A Mobility-aware Cross-edge Computation Offloading Framework for Partitionable Applications

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July 10, 2019

Outline

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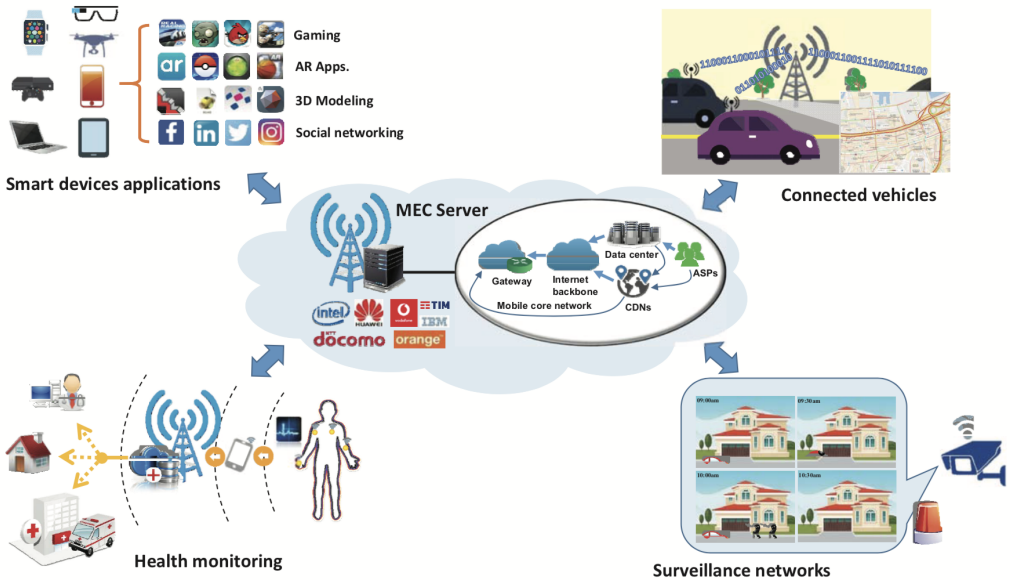
What is Mobile Edge Computing?

Mobile Edge Computing

Mobile Edge Computing (MEC) is a new computation paradigm:

1. depolyed at **the network edge**
2. use **widespread** wireless access network (Small-cell Base Station)
3. provide **service and computing resource**



