Decentralized Scheduling for Offloading of Periodic Tasks in Mobile Edge Computing

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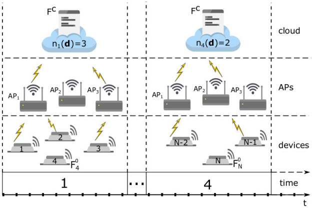
Enabler for IoT Applications

- Many IoT applications are based on deployment of wireless sensors that collect data periodically
  - computationally demanding processing
  - low latency response



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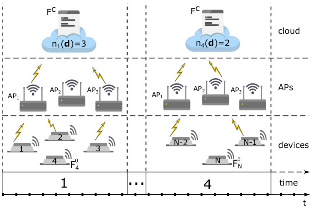

MEC can meet IoT application requirements by providing

- high bandwidth and computing resources close to the end users
- low latency
- real-time access to radio network information
- collaboration between mobile operators and application providers

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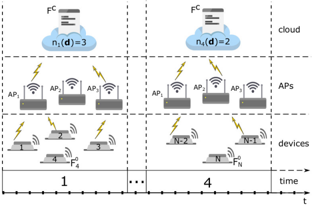

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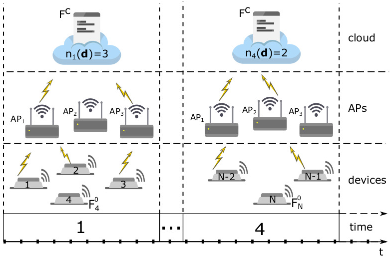
Important question

How to utilize mobile edge resources efficiently?

Mobile Cloud Computing System with Periodic Tasks



- Cloud server
- Set of APs $\mathcal{A} = \{1, 2, ..., A\}$
- Set of WDs $\mathcal{N} = \{1, 2, ..., N\}$
- Set of time slots $\mathcal{T} = \{1, 2, \dots, T\}$

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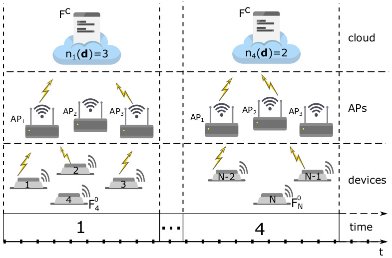

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Computation Offloading

- Decision of WD i $d_i = \begin{cases} (t, 0), & \text{if performing the task locally in time slot } t \\ (t, a), & \text{if offloading the task using AP } a \text{ in time slot } t \end{cases}$
- Set of decisions for all WDs is a *strategy profile* **d**

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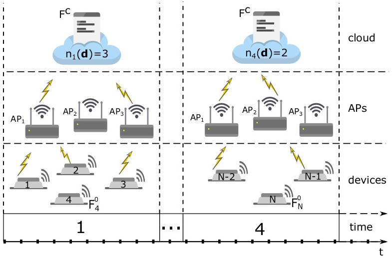

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- Set of decisions for all WDs is a *strategy profile* $\mathbf{d}$
- Number of WDs that offload via AP a in time slot t in a strategy profile $\mathbf{d}$ is $n_{(t,a)}(\mathbf{d})$
- Total number of WDs that offload in time slot t in a strategy profile $\mathbf{d}$ is $n_t(\mathbf{d})$

Local Computing Cost

$$C_i^0 = \gamma_i^T \underbrace{T_i^0}_{\text{delay}} + \gamma_i^E \underbrace{E_i^0}_{\text{energy}}$$

Cloud Offloading Cost

$$C_{i,(t,a)}^c(\mathbf{d}) = \gamma_i^T \underbrace{\left(\overbrace{T_{i,(t,a)}^{c,off}(n_{(t,a)}(\mathbf{d}))}^{\text{time to offload}} + \overbrace{T_{i,t}^{c,exe}(n_t(\mathbf{d}))}^{\text{time to execute}}\right)}_{\text{delay}} + \gamma_i^E \underbrace{E_{i,(t,a)}^c(n_{(t,a)}(\mathbf{d}))}_{\text{energy to offload}}$$

