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Optimized Contextual Data Offloading in Mobile Edge Computing

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Outline

- Introduction
  - Motivation & Challenge
  - Related Work and Contribution
- Data offloading decision making
  - System Model
  - Problem Formulation and Solution
- Performance evaluation
  - Data Set
  - Results
- Future work

Motivation

- Computational Offloading.
- The deployment of MEC servers.[1]
- MEC servers' load have large variation.[2]
- MEC servers as platform for data offloaded by mobile nodes.[3]

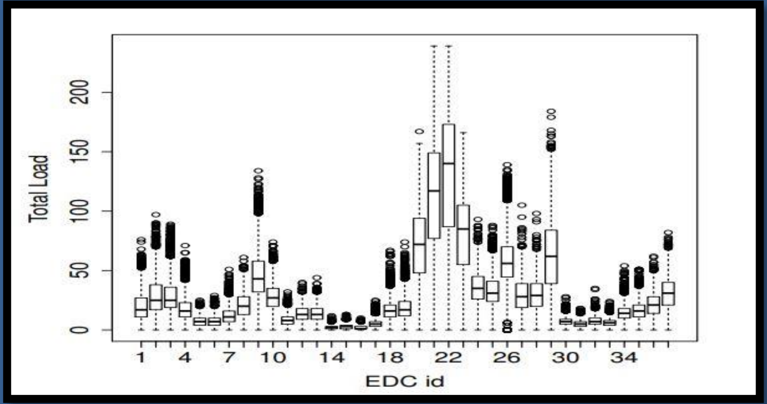


Figure 1: Workload in 37 EDCs according to the simulation in [2]

[1] M. Patel, B. Naughton, C. Chan, N. Sprecher, S. Abeta, A. Neal et al., "Mobile-edge computing introductory technical white paper," *White Paper, Mobile-edge Computing (MEC) industry initiative*, 2014.
[2] C. N. Le Tan, C. Klein, and E. Elmroth, "Location-aware load prediction in edge data centers," *in 2nd FMEC*. IEEE, 2017, pp. 25–31.
[3] Q.-V. Pham, F. Fang, V. N. Ha, M. Le, Z. Ding, L. B. Le, and W.- J. Hwang, "A survey of multi-access edge computing in 5g and beyond: Fundamentals, technology integration, and state-of-the-art," arXiv preprint arXiv:1906.08452, 2019.

