1 and d_i : (i, 1).
    - Future requests for d_i from N_2 can be redirected to N_1 to reduce query delay and resource consumption.

HybridCache- a Hybrid Scheme

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(A) When a data item d_i arrives:
        if d_i is the requested data by the current node
        then cache d_i
        else /* Data passing by */
        if there is a copy of d_i in the cache
        then update the cached copy if necessary
        else if S_i < τ_S or TTL_i < τ_TTL then
                cache data item d_i and the path;
        else if there is a cached path for d_i, then
                cache data item d_i;
                update the path for d_i;
        else
                cache the path of d_i;

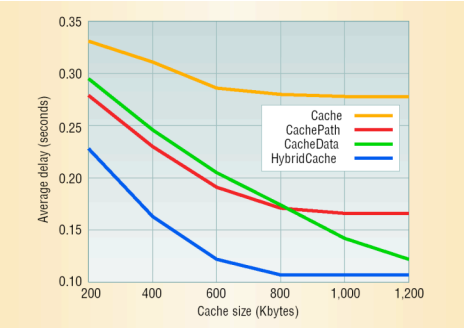
(B) When a request for data item d_i arrives:
        if there is a valid copy in the cache
        then send d_i to the requester;
        else if there is a valid path for d_i in the cache then
                forward the request to the caching node;
        else
                forward the request to the data center;
```

Fig. 5: HybridCache: take advantage of both CacheData and CachePath.

Cache Management

- Cache replacement policies
  - To determine whether to replace d_i, node Ni considers:
    - δ: Distance of Ni to the data center or a caching node of di, small δ value is preferred for removal.
    - ζ: last update time of δ, obsolete data is preferred.
    - Combinations of δ and ζ can affects the tradeoffs between query delay and data accessibility.
- Cache admission control
  - Following similar rules used in cache replacement

Experimental Result



Conclusion

- A cooperative cache-based data access framework
  - Let mobile nodes cache the data or path to the data to reduce the query delay and improve data accessibility
  - Provide secure cooperative cache, cache management, and information search services to upper layer.