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Data-Driven Analytics Task Management at the Edge: A Fuzzy Reasoning Approach

Tahani Aladwani, Christos Anagnostopoulos

Ibrahim Alghamdi, Kostas Kolomvatsos

School of Computing Science, University of Glasgow

WORLD CHANGING GLASGOW

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Outline

- Introduction
- Challenges
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- Management Reasoning
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Challenges related to data-driven tasks execution

Data-driven tasks refer to tasks that rely heavily on data generated by smart devices (e.g., sensors, smartphones) to build knowledge (e.g., ML models) and make decisions.

- **Smart Devices**
- **Cloud Computing**
- **Edge Computing**

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Challenges related to data-driven tasks execution

- EC nodes execute locally data-driven tasks because they are equipped with specific computing resources.
- However, such resources can be limited for some tasks.
- Any decision of executing *locally* or *offloading* the tasks should be made carefully.

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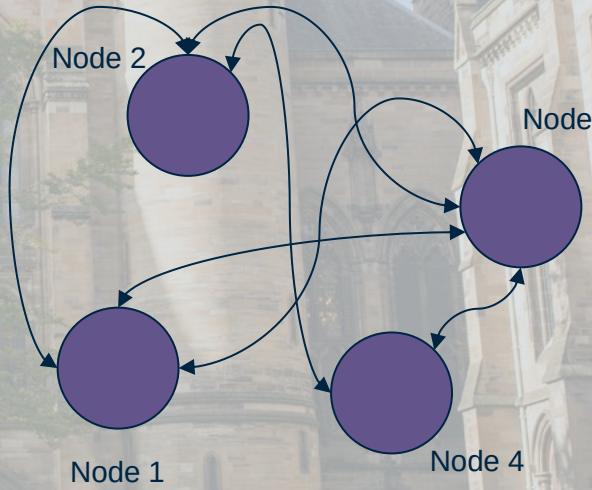
Problem Statement

- EC system with $\boldsymbol{N} = \{n_1, n_2, n_3, \dots, n_n\}$ EC nodes.
- Each n_i collects real-valued contextual data $\mathbf{x}=[x_1, x_2, \dots, x_n]^T \in \mathbb{R}^d, (\text{e.g., temperature})$.
- n_i stores locally the dataset $D_i = \{x_k\}_{k=1}^{N_i}$
- Each node n_i has a neighbourhood $N_i \subset N$ directly communicating nodes $n_j \in \mathcal{N}_i$.
- n_i communicates with applications and the cloud.



EC Environment

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Proposed Solution

Each node n_i needs to obtain certain information based on:

- **Data overlapping/availability per query**
- **Resources availability**
- **Delay/latency sensitivity**

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Offloading factors:

1st : **Data overlapping & availability** given analytics **task/ range query** (u_k).

$$Q_k = \{q_1^{min}, q_1^{max}, \dots, q_d^{min}, q_d^{max}\}$$

$$S(q_k, x) \equiv (q_1^{min} \leq x_1 \leq q_1^{max}) \wedge \dots \wedge (q_d^{min} \leq x_d \leq q_d^{max})$$

Determine data → Send Q to $n_j \subset N_i$ → Each $n_j \subset N_i$ returns u_k

