Models and Methods in Mobile Edge Computing Systems

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Outline

1 Models
   - User Mobility
   - Path Selection and Rate Allocation
   - Service Composition and Selection
   - Utility Maximization or Penalty Minimization in Networks
   - Combinations of the Above Contents in Different Scenarios
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2 Methods
- Evolutionary Algorithms
- Lyapunov Optimization
- Stochastic Programming
- Perturbation Theory
- Optimization Methods for Machine Learning
- Combinations of the Above Contents in Different Ways

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3 Future Works

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Models and Methods in Mobile Edge Computing Systems
Different Mobilities Models (ad hoc networks)

- **Entity Mobility Models**
  - random work
  - random waypoint
  - random direction
  - a boundless simulation Area
  - Gauss-Markov
  - a probabilistic version of random walk
  - city section mobility model

- **Group Mobility Models**
  - exponential correlated random mobility
  - column mobility model
  - nomadic community mobility model
  - purse mobility model
  - reference point group mobility model
Put User Mobility in Different Scenarios

- Integrate with Composite Services (mobility model grid)
- In (5G) Cell Networks (consisting of macro and small cell BSs)
- Fixed User’s Path
  - only QoM/N is changing
  - only channel power gain is changing (because of distances)
  - other variables in different networks...
In Self-Backhauled mmWave Networks

- Select the Best Paths and Allocate Rates over these Paths

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Models and Methods in Mobile Edge Computing Systems
Service Selection

- Mobility-Enabled Service Selection from Candidates
Service Composition

- Take Execution Sequence into Consideration (How?)
- The Amount of Input/Output for each Tasks are Different
- Parallel Tasks
  - each parallel task can be represented by a task buffer
  - each task buffer can be executed simultaneously in order
  - what about the tasks were offloaded to different MEC servers?
Yuyi Mao’s papers* are inundated with this kind of model!

- Match with Lyapunov Optimization Methods
  - Construct Virtual Queues for Constraints
  - Replace the Original Problem with a Deterministic one
  - Solve the Approximate-Convex Problem with Ingenious Mathematic Tricks

- Utilize Lagrange Methods and KKT Conditions

- Performance Analysis \( O(V), O\left(\frac{1}{V}\right) \)

Apparently Yuyi Mao acquires proficiency in Michael. J. Neely’s book: *Stochastic Network Optimization with Application to Communication and Queueing Systems*
There has no significant difference between $-\bar{U}$ and $\bar{p}$. But if we comprehend Neely’s book **thoroughly**, we can find that there are many variations and all of them can be utilized to form a new model!
Our 1st Model

Models and Methods in Mobile Edge Computing Systems
Our 2nd Model

I haven’t drawn the schematic diagram of the model. :-(
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Traditional Heuristic Algorithms

- Swarm Intelligence
- Tabu Search
- Simulated Annealing
- Artificial Neural Networks
- Population-based Algorithms
  - genetic algorithm
  - particle swarm optimization
  - negative selection algorithm
  - learning-teaching-based optimization
  - ...

- Too many of Them...
Zeroth-order optimization

Derivative-free optimization/black-box optimization does not rely on the gradient of the objective function, but instead, learns from samples of the search space. It is suitable for optimizing functions that are nondifferentiable, with many local minima, or even unknown but only testable.

(These works are contributed by Yang Yu from LAMDA Group, Nanjing University. Code can be found at Link)
Standard Lyapunov optimization

A trump card for stochastic optimization problems!

- Virtual Queues
- Drift-Plus-Penalty Expression
- Approximate Scheduling
- Performance Analysis
  - average penalty analysis
  - average queue size analysis
- Delay Tradeoffs
Extensions on Lyapunov Optimization

Each of these extensions can construct many models!

1. Extensions to Variable Frame Length Systems (Dynamic Optimization and Learning for **Renewal Systems**)
2. Combination with **Lagrange Multipliers**
3. Network Utility Maximization over Partially Observable **Markovian Channels**
4. Under **Non-Convex Problems** (Greedy primal-dual algorithm)
Two-Stage Stochastic Programming

- Scenario construction
- Monte Carlo techniques (SAA method)
- Evaluation Candidate Solutions (measure the optimality gap between the optimal value and the estimated value)
Multi-Stage Stochastic Programming

Take the “SAA” paper for example: (This paper can be found at [Link](#))

- Scenario construction
- Monte Carlo techniques (**SAA method**)
- The implementation of algorithms in this paper can be found at [Link](#)
Perturbation Theory

Comprise mathematical methods for finding an approximate solution to a problem.

- Time-Independent Perturbation Theory
  - Non-degenerate Case
  - Degenerate Case
  - The Stark Effect

- Time-Dependent Perturbation Theory
  - Review of Interaction Picture
  - Dyson Series
  - Fermi’s Golden Rule

Perturbation Theory always help Lyapunov Optimization work better (read Neely’s book).
Optimization for Machine Learning

What we talk about here are numerical optimization algorithms in the context of large-scale machine learning applications.

- Gradient Descent Methods (in batch)
- Stochastic Gradient Descent Methods
- Noise Reduction and Second-Order Methods
- Other Popular Methods
  - Gradient Methods with Momentum
  - Accelerated Gradient Methods
  - Coordinate Descent Methods
- Methods for Regularized Models
Deep Neural Networks

Typical method is **Deep Q-Network** (a combination of DNN and Reinforcement Learning).

- Take the paper “Performance Optimization in Mobile-Edge Computing via Deep Reinforcement Learning” for example: (which can be found at [Link](#))
Deep Neural Networks
Deep Neural Networks
Proposed Algorithms for Our Model

Didn't finish yet. :-(
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Further Work

- Combinations of different Models and Methods
- Models should be Associated with the Reality
- Thoroughly Understand Neely’s book and Convex Optimization by Stephen Boyd