Optimizing Configuration Hierarchy for Continuous Media Server

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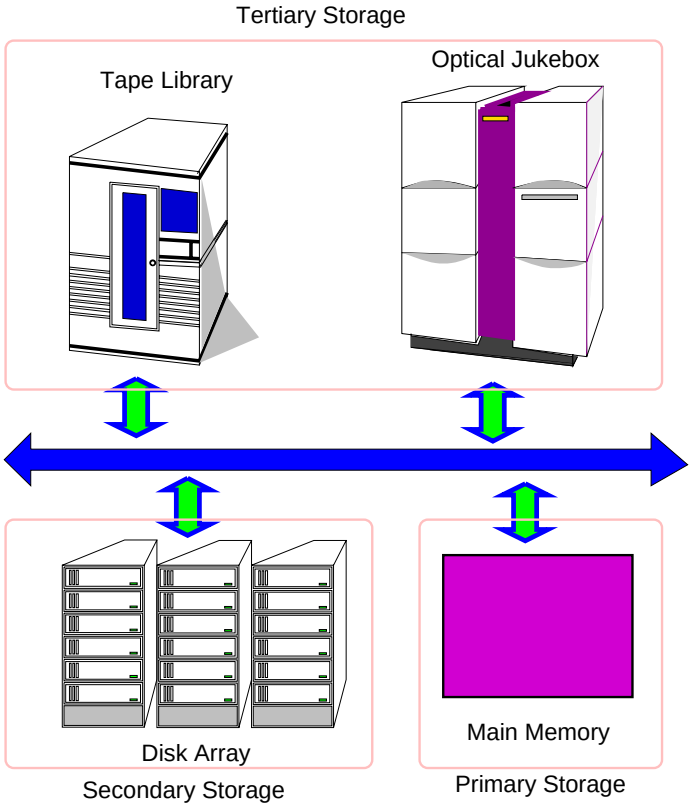
Motivation

On-Line Access of information:
Is *Per Service Cost* competitive?

- Volume Data: 3GB per 110min movie
- Excessive Bandwidth



Contribution

- System Modeling and Performance Analysis in Storage Hierarchy
  - Stochasitic Modeling: Blocking Probability and Waiting Time
  - Analysis on Performance Behavior
- Optimal Configuration of Storage Hierarchy
  - Partial Configuration and Integration
  - Balanced System and Quasi Optimal Configuration

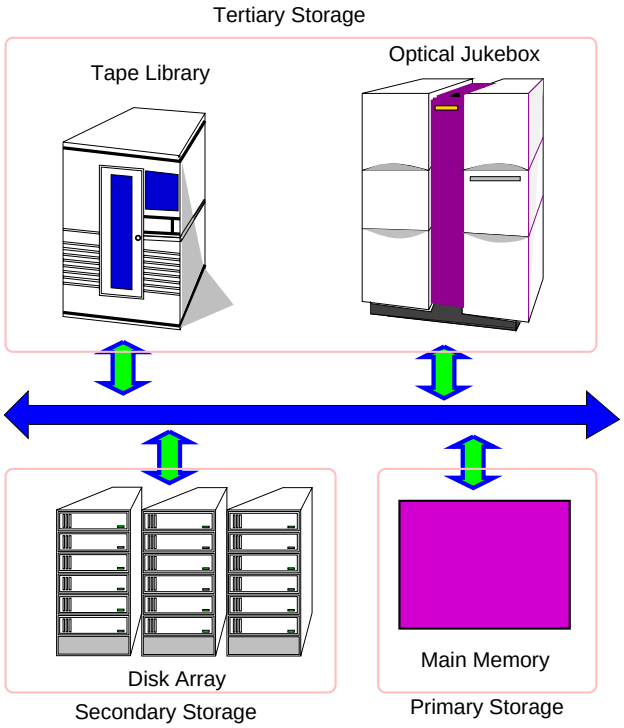
Objective

- System Modeling and Performance Analysis
- Find Optimal Configuration for Storage Hierarchy

Metrics for Server Throughput

- Expected Service Time: E(S)
- Blocking Probability: P(Block)

