Optimal Power Control for Wireless Queueing Networks
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Abstract
- Optimally controlling transmit power for jointly minimizing:
  - Energy expenditure
  - Buffer overflow
- Considered System
  - Wireless Link,
  - Finite-capacity buffer,
  - Random packet arrivals,
  - Choosing from two alternative power levels.
- Result
  - Optimal policy is of threshold type.

System Model
- Wireless Link
  - Finite buffer capacity (length= K)
  - Bernoulli packet arrivals (rate= λ)
  - Equal length packets (length= 1 bit)
- Control: ut: Power control decision
  - Two alternative power Levels (P1<P2)
  - ut is allowed only when xt=0.
- State, xt: Buffer occupancy in the t-th slot (x(t)ε{(0,1,...,K)})
  - State Transitions
    - State Transition Equations:
      \[ d_{i,j}(u) = x_{j}P_{i} = 1 + Q_{i}X_{i} = \frac{x_{j}}{x_{j}P_{i}} \]
    - Energy Expenditure cost:
      \[ E(x) = \sum_{i=1}^{n} c_{i}(u)(Q_{i})^{X_{i}}(x) \]
    - Single Stage Cost:
      \[ g(x,u) = \max \{g(x,u)\} \]
    - Dynamic Programming Equations:
      \[ V^{*}(x) = \min \{g(x,u)\} \]

Motivation
- Energy Efficiency
  - A key concern in wireless networks,
  - Limited and non renewable power supplies.
  - Power Control, Traditional Work:
    - Mitigating effects of interference,
    - Satisfying some QoS constraints,
    - SINR, BER constraints (Poschini(93), Yates(95))

Optimality of Threshold Policy
- For 0≤x<K, optimal policy chooses P2 if:
  \[ c_{1}(P2) - c_{1}(P1) = \frac{Q_{i}}{(1-Q_{i})}X_{i} = (1-Q_{i})X_{i} \]
- Here h_{i} = x_{i}^{X_{i}}(x)
- Theorem: For P1<P2 the below inequalities hold in every iteration n:
  - For x≥x_{n}: c_{i}(P2)≥c_{i}(P1)
    (1)
  - For x=0: c_{i}(P2)≥c_{i}(P1)
    (2)
  - For x=K: c_{i}(P2)≥c_{i}(P1)
    (3)

Practical Determination of Thresholds
- Let 0≤h≤K be the threshold value.
- Queue state probabilities π = [π₁, π₂, ..., πₚ] can be found by solving the Markov chain below:
- Find t* minimizing the cost below:
  \[ d_{i,j}(u) = \min \{g(0,0), g(1,1), g(2,2), g(x,2)\} \]
- Results
  - The optimal power control policy of threshold type.
  - Optimal threshold
    - Increases as P1 approaches to P2,
    - Decreases as the arrival rate increases,
    - Decreases as the discount factor α increases.