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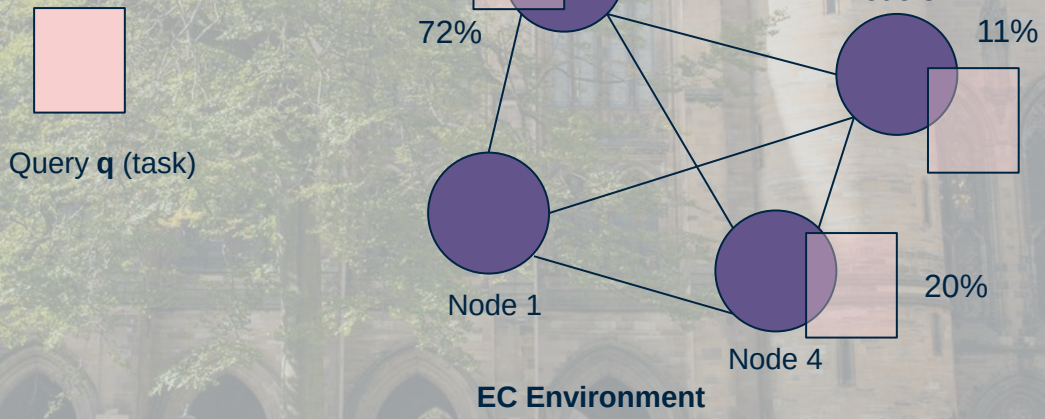
Analytics (range) query **q**: defines a data subspace/boundaries



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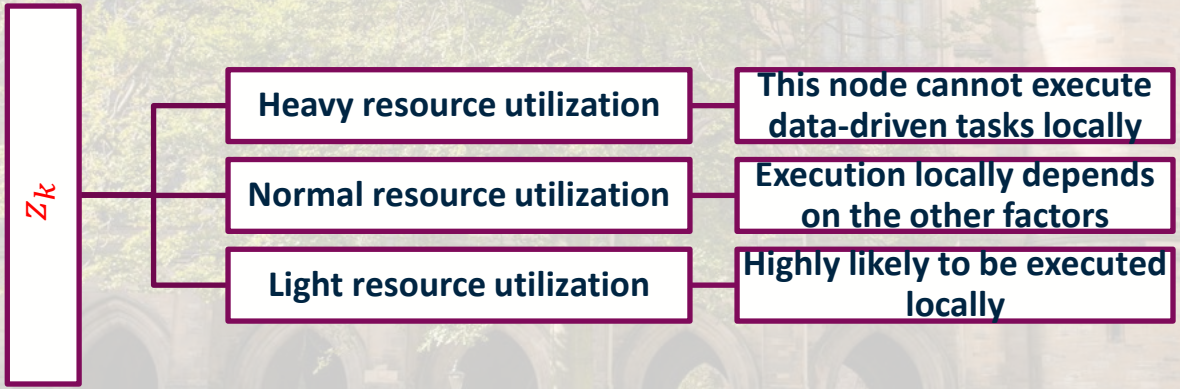
Offloading factors:

2nd : **EC Resources Utilization** (z_k).

The current utilization of the VM hosted by the local edge server.



These decisions are defined according to specific threshold values ϑ_1, ϑ_2.

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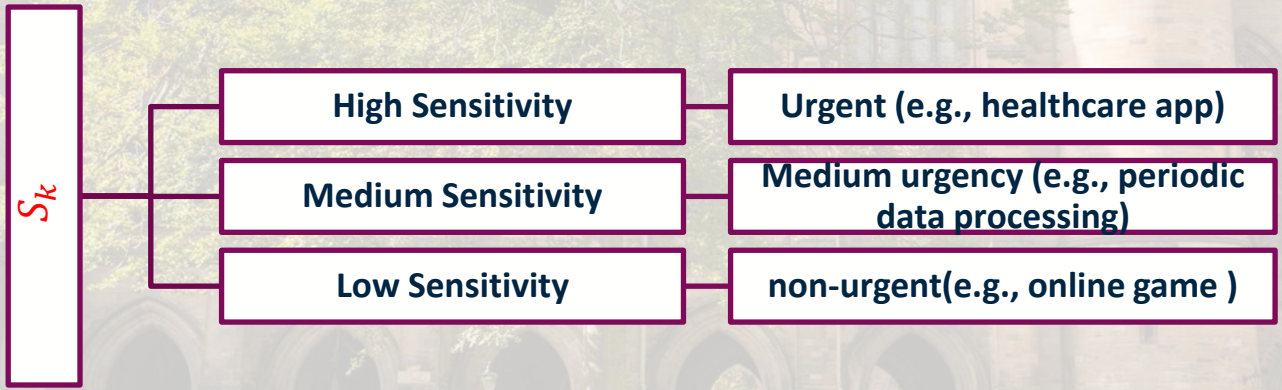
Offloading factors:

3rd : **Delay\ latency Sensitivity** (S_k).