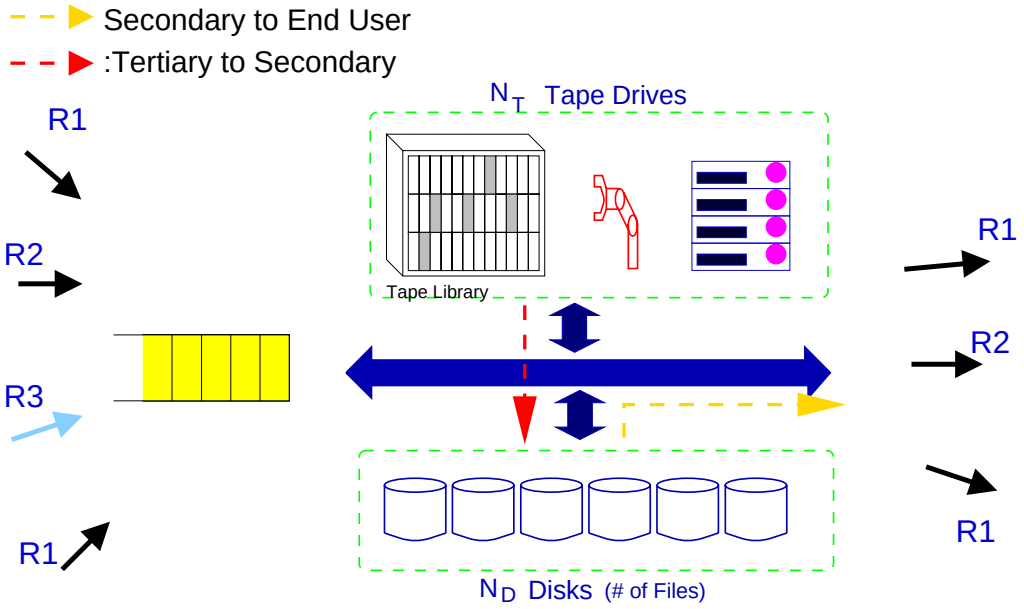
Hierarchical Storage



Role Model of Storage Hierarchy

	Secondary Storage	Tertiary Storage
Model I	Main Storage	Back-Up
Model II	*negotiation*	*negotiation*
Model III	Staging Purpose	Main Storage

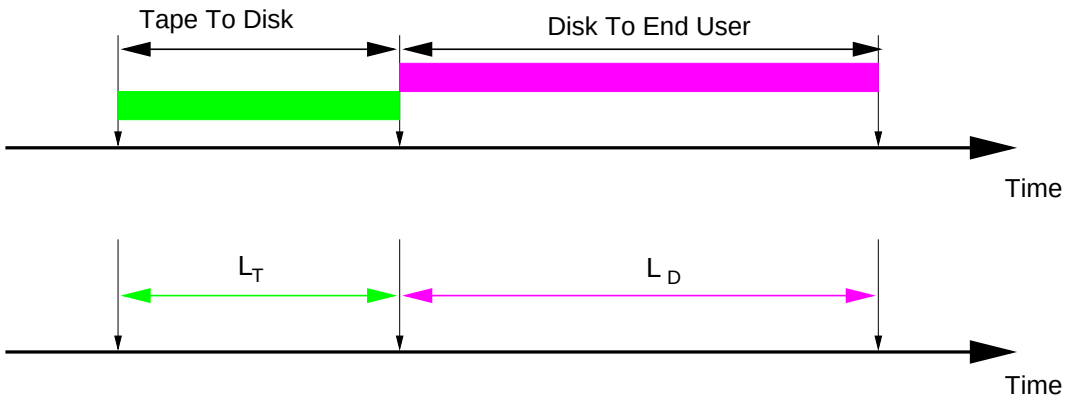
Service Mechanism for VOD Request



File is sent to User from Secondary Storage

- File Loading: $\mathcal{T} \rightarrow \mathcal{D}(L_T \text{ sec}), \mathcal{D} \rightarrow \mathcal{U}(L_D \text{ sec})$
- Disk Space Reservation: $\mathcal{T} \rightarrow \mathcal{D}$ operation
- Management of Disk Space
  - Release After Service Completion
  - Extension of Residency
- File Status: *Idle*, *On Tape*, *On Disk*

