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Energy-Efficient Transmission Scheduling with Strict Underflow Constraints

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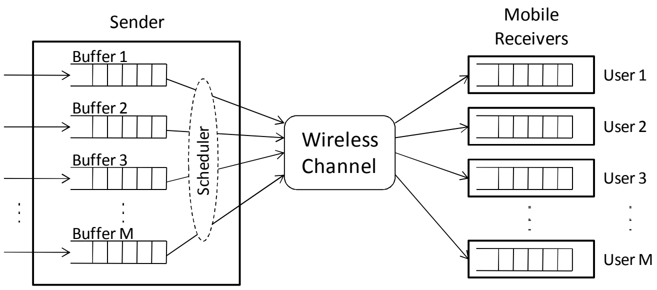
Motivating Application – Wireless Media Streaming

- Single source transmitting data streams to one or more receivers/users over a shared wireless channel
- Available data rate of the channel varies with time and from receiver to receiver



Timing in Each Slot

- Transmitter learns each channel's condition
- Transmitter allocates some amount of power (possibly zero) for transmission to each user
- Transmission and reception
- Packets are removed / purged from each receiver's buffer for playing

Transmission Scheduling Objectives

- Avoid underflow so as to ensure playout quality
- Minimize system-wide power consumption in order to:
  - Prolong the system's lifetime
  - Maximize the number of receivers the sender can support
  - Limit interference

Main idea – Opportunistic Scheduling

- Exploit the temporal and spatial variation of the channel by transmitting more data when the channel condition is "good" and less data when the channel condition is "bad"
  - Challenge is to determine what is a "good" condition and how much data to send accordingly
- Strict underflow constraints represent a competing quality-of-service interest

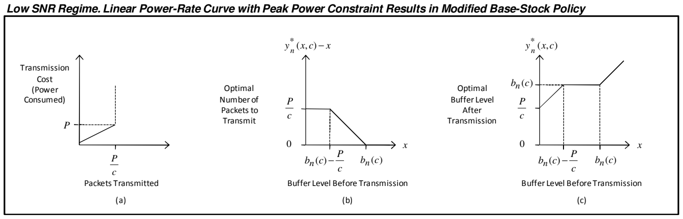
Summary of Contributions

1. Relation to inventory theory

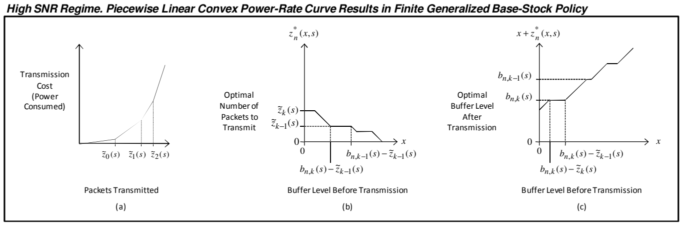
- In inventory language, our problem is a multi-period, multi-item, discrete time inventory model with random ordering prices, deterministic demand, and budget constraints
  - Items → Data streams for each of the mobile receivers
  - Inventories → Receiver buffers
  - Random ordering prices → Random channel conditions
  - Deterministic demand → Users' packet requirements for playout
  - Budget constraint → Transmitter's power constraint

2. Structure of optimal policy for the single receiver case

Low SNR Regime. Linear Power-Rate Curve with Peak Power Constraint Results in Modified Base-Stock Policy

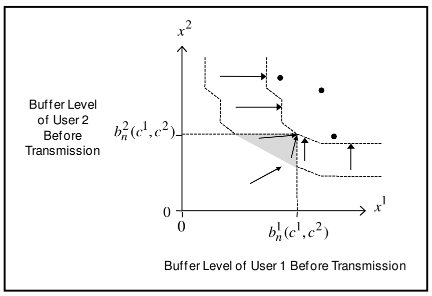


High SNR Regime. Piecewise Linear Convex Power-Rate Curve Results in Finite Generalized Base-Stock Policy



- We can also determine the "critical numbers" when certain technical conditions are satisfied

3. Structure of optimal policy for the two receiver case



Ongoing Work

- Develop near-optimal policies and better intuition for general M-receiver case through numerical approximation techniques