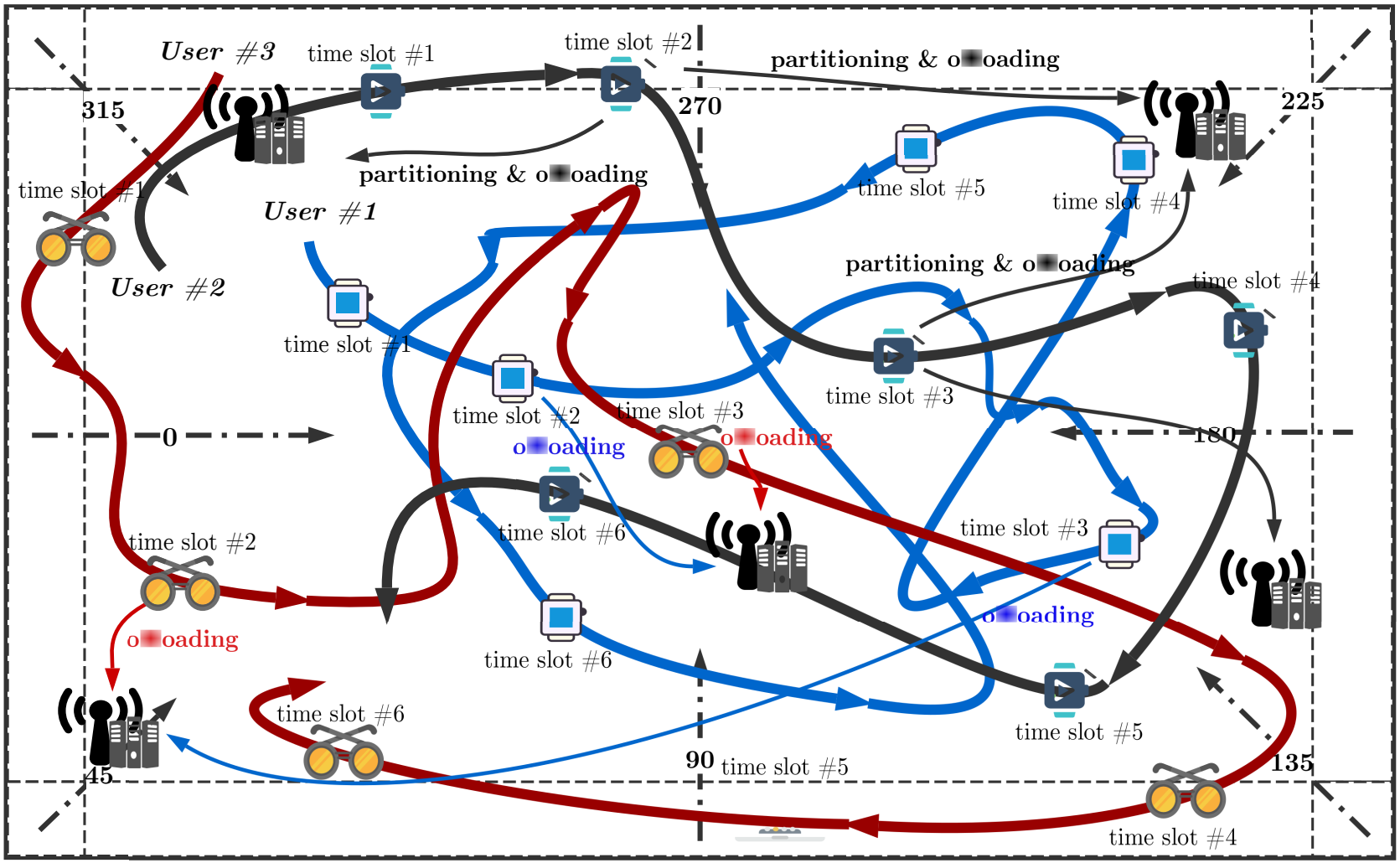
What's it properties?

Edge site

An edge site is a micro data center with applications depolyed, attached to a small-cell base station (SBS).

1. Heterogeneous edge sites
2. User mobility
3. Edge site selection and user profile handover
4. Overlapped signal coverage of SBSs (Corss-edge Collaboration!)
5. Partitionable applications (data stream)
6. Insufficient battery energy of mobile devices
7. ... ...

Motivation Scenario



Problem Definition

For partitionable applications, how to make the offloading strategy with the minimum overall cost achieved?

Composition of **overall cost**

1. execution delay
2. task dropping penalty
3. collaboration cost

Energy Harvesting (EH) technology is adopted.

Outline

System Model

1. Local execution latency evaluation
   1. execution latency: $\tau_i^{lc} \triangleq \eta_i^l / f_i$
   2. energy consumption: $\epsilon_i^l \triangleq \kappa_i \cdot \eta_i^l f_i^2$
2. Offloading latency evaluation
   1. transmission delay: $\tau_{i,j}^{tx}(t) \triangleq \frac{\mu_i^r}{\sum_{j \in \mathcal{M}_i(t)} I_{i,j}(t)} \cdot \frac{1}{R_{i,j}(t)}$
   2. execution delay: $\tau_{i,j}^{rc}(t) \triangleq \frac{\eta_i^r}{f_j \cdot \sum_{j \in \mathcal{M}_i(t)} I_{i,j}(t)}$
   3. collaboration cost: $\varphi \cdot \sum_{j \in \mathcal{M}_i(t)} I_{i,j}(t)$
   4. constraint:
      $\tau_d \geq \max_{j \in \mathcal{M}_i(t)} \left\{ \tau_{i,j}^{tx}(t) + \tau_{i,j}^{rc}(t) \right\} + \tau_i^{lc} + \varphi \cdot \sum_{j \in \mathcal{M}_i(t)} I_{i,j}(t)$
3. Battery energy level evaluation
   1. envolution function:
      $\psi_i(t+1) = \psi_i(t) - \sum_{j \in \mathcal{M}_i(t)} \epsilon_{i,j}^{tx}(t) \cdot I_{i,j}(t) - \epsilon_i^l + \alpha_i(t)$
   2. constraint: $\epsilon_i^l + \sum_{j \in \mathcal{M}_i(t)} \epsilon_{i,j}^{tx}(t) I_{i,j}(t) \leq \psi_i(t)$

