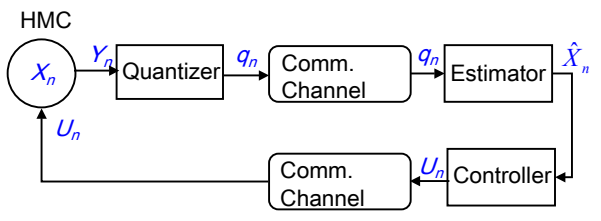


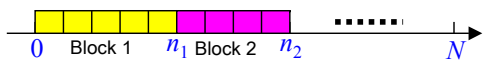
## Introduction

- ❑ **Motivation:** multiple conflicting objectives in networked control systems
  - System performance
  - Communication bandwidth
  - Delay
  - Hardware/software complexity
- ❑ **Question:** how to strike the right balance?
- ❑ **Model:** Hidden Markov chains (HMCs)



- $X_n$ : state
- $Y_n$ : output
- $q_n$ : quantized output
- $U_n$ : control

## Variable-Length Block-Quantization



- ❑ High coding-efficiency
- ❑ Inducing delay
- ❑ Equi-memory for the encoder and the decoder

## Joint Quantization, Estimation, and Control

- ❑ **Joint quantization and estimation**

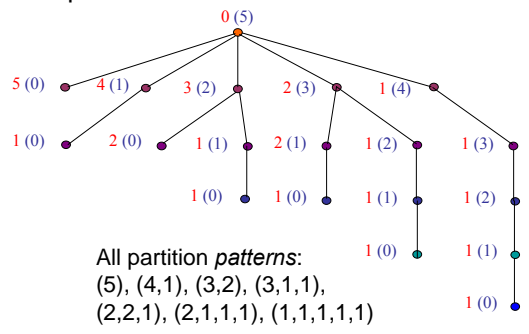
$$J(P_{0,x}, g) = E[\sum_{n=1}^N J^c(n) + l_d J^d(n) + l_e J^e(n)],$$
  - $\Pi_0$ : *A priori* PMF for  $X_0$
  - $\gamma$ : Quantization decision
  - $J^c(n)$ : Communication cost at time  $n$
  - $J^d(n)$ : Delay cost evaluated at time  $n$
  - $J^e(n)$ : Estimation error for  $X_n$

- ❑ **Joint quantization and control**

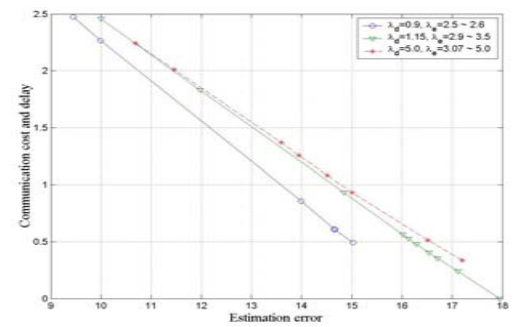
$$J(P_{0,x}) = E[\sum_{n=1}^N l_c J^c(n) + J^p(n)],$$
  - $\zeta$ : Quantization/control decision
  - $J^c(n)$ : Communication cost at time  $n$
  - $J^p(n)$ : Running cost at time  $n$

- ❑ **Dynamic programming equation**

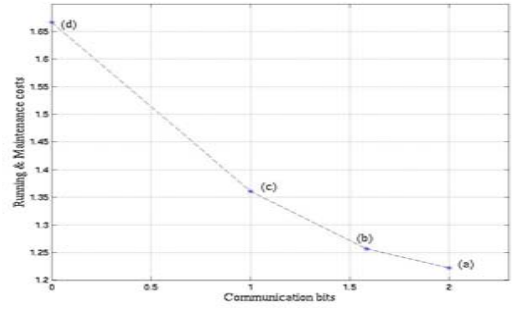
$$V_i(P_{i-1}) = \min_{\beta \in \{1, \dots, B\}} \min_{Q_j} \text{Cost for times } \{i, \dots, i+j-1\} + V_{i+j}(\hat{P}_{i+j-1})$$
  - Challenge: combinatorial problem
  - Tree-structured algorithm for enumeration of partitions



## Numerical Results



Communication cost & delay vs. estimation error.



Running cost vs. communication bits.

## Conclusion and Future Work

- ❑ **Conclusion:**
  - Multi-objective problem in networked control systems
  - DP solutions and Pareto curve
- ❑ **Future work:**
  - Efficient approximation method