Stabilized Super-Resolution Deep Learning Adaptation for UAV-Assisted Mobile Edges: A Lyapunov Optimization Approach
IEEE Seoul Section Student Paper Contest (2019)

Jaesung Yoo (Undergraduate Student of EE): Korea University, Seoul, Korea
Dohyun Kim (Graduate Student of CSE): Chung-Ang University, Seoul, Korea
Joongheon Kim (Assistant Professor of EE): Korea University, Seoul, Korea
Introduction

• Motivation
  • UAV/drone-based mobile edge computing is essential for seamless real-time surveillance applications.
  • For the surveillance, the drone records video streams and then transit them to ground mobile edge stations.
    • The stream arrivals into the mobile edge is time-varying due to the unreliability of the wireless links between drone and mobile edge.
    • Thus, the drone compresses the videos (in order to save wireless bandwidth) and then the mobile edge (receiver) conducts super-resolution for enhance the resolution.
    • Due to the static model of super-resolution neural network, it may introduce overflow when the arrivals are bursty.
Introduction

• Proposed Control Algorithm
  • In order to handle the unpredictable overflow, the proposed algorithm controls the model based on queue-backlog.
    • If queue-backlog (task queue) is long, we have to speed up the computation in the super-resolution neural network.
    • If the queue-backlog (task queue) is idle, we have to maximize the super-resolution performance even though it takes a lot of time.
    • Thus, we can observe the tradeoff between delays and utility (i.e., super-resolution performance).
  • In order to model the tradeoff, Lyapunov optimization framework is used.
    • Thus, the formulation is for the time-average maximization of the super-resolution performance subject to queue stability.
Introduction

- **System Model and Motivation**
  - Virtual Bandwidth Extension

**Drone/UAV**

- Original image (690 x 690) 141KB
- JPG comp (QF40~70) 11KB

**Mobile Edges**

- JPG comp (QF40~70) 11KB
- Super-Resolution Deep Learning Network
- 141KB
- 141KB

**How can we control this model?**

**Algorithm Details**

- **Performance Evaluation**
- **Concluding Remarks**
Algorithm Details

• Algorithm

Mobile Edge

\[ Q[t] \] → Lyapunov-Control (NN Selection) → Bag-of-Models

NN (Low-Resolution)
- Low Accuracy [-]
- Fast Computation (High Queue Stability) [+]

NN (High-Resolution)
- High Accuracy [+]
- Slow Computation (Low Queue Stability) [-]

Objective Function

Time-Average SR-based Resolution Maximization subject to Queue Stability

Introduction

Algorithm Details

Performance Evaluation

Concluding Remarks
Lyapunov Control for Learning-based Systems

- **Lyapunov Optimization Formulation**
  - Maximization of **Time-Average Learning-Accuracy** subject to **Queue Stability**

\[
\alpha^*[t] \leftarrow \arg\max_{\alpha[t] \in A} \left[ V \cdot \text{Accuracy}(\alpha[t]) - Q[t] \{ a(\alpha[t]) - b(\alpha[t]) \} \right]
\]

- **Semantical Description**
  - If the queue is near empty \((Q[t] \approx 0)\),
    - Select the \(\alpha[t]\) which can maximize \(V \cdot \text{Accuracy}(\alpha[t])\), i.e., high learning-accuracy NN will be selected.
  - If the queue is near overflow \((Q[t] \approx \infty)\),
    - Select the \(\alpha[t]\) which can maximize \(b(\alpha[t])\), i.e., fast computation (i.e., low learning-accuracy) NN will be selected.
Algorithm Details

• Algorithm Pseudo-Code

Algorithm 1 Proposed Super-Resolution Deep Neural Network Model Adaptation

Initialize:
1: $t \leftarrow 0$
2: $Q(t) \leftarrow 0$
3: Elements in Bag-of-Models: $A = \{\alpha_1(t), \cdots, \alpha_N(t)\}$

Stochastic Super-Resolution Model Adaptation:
4: while $t \leq T$ do // $T$: operation time
5: Observe $Q(t)$
6: $T^* \leftarrow -\infty$
7: for $\alpha(t) \in A$ do
8: $T \leftarrow V \cdot P(\alpha(t)) + Q(t) \cdot \mu_\alpha(t)$
9: if $T \geq T^*$ then
10: $T^* \leftarrow T$
11: $\alpha^*(t) \leftarrow \alpha(t)$
12: end if
13: end for
14: end while

$\alpha^*[t] \leftarrow \argmax_{\alpha[t] \in A} \{V \cdot \text{Accuracy}(\alpha[t]) + Q[t]b(\alpha[t])\}$

Introduction
Algorithm Details
Performance Evaluation
Concluding Remarks
• Experimental Results
  • In the initial phase, the proposed control algorithm follows the model which is for maximizing super-resolution performance.
  • In the end, the proposed algorithm starts to control the model selection in order to handle the tradeoff between utility and delays via Lyapunov optimization framework.

- x-axis: unit time
- y-axis: queue-backlog
Conclusions and Future Work

• **Conclusions**
  • This paper proposes a Lyapunov optimization framework for time-average maximization of super-resolution performance subject to queue stability.
  • This control algorithm is used for the virtual bandwidth extension between drones and mobile edges.

• **Future Work**
  • The scenario with multi-drone networks is considerable.
    • In this case, appropriate scheduling policies are required.

• **Q&A**
  • joongheon@korea.ac.kr (Prof. Joongheon Kim)