Problem Formulation

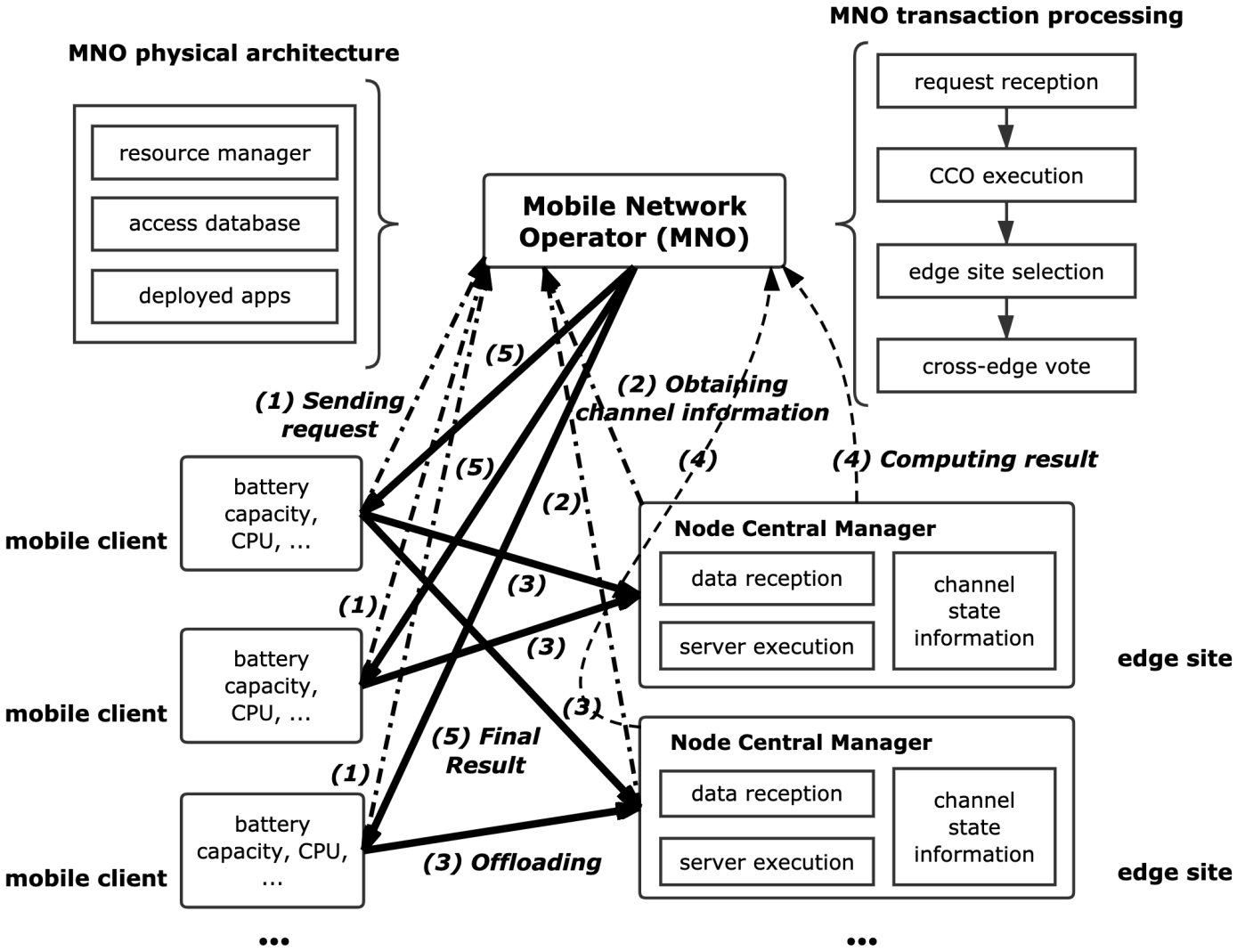
A non-convex optimization problem

$$\mathcal{P}_1: \quad \min_{\forall i, \mathbf{I}_i(t), \alpha_i(t)} \quad \lim_{T\to\infty} \frac{1}{T} \sum_{t=0}^{T-1} \mathbb{E}\Big[\sum_{i\in\mathcal{N}} \mathcal{C}(\mathbf{I}_i(t)) \Big],$$

with several constraints.

$$\begin{aligned} \mathcal{C}(\mathbf{I}_i(t)) \quad &\triangleq \quad \max_{j\in\mathcal{M}_i(t): I_{i,j'}(t)=1} \left\{ \tau_{i,j}^{tx}(t) + \tau_{i,j}^{rc}(t) \right\} \\ &+ \quad \tau_i^{lc} + \varphi \cdot \sum_{j\in\mathcal{M}_i(t)} I_{i,j}(t) + \varrho_i \cdot D_i(t) \end{aligned}$$

Proposed Framework



Proposed Algorithms

The CCO algorithm

1. Lyapunov optimization (drift-plus-penalty)

$$\mathcal{P}_2 : \min_{\forall i, \mathbf{I}_i(t), \alpha_i(t)} \Delta_V^{up}(\mathbf{\Theta}(t)),$$

with several constraints.

$$\begin{aligned} \Delta_V^{up}(\mathbf{\Theta}(t)) \triangleq & \sum_{i=1}^{N} \psi_i'(t)\left[\alpha_i(t) - \epsilon_i^l - \sum_{j=1}^{M} \epsilon_{i,j}^{tx}(t) I_{i,j}(t)\right] \\ + & V \sum_{i=1}^{N} \mathcal{C}(\mathbf{I}_i(t)) + C \end{aligned}$$