Delay sensitivity reflects data-driven task delay/ failure tolerance.



When n_i receives a set of data-driven tasks, it classifies their sensitivities according to specific levels of thresholds ψ_1, ψ_2.

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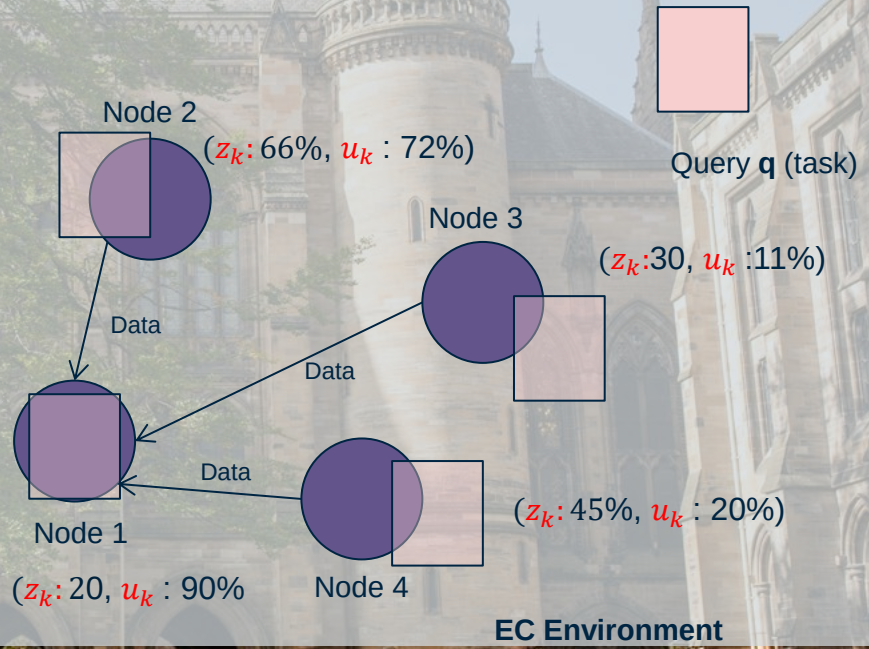
Task Management Reasoning

Step 1: Acquiring tasks information
Step 2: Fuzzy Logic (FL) inference.

- n_i is assigned with the **leadership** role to execute the FL inference engine, where all the neighboring nodes $n_j \in \mathcal{N}_i$ directly communicate with their leader n_i.

Step 1 : Acquiring tasks information
Matching between **tasks** and **nodes**.

Assigning task t_k to node n_k that gives the highest data overlapping, lowest resource utilization and a high possibility to execute a highly sensitive data-overlapping tasks.



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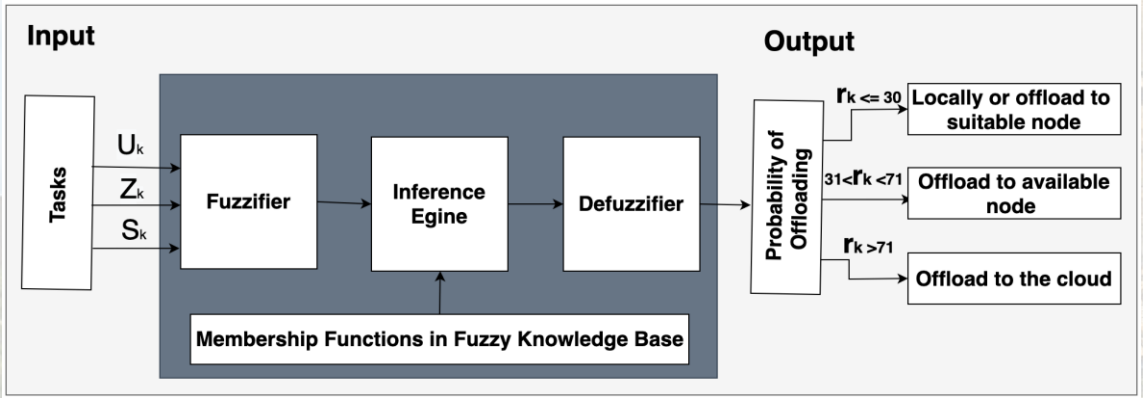
Step 2: Fuzzy Reasoning

