Consolidated Caching with Cache Splitting and Trans-rating in Mobile Edge Computing Network

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Overview

Mobile Edge Computing (MEC)

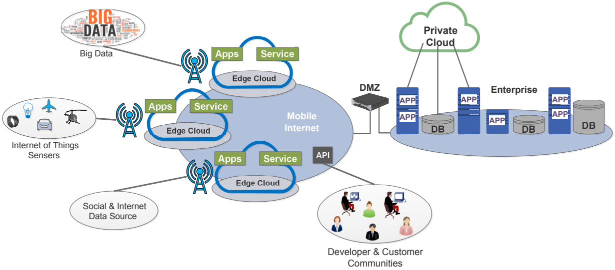

Figure 1: An overview of Mobile Edge Computing(MEC) [1].

- Proximity
- Ultra-low latency
- High bandwidth
- Real-time access to radio network information
- Location awareness

[1] Image source - ETSI White Paper on MEC 2014.

Motivation

- Global data traffic will reach 49 Exabytes per month by 2021 and 78% of total mobile data traffic will be video data [2].
- Expanding network capacity may temporarily mitigate the network congestion!
- In network caching can solve the problem.
- To enable caching in the network - An architecture is required to provide storage and processing.
- Mobile Edge Computing (MEC) is a suitable architecture to enable edge caching [3].

System Architecture

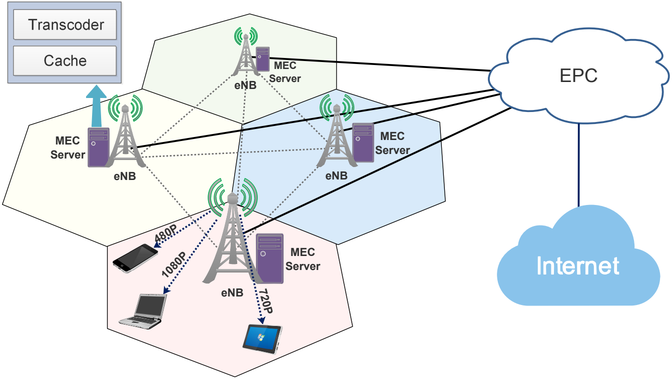

Figure 2: Mobile caching system where the edge-cache is deployed on the MEC server at the eNBs.

Proposed Solutions

Cache Consolidation

- No replication, only one copy of video in the cache network.
- More videos can be stored in the network.
- May lead to increase in delay.

Cache Splitting

- Logical splitting of cache storage to store complete and initial segments of the video.
- Helps in keep check on delay.

Proposed Solution: Cache Consolidation

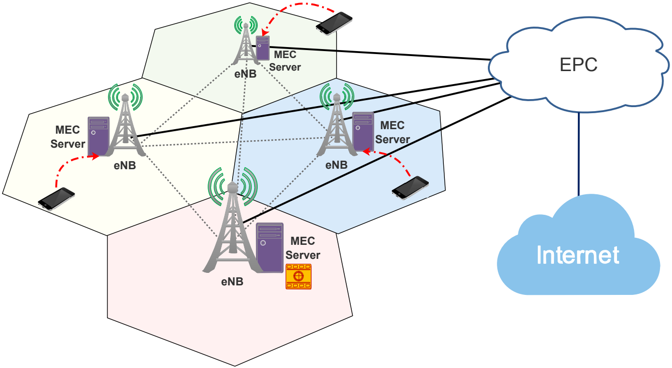

Figure 3: Cache consolidation in MEC network.

Proposed Solution: Cache Consolidation

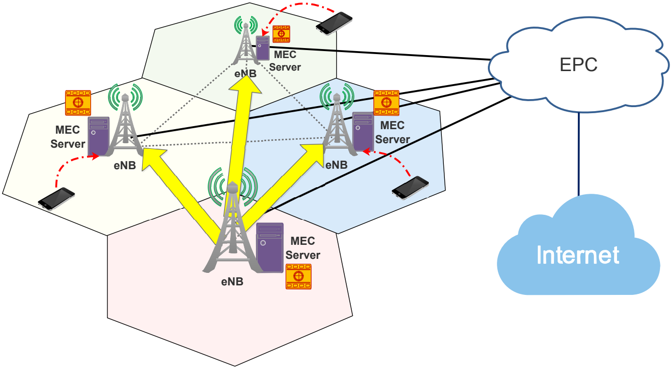

Figure 4: Cache consolidation in MEC network.

