Stabilized Super-Resolution Deep Learning Adaptation for UAV-Assisted Mobile Edges: A Lyapunov Optimization Approach

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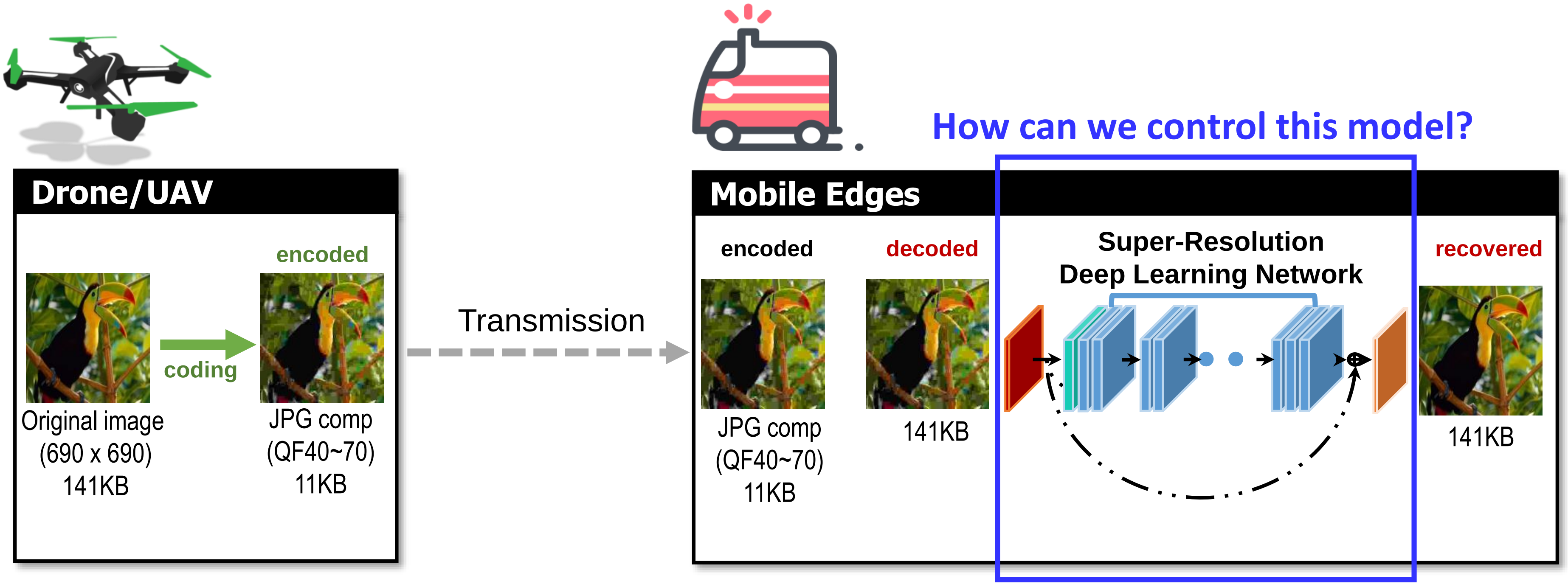
- **Motivation**
  - UAV/drone-based mobile edge computing is essential for seamless real-time surveillance applications.
  - For the surveillance, the drone records video streams and then transit them to ground mobile edge stations.
    - The stream arrivals into the mobile edge is time-varying due 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.