Intra-Hierarchy Stream Transfer



L_T: Time for Tape to Disk File Transfer
L_D: Time for Disk to User Transfer

$$Service\ Time = Time(\mathcal{T} \rightarrow \mathcal{D}) + Time(\mathcal{T} \rightarrow \mathcal{U})$$

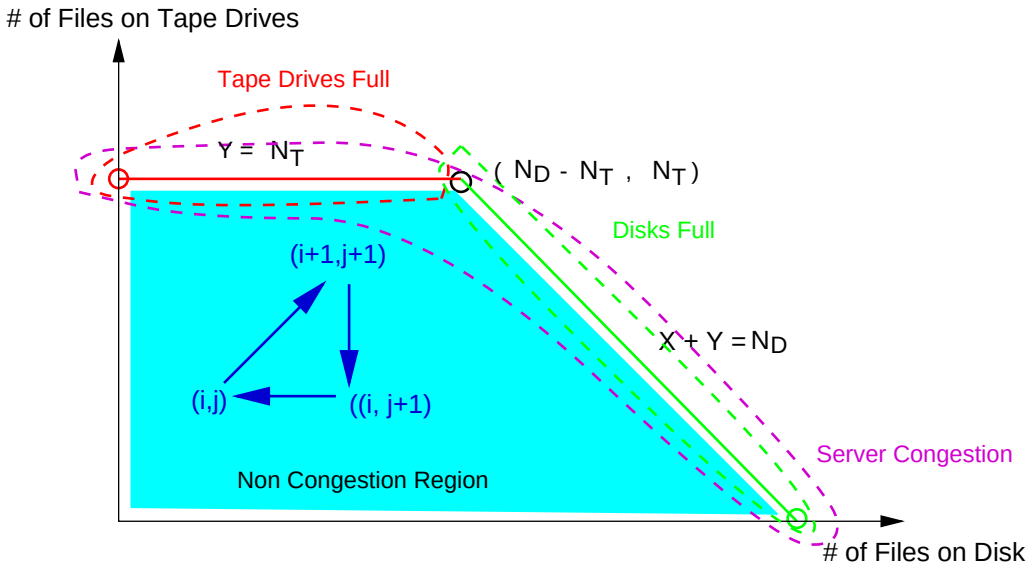
$\mathcal{T} \rightarrow \mathcal{D}$:

- *Tape Read + Disk Write*
- Buffer: To Compensate Speed Mismatch

$\mathcal{D} \rightarrow \mathcal{U}$:

- Buffer: Determined by Scheduling Algorithm
- Pipelining
  - *Disk Write + Playback*: *Only in Pipelining*
  - Latency

Modeling of Hierarchical Storage



State Vector : $\pi = \langle F_1, \ldots, F_M \rangle,\ F_i = \mathcal{I}|\mathcal{D}|\mathcal{T}$

Valid Operating States

$$\Pi = \{\pi; |\pi^{\mathcal{T}}| \leq N_T,\ |\pi^{\mathcal{T}}| + |\pi^{\mathcal{D}}| \leq N_D\}$$

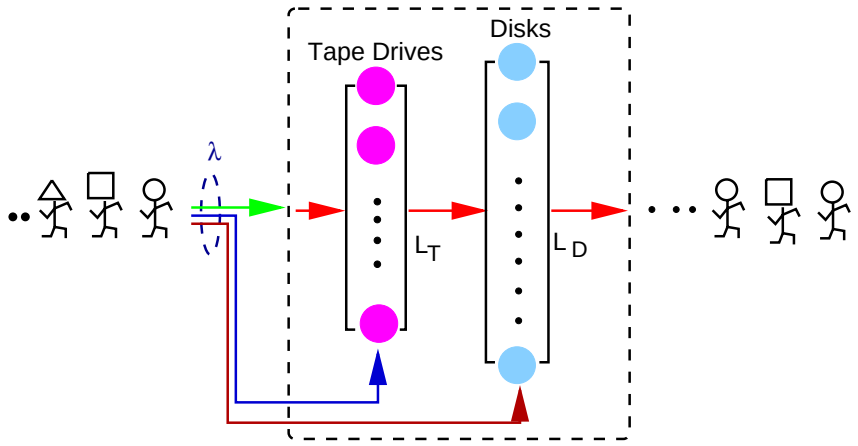
Transition Matrix: P

$$(\ldots, \mathcal{I}, \ldots) \xrightarrow{\lambda_i} (\ldots, \mathcal{T}, \ldots)$$