Motivation Example: MEC in RSU

- *Autonomous, Smart Vehicles:*

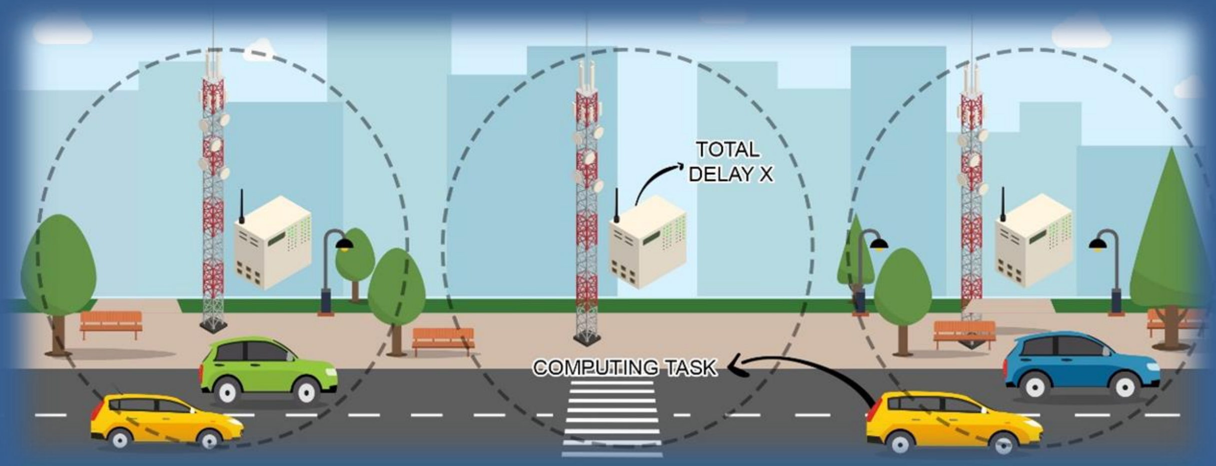
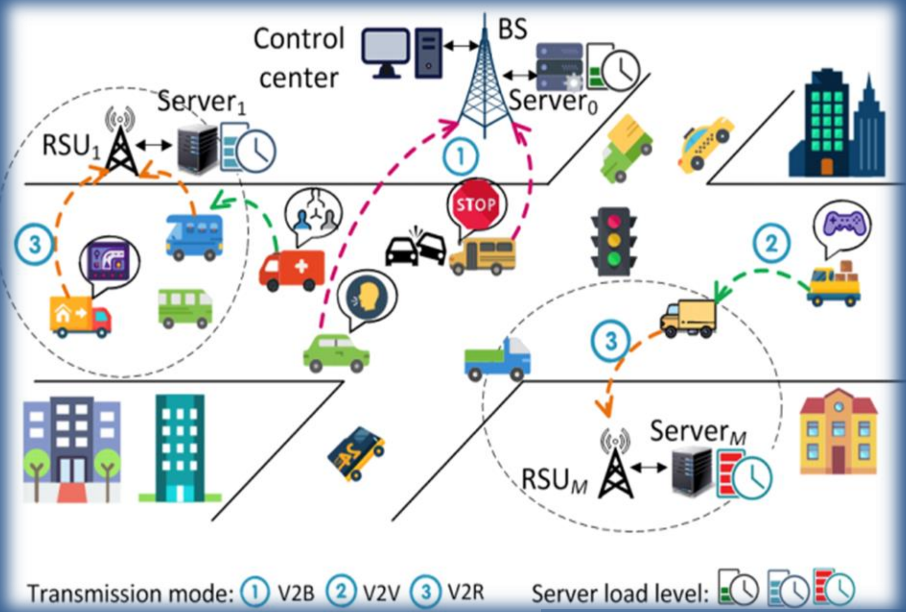


Figure 2: MEC environment. [4,5]

[4] K. Zhang, Y. Mao, S. Leng, Y. He, and Y. Zhang, "Mobile-edge computing for vehicular networks: A promising network paradigm with predictive off-loading,"IEEE Vehicular Technology Magazine, vol. 12,no. 2, pp. 36–44, 2017.

[5] R. Akmam Dziyauddin, D. Niyato, N. Cong Luong, M. A. M. Izhar,M. Hadhari, and S. Daud, "Computation offloading and content caching delivery in vehicular edge computing: A survey,"arXiv, pp. arXiv–1912,2019.

Naïve Approach



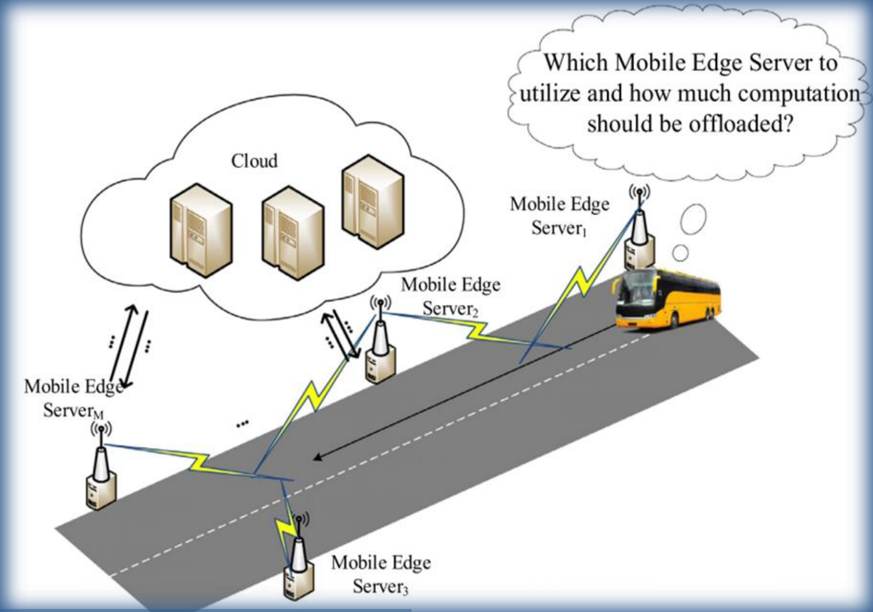


Figure 3: Centralised offloading. [6,7]