Proposed Solution: Cache Consolidation

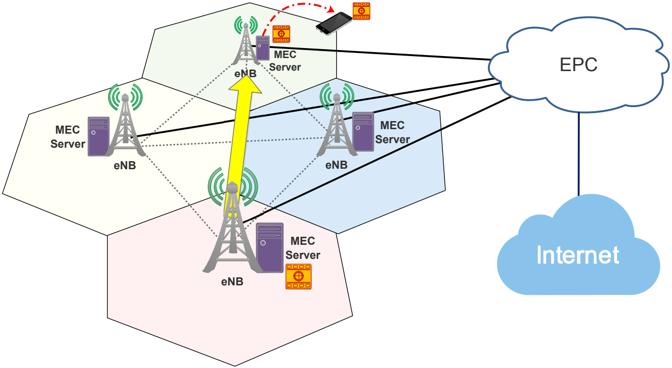

Figure 5: Cache consolidation in MEC network.

Proposed Solution: Cache Consolidation

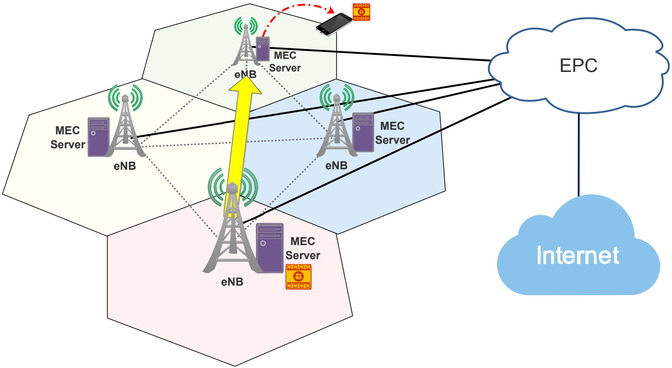

Figure 6: Cache consolidation in MEC network.

Proposed Solution: Cache Consolidation

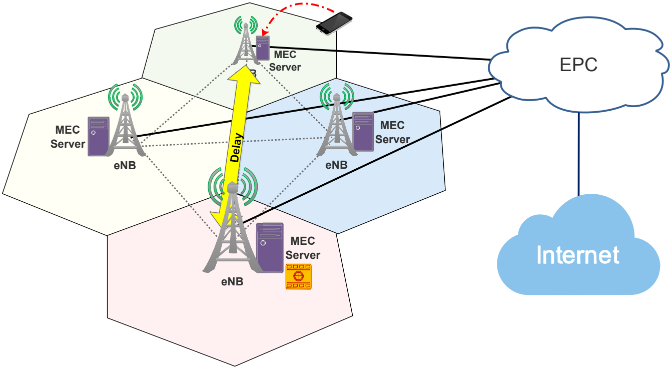

Figure 7: Cache consolidation in MEC network.

Proposed Solution: Cache Splitting

- Cache storage can be split logically to store complete and initial segments of the videos.
- Caching initial segments helps in reducing the delay.

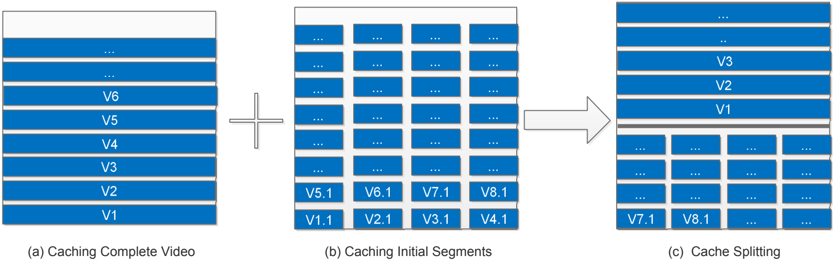

Figure 8: Cache splitting to store complete and initial video.