Proposed Algorithms

The CCO algorithm

Algorithm 1 Cross-edge Computation Offloading (CCO)

1: At the beginning of the tth time slot, obtain i.i.d. random events $\mathbf{A}(t), \mathbf{E}^h(t) \triangleq [E_1^h(t), ..., E_N^h(t)]$ and channel state information.
2: $\forall i \in \mathcal{N}$, decide $\mathbf{I}_i^\star(t), \alpha_i^\star(t)$ by solving the deterministic problem $\mathcal{P}_2$.
3: $\forall i \in \mathcal{N}$, update the battery energy level $\psi_i(t)$.
4: $t \leftarrow t + 1$.

1. optimal energy harvesting: $\alpha_i^\star(t)$
2. optimal edge site selection: $\mathbf{I}_i^\star(t)$

Benchmark Policies

1. Random Selection (RS)
2. Greedy Selection on Communication (GSC1)
3. Greedy Selection on Computation (GSC2)

Parameter settings

Parameter	Value	Parameter	Value
τ_d	2 ms	ϱ_i	2 ms
φ	0.02 ms	ρ_i	0.6
μ_i^l	100 bits	μ_i^r	3000 bits
f_i	1.5 GHz	f_j	32 GHz
κ_i	10^{-28}	ψ_i^{safe}	40 mJ
N_j^{max}	5	ω	$1.5/\sum_{i\in\mathcal{N}_j(t)} I_{i,j}(t)$ GHz
ϖ_0	10^{-13} W	p_i^{tx}	1 W
g_0	10^{-4}	$E_{i,h}^{max}$	4.8×10^{-4} J