[6] W. Tang, X. Zhao, W. Rafique, L. Qi, W. Dou, and Q. Ni, "An offloading method using decentralized p2p-enabled mobile edge servers in edgecomputing,"Journal of Systems Architecture, vol. 94, pp. 1–13, 2019.
[7] K. Zhang, Y. Zhu, S. Leng, Y. He, S. Maharjan, and Y. Zhang, "Deep learning empowered task offloading for mobile edge computing in urban informatics,"IEEE Internet ofThings Journal, vol. 6, no. 5, pp. 7635–7647, 2019

V2V Approach

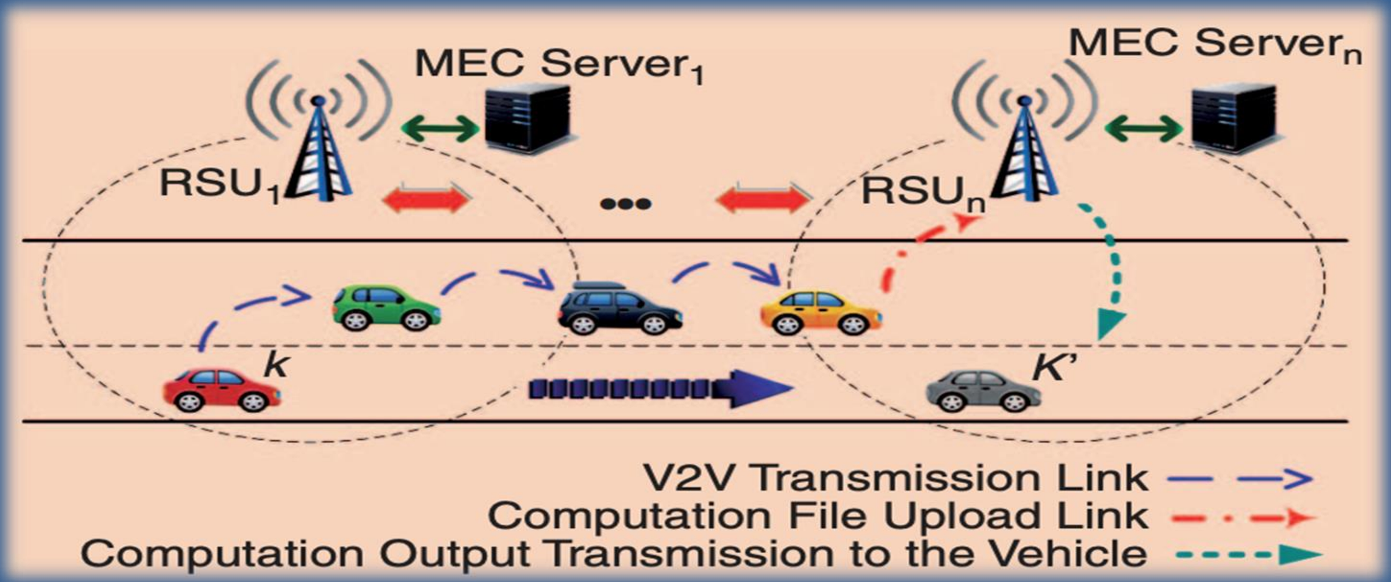


Figure 4: V2V offloading method. [4]

[4] K. Zhang, Y. Mao, S. Leng, Y. He, and Y. Zhang, "Mobile-edge computing for vehicular networks: A promising network paradigm with predictive off-loading,"IEEE Vehicular Technology Magazine, vol. 12,no. 2, pp. 36–44, 2017.