Proposed Solution: Cache Splitting

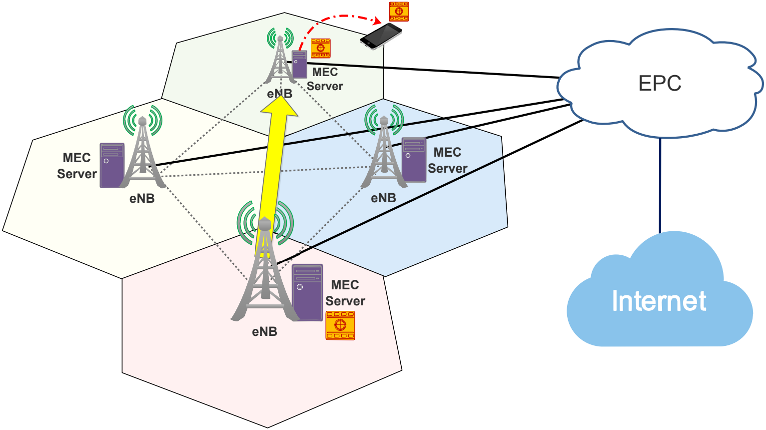

Figure 9: Cache splitting to store complete and initial video.

Proposed Solution: Cache Splitting

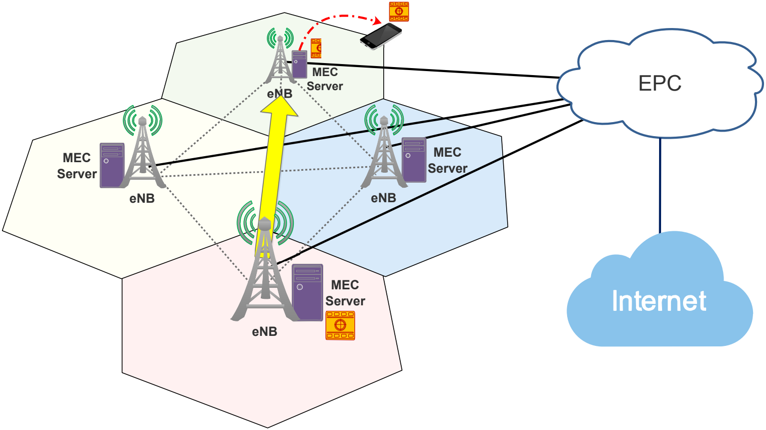

Figure 10: Cache splitting to store complete and initial video.

Analytical Model for Cache Splitting

Average delay D,

$$D = H.d_h + (1 - H).d_m$$
$$D = d_m - (d_m - d_h).\left\{\frac{ln(C_s) - ln(1 - x.(1 - n)) - ln(n.b)}{ln(N)}\right\}$$

Total external traffic T,

$$T = H_i.(1 - n).b + (1 - H).b$$
$$T = b - \frac{b}{ln(N)}[(1 - n).ln(x) + n.ln(1 - x.(1 - n)) + ln(C_s) - ln(b) - n.ln(n)]$$

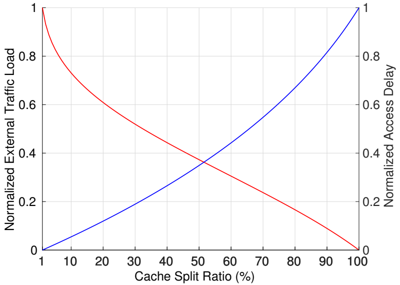

Figure 11: Effect of cache splitting on delay and external traffic.

Related Work

CachePro[4]

- Proposed ABR rate selection algorithm.
- Cache the content at the base station on MEC.
- Apply transcoding/transrating to convert the high bitrate video to low bitrate video and use proactive caching to download videos beforehand.

- There is no collaboration among the MEC servers, so same video might stored on different MEC servers.