Idea: All factors are feed to a Fuzzy Inference System to derive the **probability of offloading** for each task. In order to decide whether task t_k should execute locally on n_i (action a_0) , offload to node n_k (action a_{11}) or offload to the cloud (action a_{12}).



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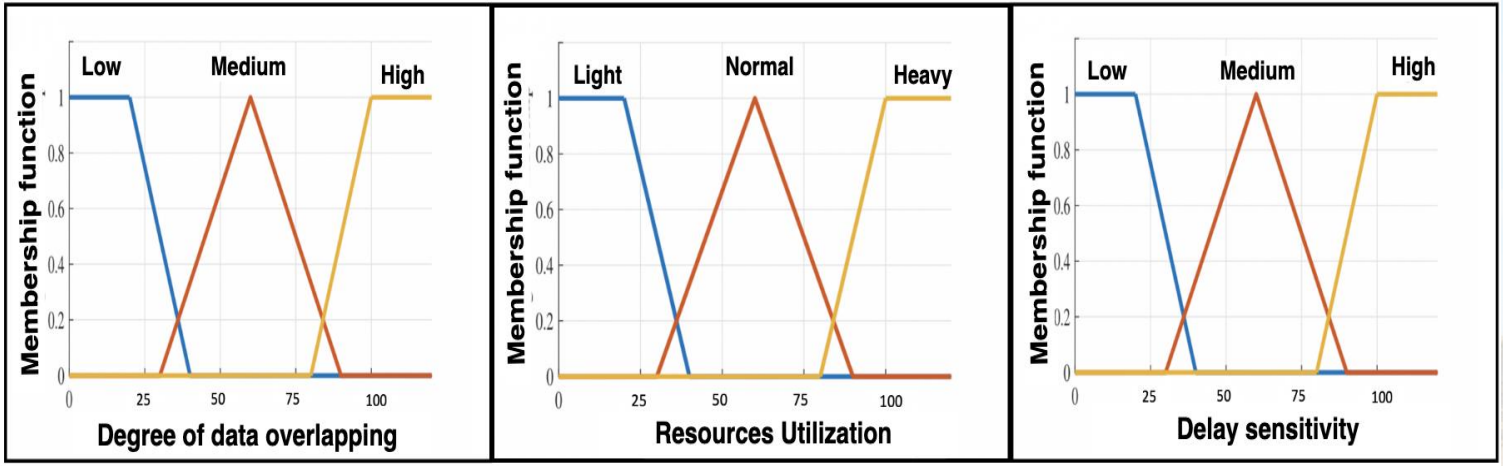
Step 2: Fuzzy Reasoning—Factors Membership Functions



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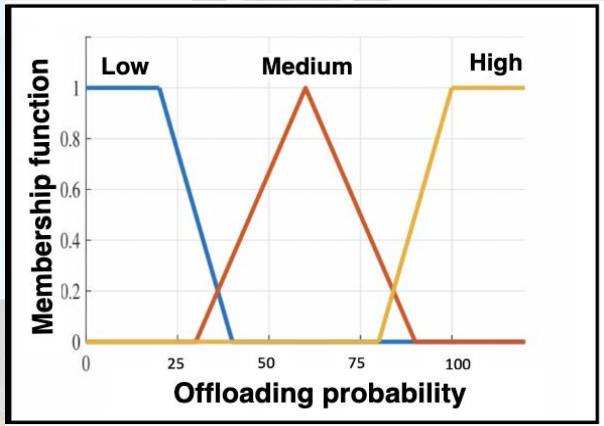
Step 2: Fuzzy Reasoning—Probability of Task Offloading