Contributions

- Offloading decision.
  - Independent
- Considerations:
  - Mobility:
    - Higher chance of meeting better resources. [7]
  - Deadline:
    - We must offload before T. [6]
  - Sequential:
    - Optimality found in the optimal stopping theory

[6] W. Tang, X. Zhao, W. Rafique, L. Qi, W. Dou, and Q. Ni, "An offloading method using decentralized p2p-enabled mobile edge servers in edgecomputing,"Journal of Systems Architecture, vol. 94, pp. 1–13, 2019.
[7] K. Zhang, Y. Zhu, S. Leng, Y. He, S. Maharjan, and Y. Zhang, "Deep learning empowered task offloading for mobile edge computing in urban informatics,"IEEE Internet ofThings Journal, vol. 6, no. 5, pp. 7635–7647, 2019

Setting/system model [4]

- Multiple MEC servers.
- Mobile node
- Data to be offloaded to one of the MEC servers.
- The mobile node only knows about the current MEC (the one in the range of mobile node).
- Processing time X.

Figure 5: Context

[4] K. Zhang, Y. Mao, S. Leng, Y. He, and Y. Zhang, “Mobile-edge computing for vehicular networks: A promising network paradigm with predictive off-loading,” IEEE Vehicular Technology Magazine, vol. 12, no. 2, pp. 36–44, 2017.

Problem Statement and Formulation

- A mobile node:
  - collects contextual data from its surrounding environment
  - offload them to the best MEC server in terms of:
    - X_k.
    - n.
- $\boldsymbol{Y_k = X_k + c \,.\, k}$**, with cost rate c = 1/n, n>0.**
- Find the optimal stopping time:
  - $k = \inf\{k: Y_k < \mathbb{E}[Y_{k+1}]\}$

Optimal Offloading Policy/Rule

- At each observation take the minimum between:
  - current processing time
  - or the expected processing time in the next time ➔ a_k
- a_k is calculated through the backward indication

$$a_k = a_{k+1}(1 - F_X(a_{k+1})) + \int_0^{a_{k+1}} x dF_X(x) + c,$$

for $k = 1, \ldots, n-1$, *with initial condition*

$$a_n = \mathbb{E}[X] + c,$$

where $F_X(x) = P(X \leq x)$ *is the cumulative distribution function of the delay* X.

- If $X_k \leq a_k$, offload, otherwise continue.

Cont’d

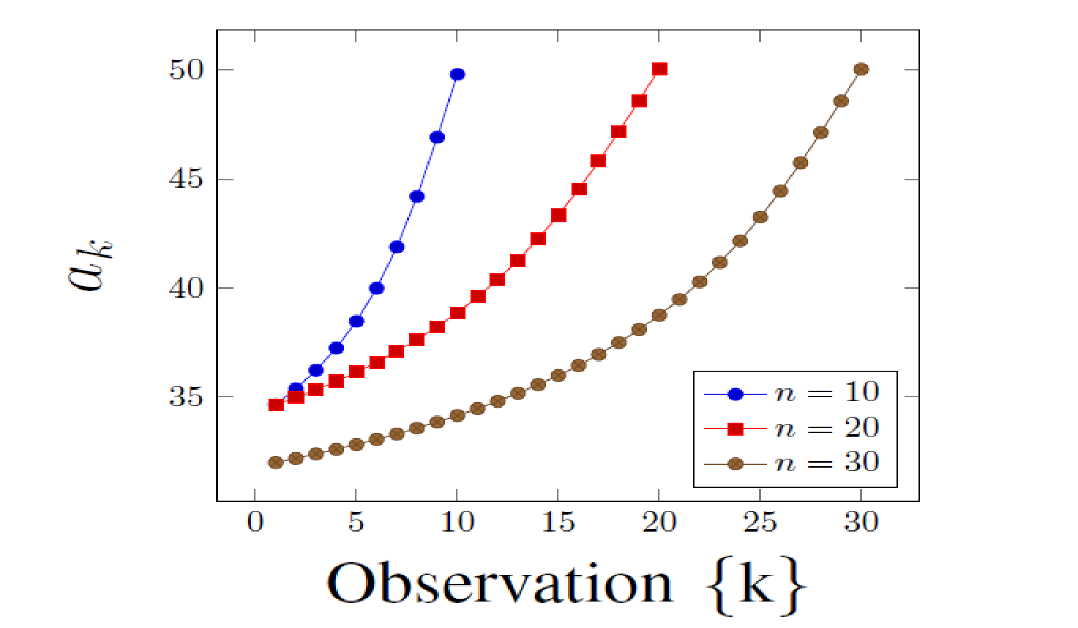


Figure 6:The optimal values $\{a_k\}_{k=1}^{n}$ for data staleness horizon $n \in \{10,20,30\}$ and X is normally distributed μ = 50 σ = 10.