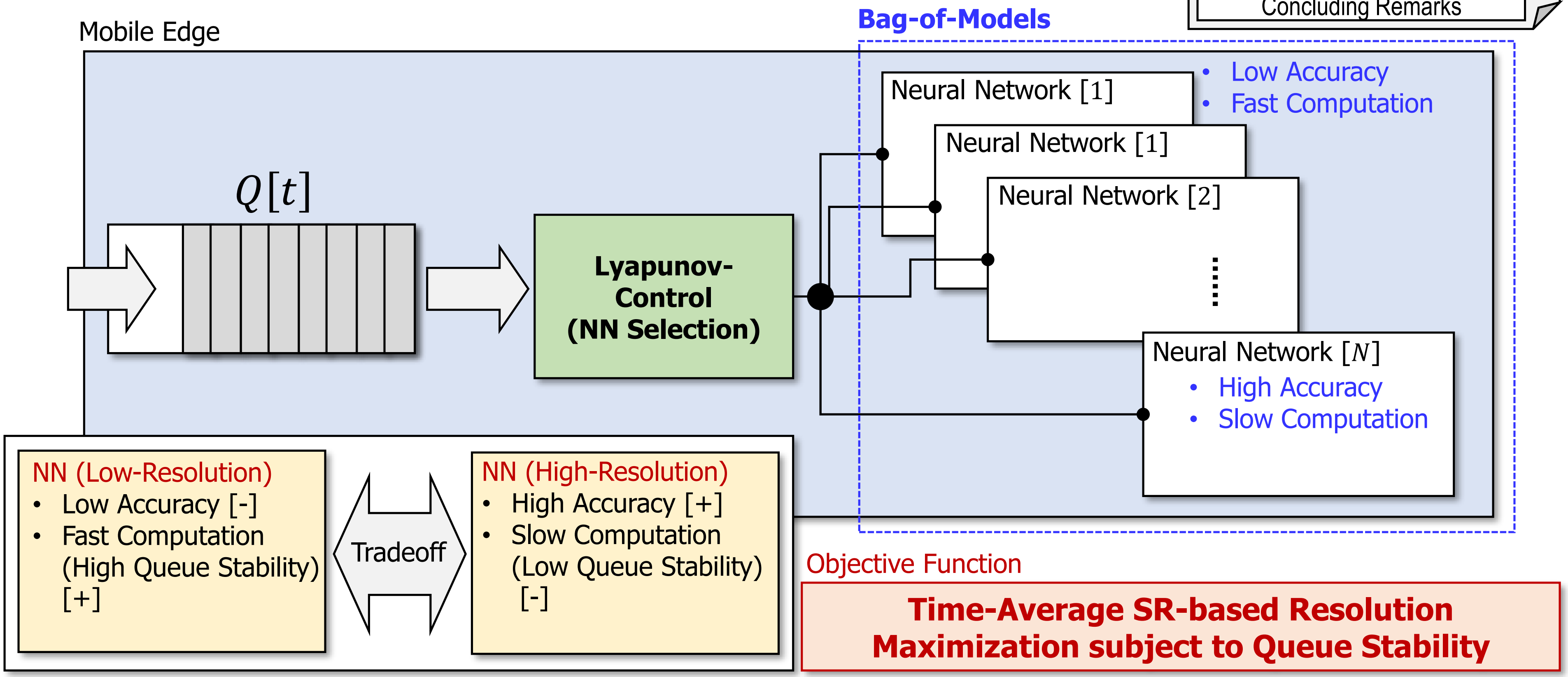
- **Proposed Control Algorithm**
  - In order to handle the unpredictable overflow, the proposed algorithm controls the model based on queue-backlog.
    - If queue-backlog (task queue) is long, we have to speed up the computation in the super-resolution neural network.
    - If the queue-backlog (task 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**.

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



Algorithm Details

- **Algorithm**



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

$$\alpha^*[t] \leftarrow \underset{\alpha[t]\in A}{argmax}[V \cdot Accuracy(\alpha[t]) - Q[t]\{\boxed{a(\alpha[t])} - b(\alpha[t])\}]$$

Not Controllable

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

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

• Algorithm Pseudo-Code

Algorithm 1 Proposed Super-Resolution Deep Neural Network Model Adaptation

Initialize:

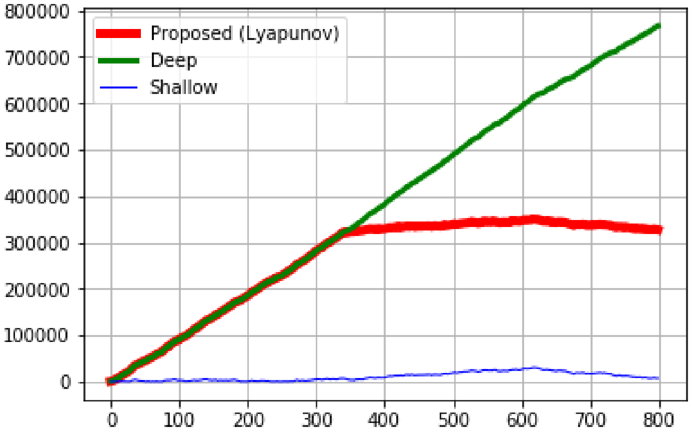
$t \leftarrow 0$
$Q(t) \leftarrow 0$
Elements in Bag-of-Models: $A = \{\alpha_1(t), \cdots, \alpha_N(t)\}$

Stochastic Super-Resolution Model Adaptation:

while $t \leq T$ **do** // T: operation time
  Observe $Q(t)$
  $\mathcal{T}^* \leftarrow -\infty$
  for $\alpha(t) \in A$ **do**
    $\mathcal{T} \leftarrow V \cdot P(\alpha(t)) + Q(t) \cdot \mu_\alpha(t)$
    if $\mathcal{T} \geq \mathcal{T}^*$ **then**
      $\mathcal{T}^* \leftarrow \mathcal{T}$
      $\alpha^*(t) \leftarrow \alpha(t)$
    end if
  end for
end while

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

Preliminary Result



- x-axis: unit time
- y-axis: queue-backlog

Shallow, faster, lower performance ← → Deeper, slower, higher performance

Depth	0	4	6	8	11	14	17	20
PSNR (dB)	30.4	32.56	33.01	33.229	33.379	33.435	33.495	33.523
Processing time (GPU)	0.001	0.01	0.012	0.0152	0.0189	0.0224	0.0262	0.0305

- **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.

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**
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