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Coordinating MEC resources for offloading of periodic tasks

- Interactions between WDs modeled as a strategic game $\Gamma = <\mathcal{N}, (\mathfrak{D}_i)_i, (C_i)_i>$

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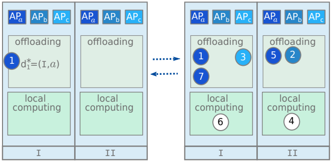
- Interactions between WDs modeled as a strategic game $\Gamma = <\mathcal{N}, (\mathfrak{D}_i)_i, (C_i)_i>$
- Is there a task allocation in which all selfish WDs are satisfied?
- Can it be computed using a decentralized algorithm?
- What is the complexity of the algorithm?
- How good are the system performance?

Coordinated Myopic Alternating Best (MB)

- WDs enter the game one at a time and implement BR over all time slots

- Induction phase - starting from an empty system, WDs enter the game one at a time and play BR



- Update phase - consists of two types of BR sequences that are played alternatingly
  (1) WDs are not allowed to replace the previous deviators
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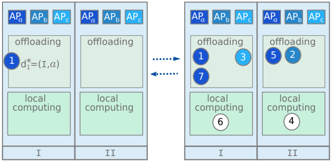

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Random Slot (RS) Equilibrium

- WDs enter the game one at a time and choose a time slot at random
- WDs implement BR within the chosen time slot

Main Results

Computability

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Price of Anarchy (PoA) Bounds

- Upper bound on the PoA for the computation offloading game:
  - $N \leq T$: $PoA = 1$
  - $N > T$: $PoA \leq \dfrac{\sum_{i \in \mathcal{N}} C_i^0}{\sum_{i \in \mathcal{N}} \min\{C_i^0, C_{i,1}^{\bar{c}}, ..., C_{i,A}^{\bar{c}}\}}$
  - $C_{i,a}^{\bar{c}}$ is the offloading cost of WD i via AP a when she offloads alone

Performance Evaluation - Simulations

Evaluation scenario

- $A = 4$ APs, $F^c = 100$ *Gcycles* and $F_i^0 \sim \mathcal{U}(0.5, 1)$ *Gcycles*
- Tasks: data size $\sim \mathcal{U}(0.42, 2)$ Mb , complexity $\sim \mathcal{U}(0.1, 0.8)$ *Gcycles*

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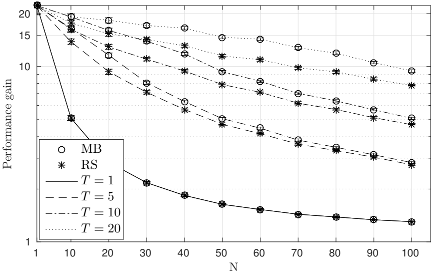
System Cost Performance



- *Performance gain* defined w.r.t. a strategy profile in which all WDs perform computation locally
- *Performance gain* of the MB algorithm is higher than that of the RS algorithm for $T > 1 \implies$ coordination is important

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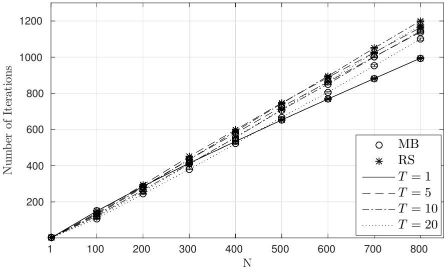
Computational complexity



- Number of iterations scales approximately linearly with the number of WDs for both algorithms

Summary and Future Work

- Provided a game theoretical treatment of computation offloading for periodic tasks
- Proved the existence of equilibrium allocations
- Provided a polynomial time decentralized algorithm for computing an equilibrium

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- Interesting extensions
  - WDs with heterogeneous periodicities
  - resource allocation from the perspective of mobile cloud providers
  - D2D collaborative computation offloading

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