Cont’d

- The decision values (black points).
- Simulated server processing time (blue points).
- The optimal data offloading time when k= 27,29,46,47,48and 50 where X < a.
- We offload at k=27

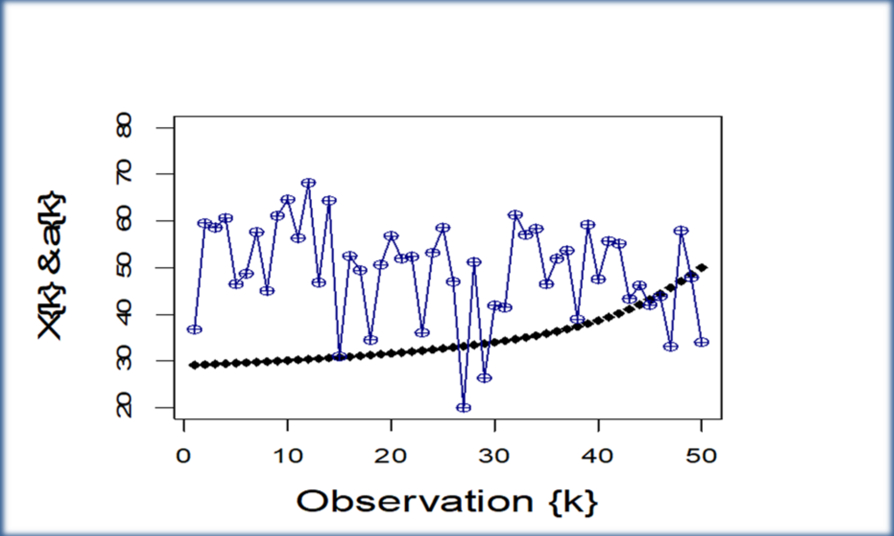


Figure 7:The decision values a and X vs observation k

Performance Evaluation: Data set

- We used the real dataset of taxi cabs' movements in Rome [8].
- Real Server utilisation [9]

Cap id	Movement time	Location	Machine name	CPU utilization
156	2014-02-05 00:11:01	(41.8911, 12.49073)	m_1939	(51)
156	2014-02-05 00:11:11	(41.89905,12.4899)	m_1936	(47)
156	2014-02-05 00:11:22	(41.8994,12.48940)	m_1941	(20)
156	2014-02-05 00:11:31	(41.8994,12.489401)	m_1941	(37)

Table 5.2: A sample of the data set used in the experiment.

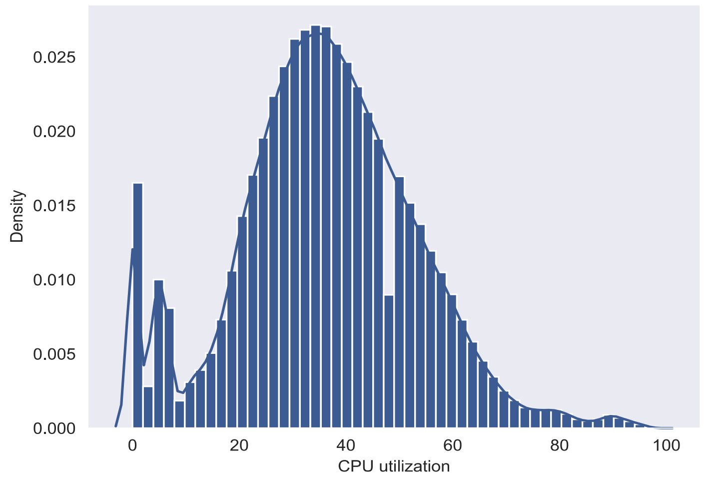


Figure 8: Density of Server utilisation.

[8] L.Bracciale,M.Bonola,P.Loreti,G.Bianchi,R.Amici,andA.Rabuffi, "CRAWDAD dataset roma/taxi (v. 2014-07-17)," Downloaded from https://crawdad.org/roma/taxi/20140717, Jul. 2018.