$$(\ldots, \mathcal{T}, \ldots) \xrightarrow{\frac{1}{L_T}} (\ldots, \mathcal{D}, \ldots)$$

$$(\ldots, \mathcal{D}, \ldots) \xrightarrow{\frac{\lambda_i}{e^{\lambda_i L_D} - 1}} (\ldots, \mathcal{I}, \ldots)$$

Expected Service Time: Open System's Perspective



- Request for file i: $\underbrace{P(D_i),\ P(T_i),\ P(I_i)}_{Admitted}$, and $\underbrace{P(B_i)}_{Blocked}$

$$P(I_i) = \sum_{\pi_j \in \Pi} \pi_j I(I_i)$$

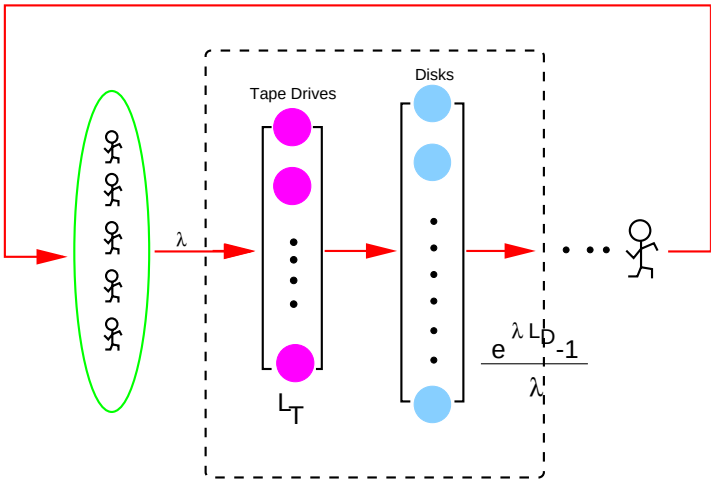
$$P(T_i) = \sum_{\pi_j \in \Pi} \pi_j I(T_i)$$

$$P(D_i) = \sum_{\pi_j \in \Pi} \pi_j I(D_i)$$

- $P(D_i)$, $P(T_i)$, $P(I_i)$, $P(B_i)$ are Function of L_D, L_T and λ_i
- Expected Service Time of Request for file i:

$$E(S_i) = P(I_i)(L_T + L_D) + P(D_i)L_D + P(T_i)(\frac{L_T}{2} + L_D)$$

Blocking Probability: Closed System's Perspective



Congestion States

$$\Pi_{\mathcal{C}} = \{\pi; |\pi^{\mathcal{T}}| = N_T,\ |\pi^{\mathcal{T}}| + |\pi^{\mathcal{D}}| = N_D\}$$

Steady State Probability: $\boldsymbol{\pi} = \boldsymbol{\pi} P$

P(Block) = P(Congestion)*P(Arrival of new File)

$$P(Block) = \sum_{\pi_i \in \Pi_{\mathcal{C}}} \pi_i \sum_{j \in \pi_i^{\mathcal{I}}} p_j$$