Optimality and stability

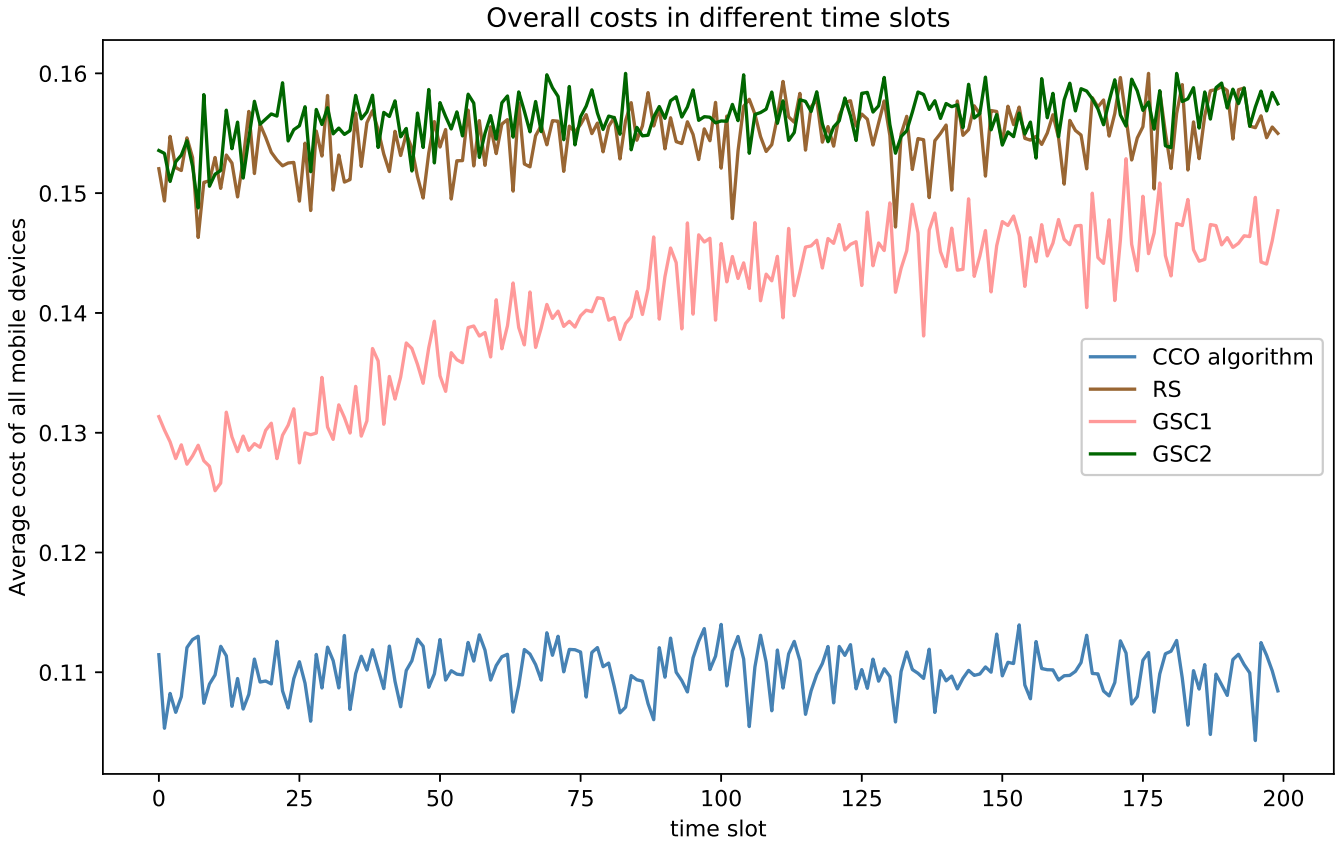


Figure: Average cost of mobile devices.

