Elective Course Name: Control of Queues and other networked Systems (L-T-P: 3-1-0, CRD: 4)

Description: This course focuses on the optimal control of discrete-event stochastic dynamic systems, and in particular queuing networks. The theoretical framework is that of Markov Decision Processes, complemented by additional tools such as stochastic coupling, stability theory and Lyapunov functions. Also discussed are non-centralized decisions by rational (selfish) customers or servers, in the framework of non-cooperative game theory. Applications to communication networks, computing systems, Smart grid, Intelligent Transportation systems, service systems, and manufacturing will be discussed.

Course Syllabus:

1. **Introduction to dynamic programming, examples, problem formulation**.
2. The dynamic programming algorithm: Principle of optimality
3. Deterministic systems and the shortest path problem
4. Deterministic continuous-time optimal control

5. **Related Issues:** Optimal stopping problem: Bruss's odds algorithm, Examples.
6. Continuous time dynamic programming: HJB equation
7. Pontryagin's Maximum Principle: Application of the same

8. **Markov Decision Processes: Introduction & Examples, Stationary Policies**
9. Infinite and finite horizon problems
10. Value function, Value iteration, Odoni's result and implications.
11. Markov Decision Processes: LP Solution
12. Policy Improvement Algorithm
13. Discounted Cost Criterion and Average Cost Criterion
14. Problems with perfect and imperfect state information (POMDP)
15. Constrained Markov decision process
16. Continuous time Markov decision process

17. **Control and management of queuing systems**
18. Admission and service control in a single queue
19. Routing into parallel queues
20. Routing and service control in queuing networks
21. Scheduling: Deterministic, Stochastic, Finite number of jobs, Duality with Routing.
22. Multi-Armed Bandits: Gittins indices
23. Proof of Gittin's index theorem and calculation of the same
24. Server scheduling in parallel queues: the c-mu rule
25. Server scheduling in Klimov networks
26. LP method for finding properties of value functions
27. Sample path method in control of queues: Interchange arguments, backward induction, and forward induction. Stochastic majorization and stochastic order
28. Fluid models: flow-level control, optimal scheduling with fluid models
29. Controlled Queuing systems: Models approximating the controlled queuing systems (G/G/1): Renewal processes, Random Walks, Brownian Motion and Fluid models
30. Power of 2 choices: Performance upper and lower bounds, applications and examples.

31. Definitions of Stability, Introduction to Lyapunov Analysis
32. Single and two Queue system Control Problem, Multihop Network Scheduling
33. Multihop Network Scheduling, Caratheodory's Theorem, Virtual Queues
34. Scheduling for Utility Maximization
35. Wired Network optimization, NUM and Dual Decomposition, Linear Fractional Programming
36. Lyapunov method based Delay Reduction Techniques
37. Max-Weight CSMA, Markov Approximation and its Applications, Mixing Time

38. Queueing games: Strategic decisions in queues
39. Nash Equilbrium
40. Strategic arrivals, reneging and routing decisions, Server competition

References:

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27. Eitan Altman, "Network Engineering Games", monograph in preparation.
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