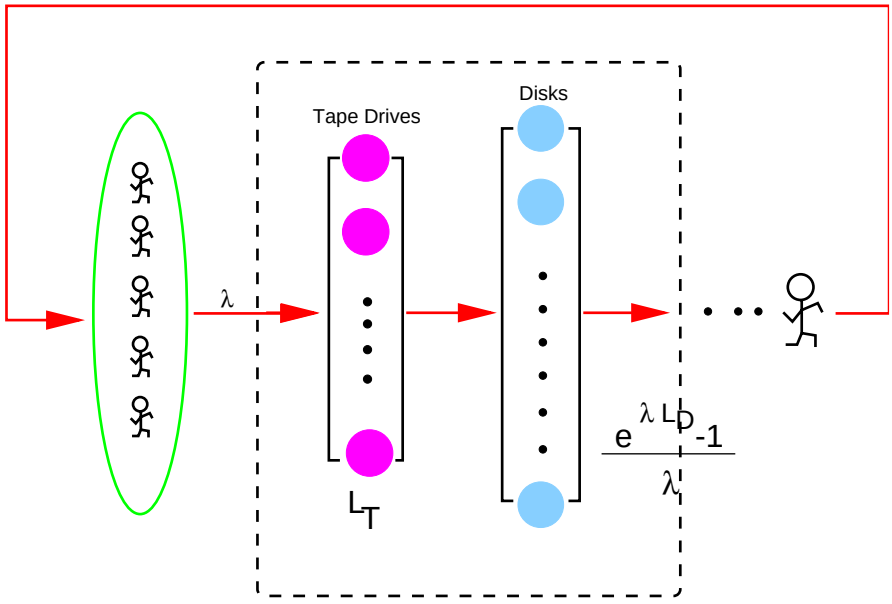
Behavior of *P(Block)*:

Visualized with $N_T = N_D = 1, M = 1$.

Configuration of Storage Hierarchy

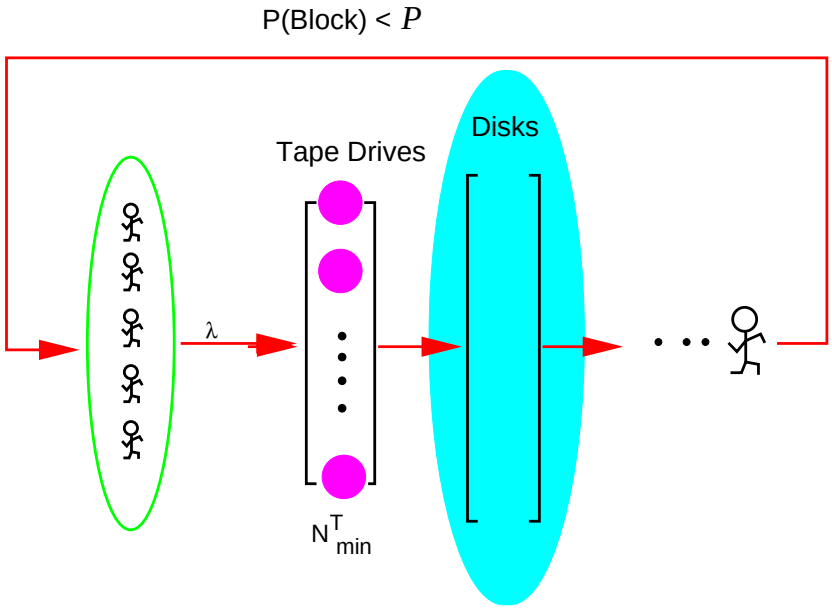
- Configuration $\Re = \langle N_T, N_D, \mu_T, \mu_D \rangle$
- User Profile $\Im = \langle P, \lambda \rangle$

Given $\Im$, μ_T, and μ_D, Find N_T^{min} and N_D^{min} with $P(Block) < \mathcal{P}$



