Time-Optimized Task Offloading Decision Making in Mobile Edge Computing

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Outline

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Background[1]

- The recent advances in mobile devices
  - Example
  - Limitation
- Mobile Cloud Computing (MCC)
  - What is MCC?
  - Limitation
- Mobile Edge Computing (MEC)
  - What is MEC?
  - Names
    - iCloud
    - Fog Computing
    - **Mobile Edge Computing**
  - Use cases

[1] Pavel Mach and Zdenek Becvar. "Mobile edge computing: A survey on architecture and computation offloading". In: *IEEE Communications Surveys & Tutorials* 19.3 (2017), pp. 1628–1656.

Computation Offloading

- Dispatching intensive tasks to an external server, i.e., Cloud or an Edge server.[2]
  - Face/speech recognition;
  - Augmented, assisted or virtual reality;
  - Low latency applications, such as online gaming or remote desktop;
  - Big data analytic.
- The authors[3] demonstrated on a real MEC testbed that the reduction of **latency** up to 88% and **energy consumption** of the mobile device up to 93% can be accomplished by the computation/task offloading in MEC.

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[2] Pavel Mach and Zdenek Becvar. "Mobile edge computing: A survey on architecture and computation offloading". In: *IEEE Communications Surveys & Tutorials* 19.3 (2017), pp. 1628–1656.

[3] Jakub Dolezal, Zdenek Becvar, and Tomas Zeman. "Performance evaluation of computation offloading from mobile device to the edge of mobile network". In: *2016 IEEE Conference on Standards for Communications and Networking (CSCN)*. IEEE. 2016, pp. 1–7.

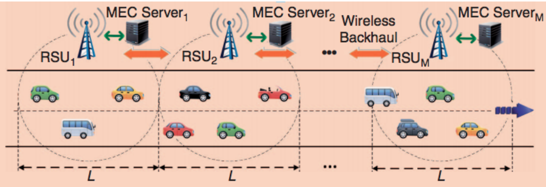
Challenges[4]

- Offloading Sequential Decision Making
  - Doing the tasks **either** locally **or** offloading them
  - Locally, Cloud, or at the Edge
  - **Which Edge server to offload?**

[4] Pavel Mach and Zdenek Becvar. "Mobile edge computing: A survey on architecture and computation offloading". In: *IEEE Communications Surveys & Tutorials* 19.3 (2017), pp. 1628–1656.

Previous Work

- Different from previous work, we focus on the **decision of when** to offload to an edge server, i.e., the selection of MEC servers/time.
- ST-CODA[5]: A spatial and temporal computation offloading decision algorithm.
- A predictive off-loading framework in vehicular networks.[6]

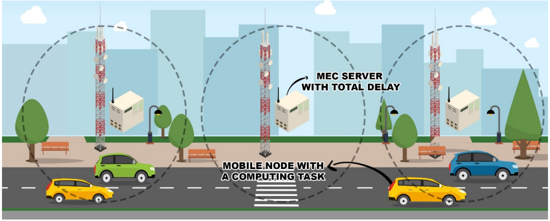


[5] Haneul Ko, Jaewook Lee, and Sangheon Pack. "Spatial and Temporal Computation Offloading Decision Algorithm in Edge Cloud-Enabled Heterogeneous Networks". In: *IEEE Access* 6 (2018), pp. 18920–18932.

[6] Ke Zhang et al. "Mobile-edge computing for vehicular networks: A promising network paradigm with predictive off-loading". In: *IEEE Vehicular Technology Magazine* 12.2 (2017), pp. 36–44.

System Model

- Mobile device
- MEC server
- Computing task with total delay D such that:
  - $D_{offload} < D_{local}$
- $D_{offload}$ delay includes:
  1. Transmission Time;
  2. Processing Time;
  3. Time spent to receive the processed data from MEC server to mobile device.



Problem Statement

The mobile node should find the best time instance t^* such that the expected total delay $\mathbb{E}[D]$ for the offloading is minimized, i.e., the optimal stopping time t^* achieves the essential infimum:

$$\operatorname*{ess\,inf}_t \mathbb{E}[D_t] \tag{1}$$

This problem is a sequential decision making solved based on the principles of the Optimal Stopping Theory (OST).