Related Work

Joint Collaborative Caching and Processing(JCCP)[5]

- Apply transcoding/transrating to convert the high bitrate video to low bitrate video.
- Collaboration among the MEC servers for cached content and transrating.
- Formulation of delay a optimization problem

- Collaboration among MEC servers but no cache consolidation.
- Complete videos are cached.

Performance Metrics

Hit Ratio

Fraction of requests fulfilled from the MEC network cache.

Average Access Delay

The average latency of content traveling from cache or CDN/content server to the user device.

External Backhaul Traffic Load

The amount of data fetched from CDN/content server to fulfill the user request.

Simulation Parameters

Parameter	Value
MEC Servers	4
UEs per MEC	100
Inter request interval	8 Min.
Total simulation time	5000 Min
Length of the video	10 Min.
Number of videos	2000
Bitrates(360p, 480p, 720p, 1080p)	[0.4, 1.2, 2.5, 5] Mbps
Video Size	[5, 8, 10, 15] MB/Min.
Zipf parameter (α)	0.8
Delay (MEC — MEC)	[20, 60] ms.
Delay (MEC — Origin server)	[100, 200] ms.
Cache Size	30 GB
Processing Power	30Mbps.
Initial Segments	2 Min.
Split Ratio	75%

Results:

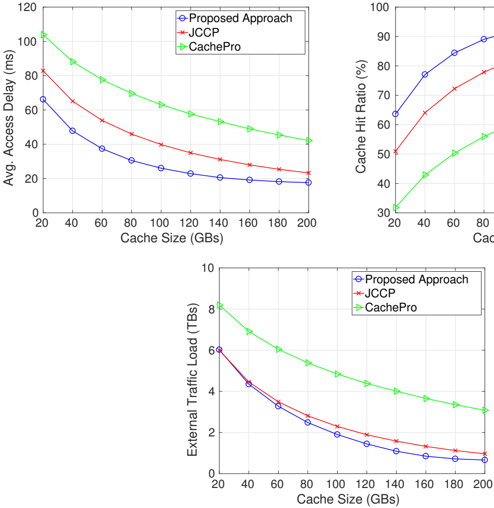

Figure 12: Comparison of caching schemes for different cache size at each MEC server; cache split ratio $x = 75\%$; processing power at each MEC server $G_j = 50Mbps$.

Results:

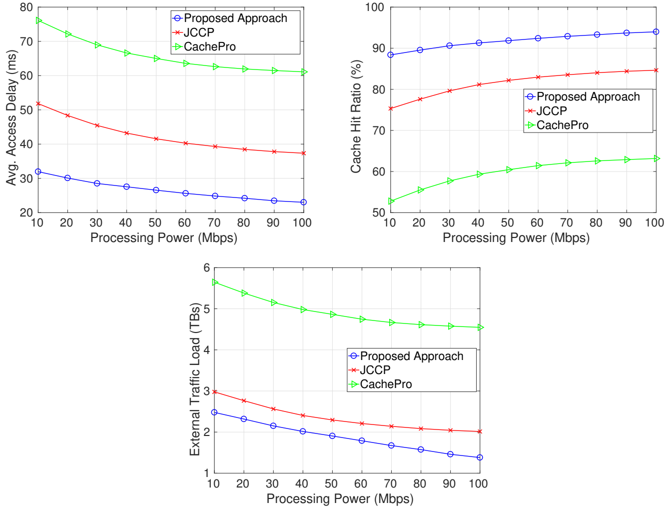

Figure 13: Comparison of caching schemes for different processing power at each MEC server; cache split $x = 75\%$; Cache size at each MEC server $C_j = 100GB$.

Conclusions and Future Work

- Two-fold solution for caching at the edge of the mobile network, using MEC cache consolidation and cache splitting.
- By cache consolidation, more number of videos can be stored in distributed MEC cache which results in more hit ratio, less delay, and reduction in external backhaul traffic.
- Cache splitting further reduces the average access delay.
- Simulation results show that proposed scheme reduces the delay and backhaul traffic compared to the previous work.
- We are implementing a real time distributed caching system using OpenStack.

Acknowledgment

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THANK YOU

Queries ?

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