$$P(Block) = P_{Tape\ Drive}(Block) + P_{Disk}(Block)$$

Partial Optimal Configuration for N_T^{min}



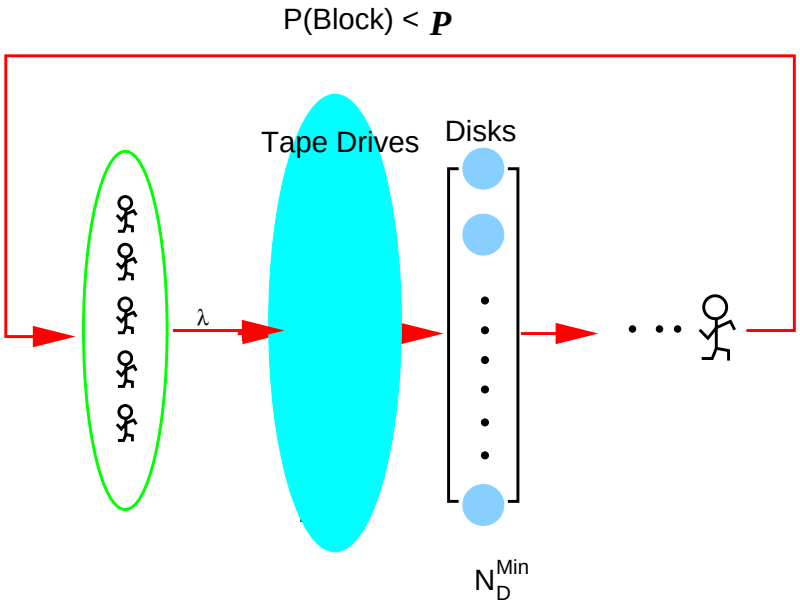
Let $N_D = \infty$.

Find N_T^{min} with $\Re = \langle N_T, \infty, \mu_T, \mu_D \rangle$.

How to Obtain N_T^{min}?

- Simulation
- Application of Generalized Engset Formula

Partial Optimal Configuration for N_D^{min}



Let $N_T = \infty$.

Find N_D^{min} with $\Re = \langle \infty, N_D, \mu_T, \mu_D \rangle$.

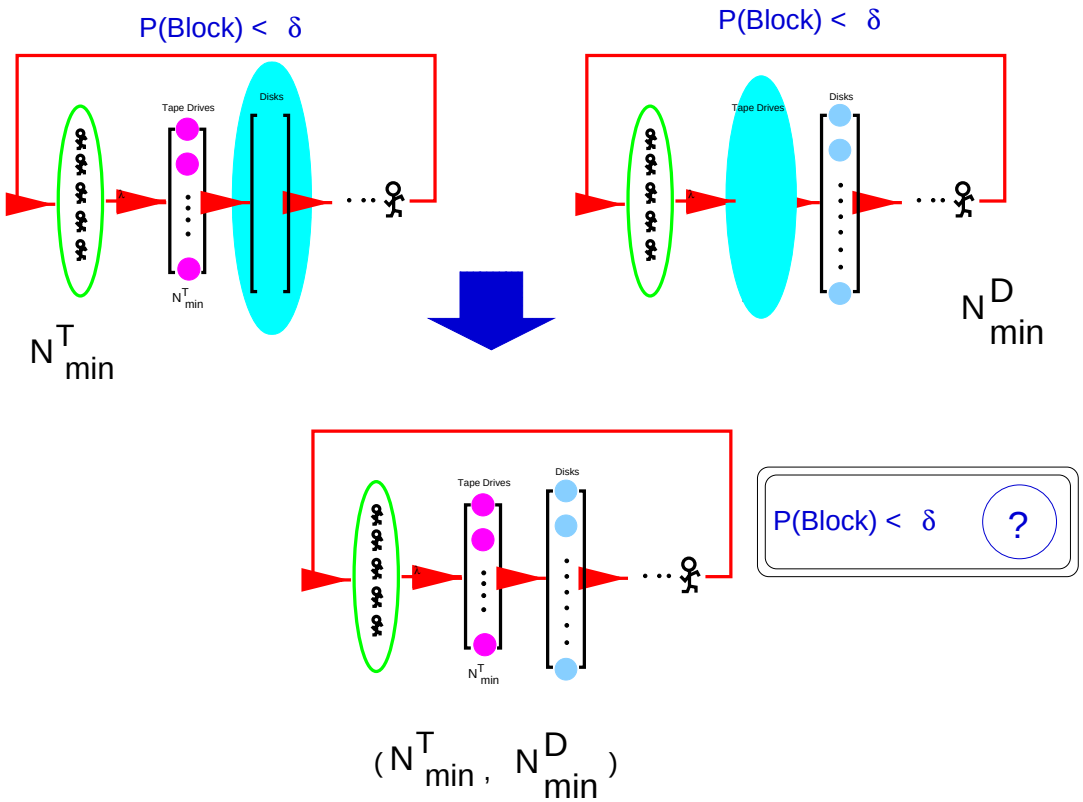
How to Obtain N_T^{min}?