[9] https://github.com/alibaba/clusterdata/blob/master/cluster-trace-v2018/trace_2018.md

Performance Evaluation: Baselines

- Comparison:
  - Best Choice Problem (BCP) [10]
  - Delay-Tolerant Sequential Decision-making (DTO) [11]
  - Cost-Based Task Offloading [10]
  - Random.
    - Select a server randomly.
  - *p*-model with different probability *p=0.8*
    - *Select the first server.*
  - ***The optimal.***
    - ***The server with the minimum CPU utilisation.***

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[10] I. Alghamdi, C. Anagnostopoulos, and D. P. Pezaros, “On the optimality of task offloading in mobile edge computing environments,” in 2019 IEEE Global Communications Conference (GLOBECOM), 2019, pp. 1–6.
[11] I. A. I. Alghamdi, C. Anagnostopoulos, and D. Pezaros, “Delay-tolerant sequential decision making for task offloading in mobile edge computing environments,” Information, 2019.

Main Results

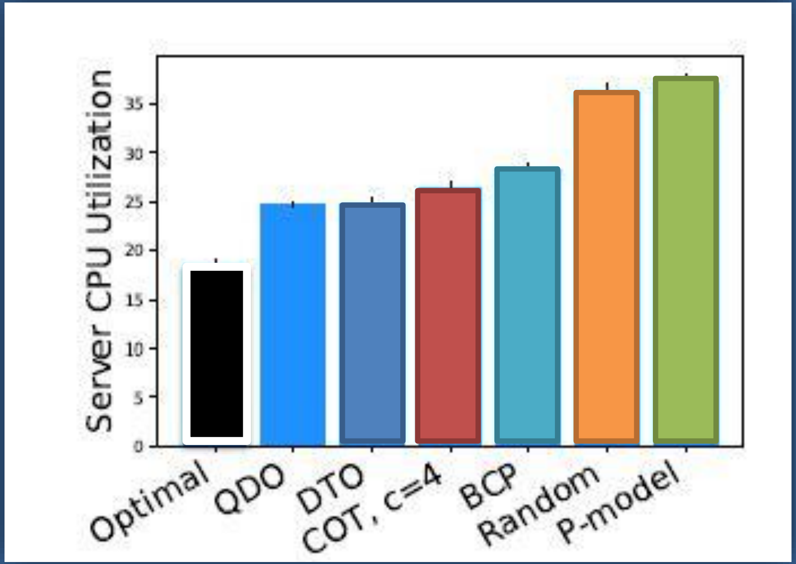

Figure 9: Expected CPU utilization.

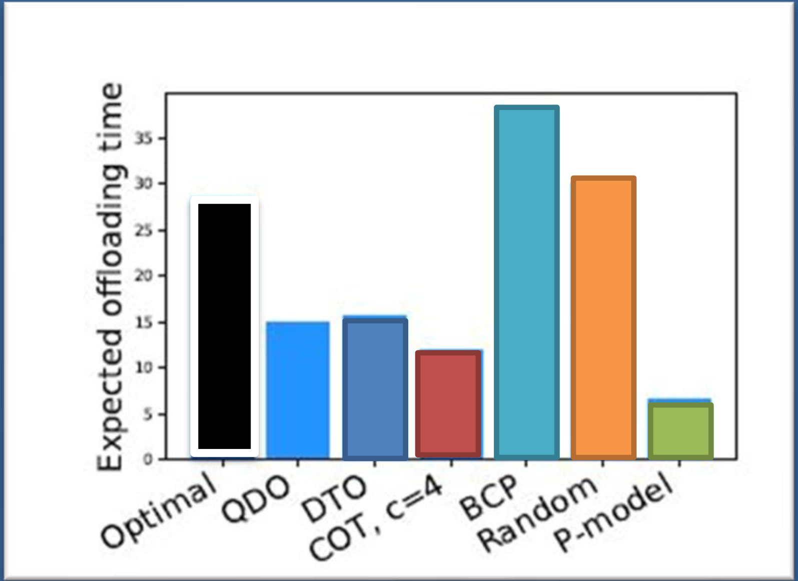

Figure 10: Expected offloading time for each model.

Future Work

Implemented in a mobile node:

- Test different random variables
- Different probability distribution

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Thank you!
Questions

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