Offloading probability r_k is transformed to a decision:

- First threshold is 30%, if r_k for task t_k in n_k is less than or equal 30%, the decision is **to locally execut**e this task (action $\boldsymbol{a_0}$) or offload it directly to the suitable node n_k (action $\boldsymbol{a_0}$).
- Second threshold is 70%, if r_k for a task t_k is less than or equal 70%, the decision is **offload** to n_k, if it is available, or to the cloud.
- Third threshold is higher than 70%, if r_k for a task t_k in n_i is greater than 70%, the decision is **to offload to the cloud**. Since this task does not has a high data overlapping with any n_k .



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Experimental Results

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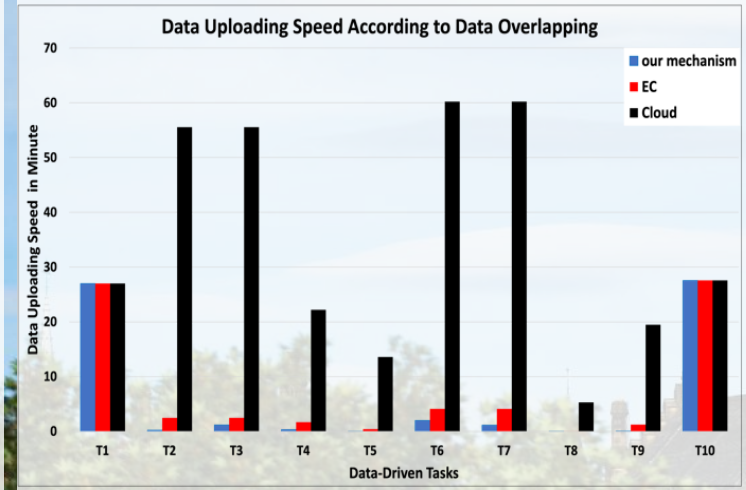
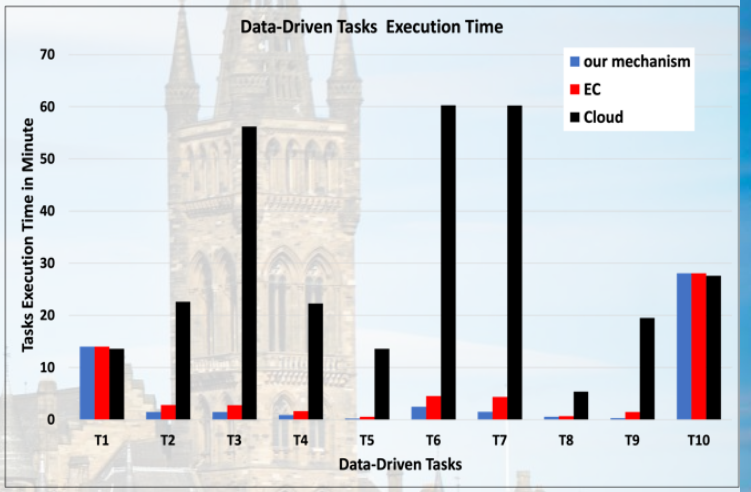
Simulator:
CloudSim Plus [*]

Performance Metrics:
- Data Uploading Speed
- Task Execution Time

Models:
EC, Ours, Cloud





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Conclusions

A mechanism for data-driven analytics task execution in EC environment with the objective of exploiting their resources efficiently.

Our mechanism focuses on three factors to make the decision for each task:

- Data overlapping, EC resource utilization and task sensitivity.

Factors are inputs to a FL system to derive the **probability of task offloading**.

Our mechanism outperforms other benchmarks in terms of reducing uploading data size, execution time and bandwidth and RAM usage.


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Thank you!
Questions?
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