- Simulation
- Application of Generalized Engset Formula

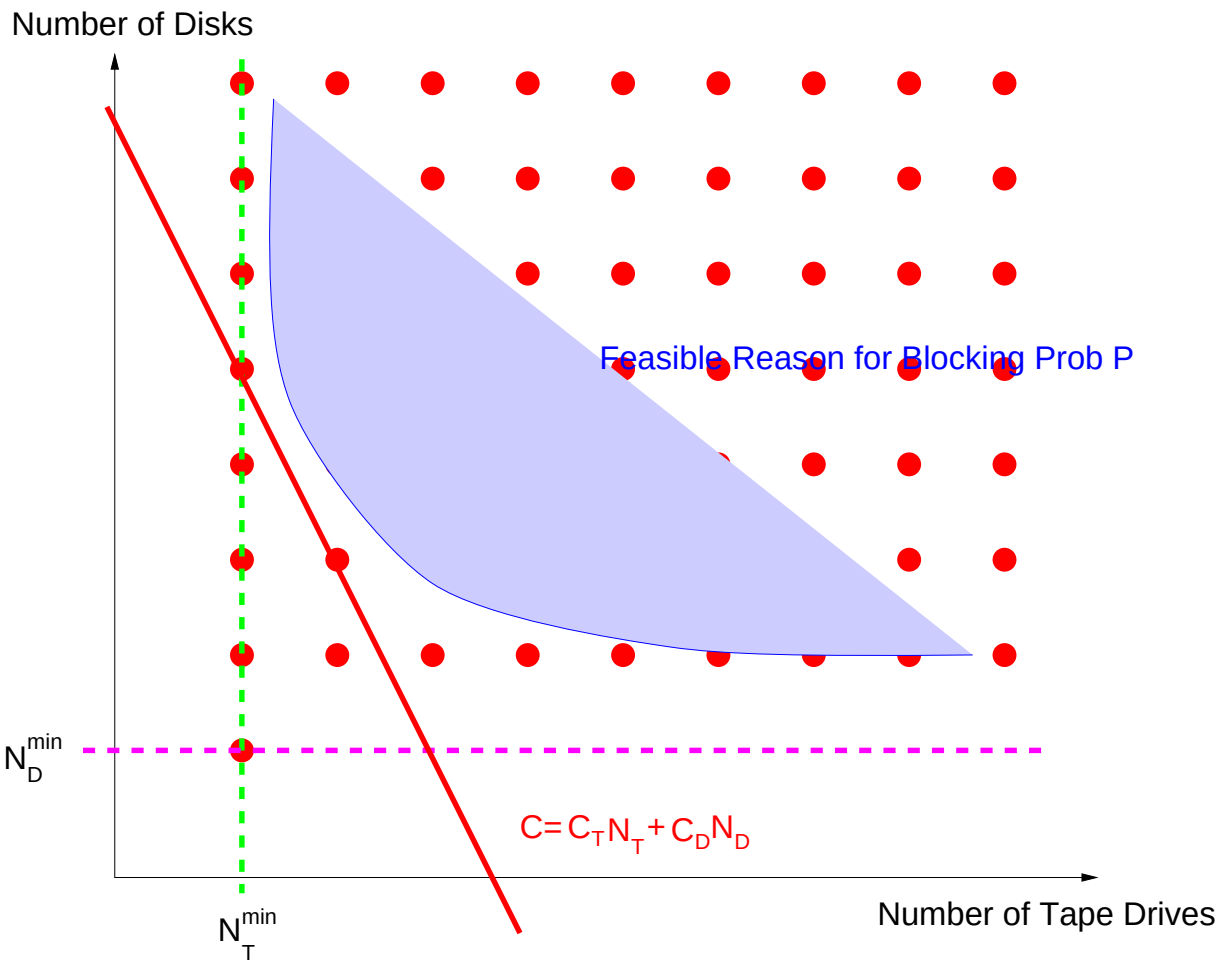
Integration of Partial Optimal Solution

- C_T: unit cost for tape drive
- C_D: unit cost for disk

Minimize $C_T N_T + C_D N_D$.