Optimal Stopping Theory

- Concerned with the problem of choosing the **best time instance** to take a given action based on sequentially observed random variables in order to minimize an expected cost.
- In our problem, we have two actions: **offload** or **continue observing**.
- We have two states: the user has offloaded the data, or still looking for a MEC server.
- **Abstraction**: we cast our offloading problem as a finite horizon OST problem, in which we know the upper bound n, i.e., the number of stages at which one may stop[7].

[7] Ke Zhang et al. "Mobile-edge computing for vehicular networks: A promising network paradigm with predictive off-loading". In: *IEEE Vehicular Technology Magazine* 12.2 (2017), pp. 36–44.

Optimal Offloading Rule

- We provide an **estimate** of the optimal offloading time.
- The optimal offloading time is determined by the scalar values $a_1, a_2, \ldots, a_n$ through which the mobile node decides either to offload or not:

Optimal Task Offloading Rule

Offload the data at the k-th MEC server if $D_k \leq a_k$; otherwise continue the observation if $D_k > a_k$.

Cont'd

Problem: Estimation of the scalar variable $\{a_k\}$.
The scalar variable a values are calculated once through *backward induction*.

$$a_k = \frac{1}{1+r}\left(a_{k+1}(1 - F_D(a_{k+1})) + \int_0^{a_{k+1}} udF_D(u)\right) \quad (2)$$

$$a_n = \frac{1}{1+r}\int_0^1 udF_D(u) = \frac{1}{1+r}\mathbb{E}[D], \quad (3)$$

$F_D(u) = P(D \leq u)$ is the cumulative distribution function of the total delay D.

From Model to Algorithm

Input: Decision scalar values $a_1, a_2, ..., a_n$
Output: Decision of which MEC server to offload

```
Offload ← FALSE
for k = 1 : n do
    if current total delay D_k ≤ a_k then
        MEC-Server ← k ;
        Offload ← TRUE; break;
    end if
end for
if Offload == FALSE then
    MEC-Server ← n;
end if
Offload tasks/data to the MEC-Server;
```

Experiment: Data Set

- We used the real dataset of taxi cabs' movements in Rome[8].
- The dataset contains GPS coordinates of 320 taxis collected over 30 days.
- For each movement, the mobile node is observing a server to check the the expected delay D.

Car id	Time	lat	long	Delay	Server
156	"2014-02-0100:00:00.73"	41.88	12.48	80.61	4
156	"2014-02-0100:00:16.47"	41.88	12.48	62.97	4
156	"2014-02-0100:00:30.70"	41.88	12.48	4.53	4
156	"2014-02-0100:00:45.30"	41.88	12.49	4.37	4
187	"2014-02-0100:00:01.14"	41.92	12.46	70.17	1
187	"2014-02-0100:00:16.15"	41.92	12.46	66.59	1
187	"2014-02-0100:00:30.81"	41.92	12.47	31.65	4

[8] Lorenzo Bracciale et al. *CRAWDAD dataset roma/taxi (v. 2014-07-17)*. Downloaded from https://crawdad.org/roma/taxi/20140717. July 2014. DOI: 10.15783/C7QC7M.

Evaluation

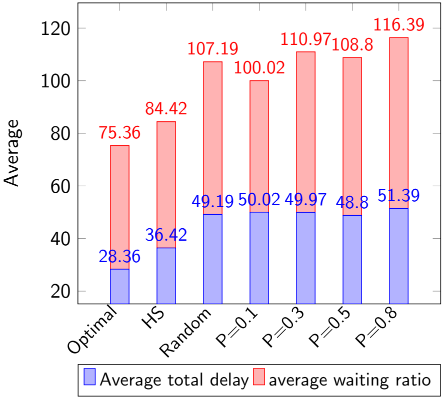


Figure: Average total delay and average waiting ratio of all models

Future Work and Conclusions

- We aim to consider the case where the number of the servers (times) is **unknown and not provided** to the mobile nodes.

The End

Thank you!

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