Optimality and stability

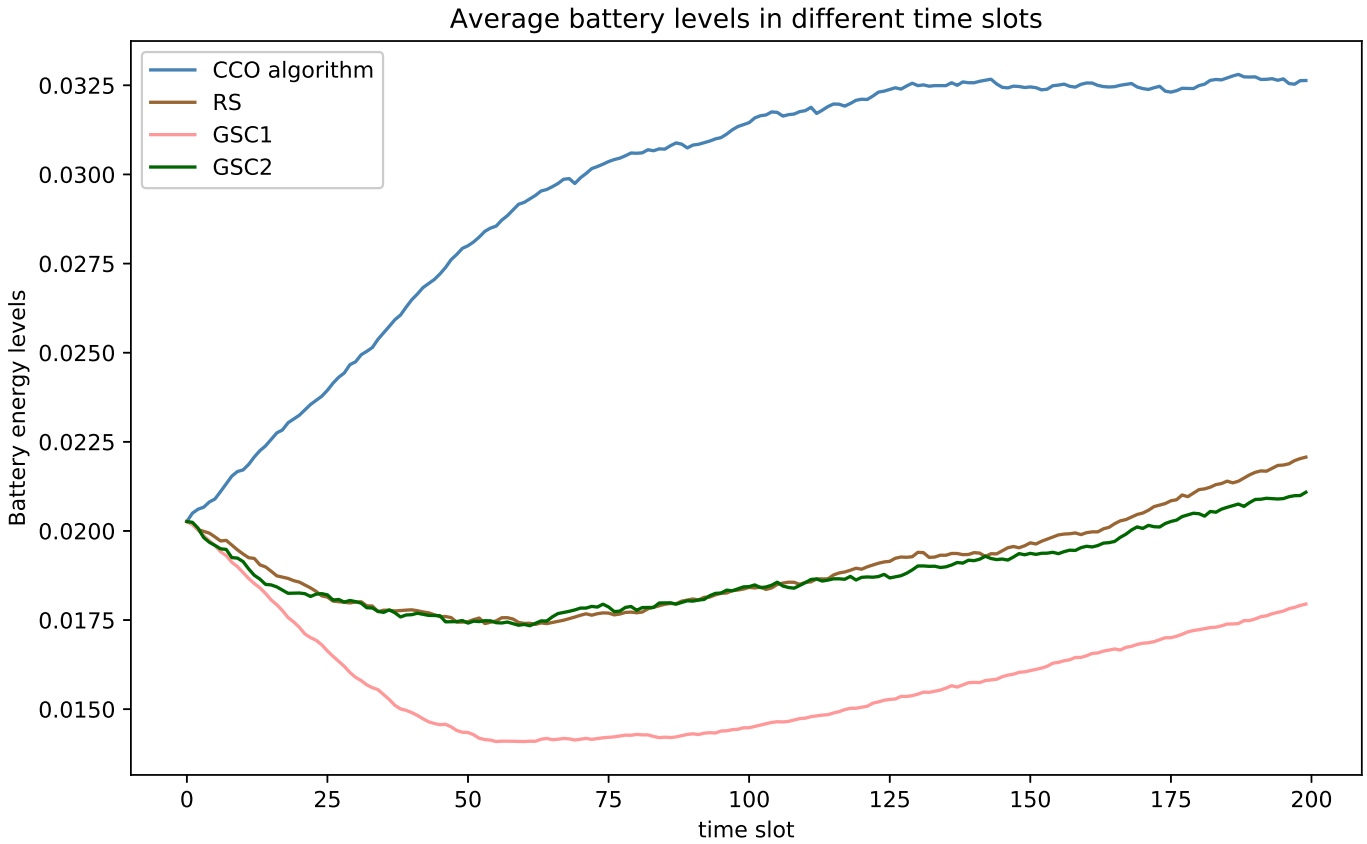


Figure: Average battery energy level of mobile devices.