Finding Optimal Configuration

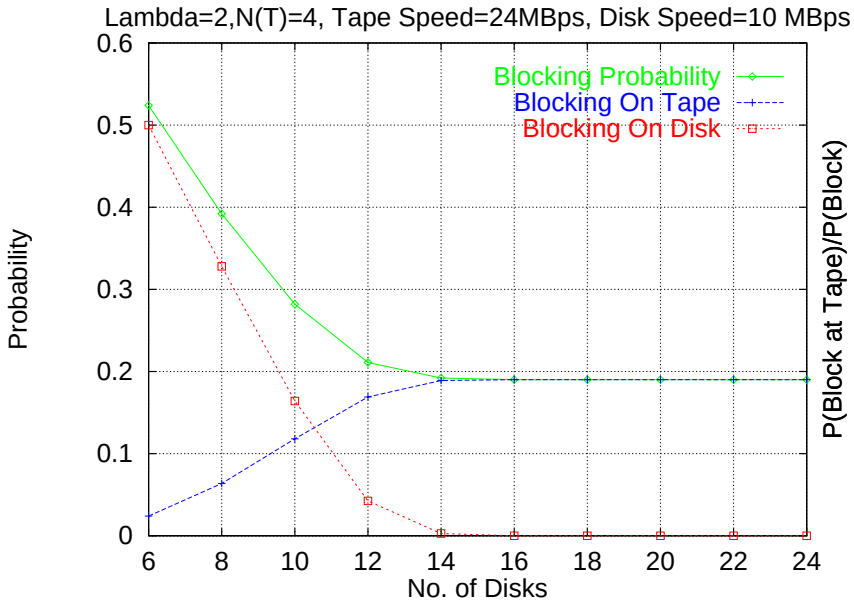


Conjecture

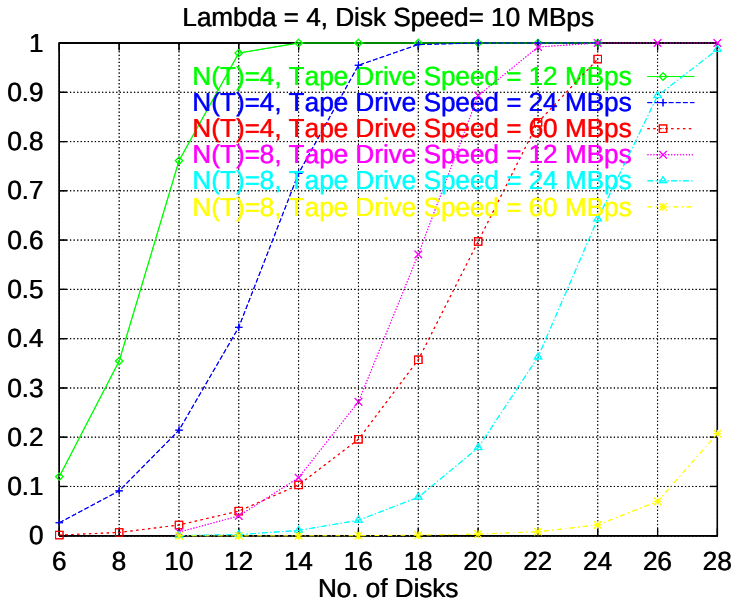
The configuration $\Re = \langle N_T^{min}, N_D^{min}, \mu_T, \mu_D \rangle$ is

- Balanced
- Optimal, or Quasi Optimal

Balanced System



Bottleneck Analysis



Summary

Solution for Affordable On-Line Multimedia Service

- Hierarchical Storage Architecture
- Distributed Extension of Hierarchical Storage Architecture

Environmental Assumption

- Skewed Access Pattern
- Wide Variety of Selection
- Large Individual File Size
- Relatively Less Critical Application Environment