به نام خدا

Performance Evaluation of Computer Systems

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Performance Modeling and Design of Computer Systems

7- MODIFICATION ANALYSIS: "WHAT-IF" FOR CLOSED SYSTEMS

Asymptotic Bounds for Closed Systems

- **m :** number of devices in our system
- $D = \sum_{i=1}^{m} E[D_i]$
- $D_{max} = max_i\{E[D_i]\}$
- Bounds are **asymptotes** → For large **N** or small **N**, the curve comes very close to touching these lines

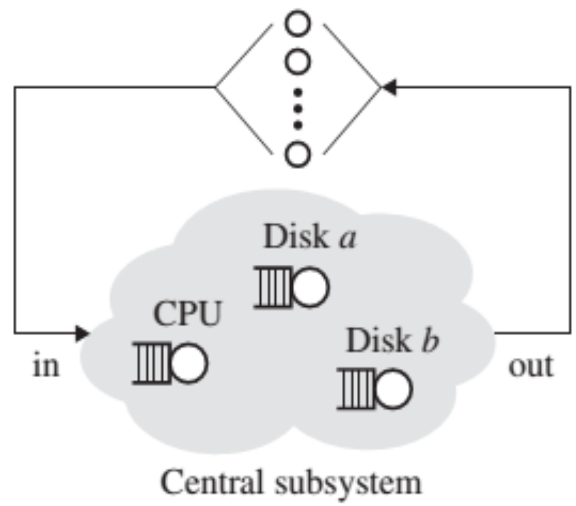
Theorem 7.1 *For any closed interactive system with N terminals,*

$$X \leq \min\left(\frac{N}{D + \mathbf{E}[Z]}, \frac{1}{D_{\max}}\right).$$
$$\mathbf{E}[R] \geq \max(D, N \cdot D_{\max} - \mathbf{E}[Z]).$$

Importantly, the first term in each clause ($\frac{N}{D+\mathbf{E}[Z]}$ or D) is an asymptote for small N, and the second term ($\frac{1}{D_{\max}}$ or $N \cdot D_{\max} - \mathbf{E}[Z]$) is an asymptote for large N.

Example

- $\mathbf{E}[Z] = 18$
- $\mathbf{E}[D_{\text{CPU}}] = 5$ sec
- $\mathbf{E}[D_{\text{disk a}}] = 4$ sec
- $\mathbf{E}[D_{\text{disk b}}] = 3$ sec



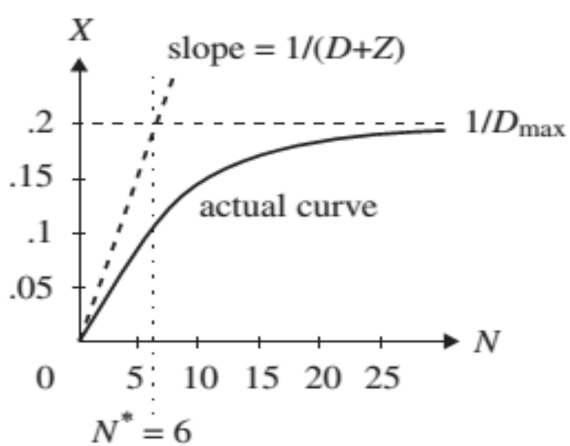
- $\boldsymbol{X}$?
- $\boldsymbol{E}[\boldsymbol{R}]$?

Example

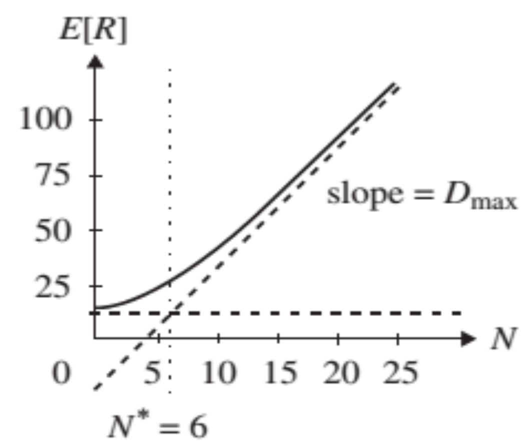
- $D = 5 + 4 + 3 = 12$ seconds
- $D_{\max} = 5$ (the CPU is the bottleneck device)

$$X \leq \min\{N/30, 1/5\}$$

$$\mathbf{E}[R] \geq \max\{12, 5N - 18\}$$



(a) X versus N



(b) $\mathbf{E}[R]$ versus N

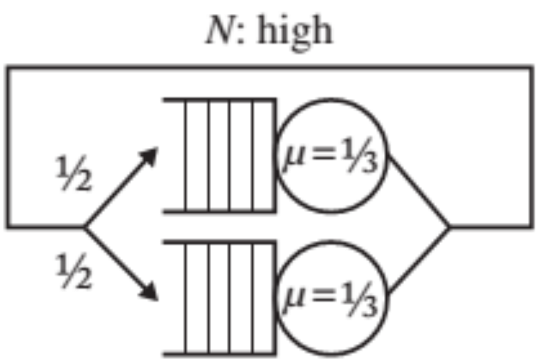
N*?

- Point beyond which there must be some queuing in the system ($E[R] > D$)

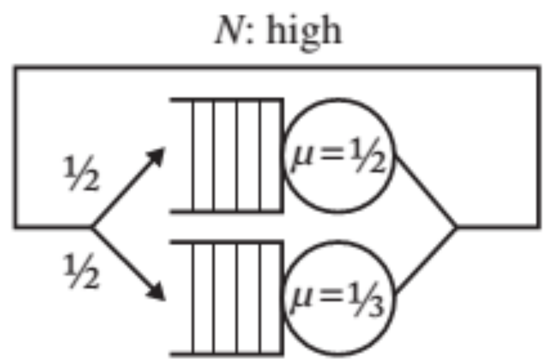
- N : fixed and N > N*
  - Get more throughput → Decrease D_{max}
  - Get lower response time→ Decrease D_{max}
  - Decrease $D_{next\_to\_max}$?
    - Performance for N >> N* does not change
    - Performance for N << N$*$ will improve a little

Modification Analysis

- **How much does the throughput improve?**
- **How much does the mean response time improve?**



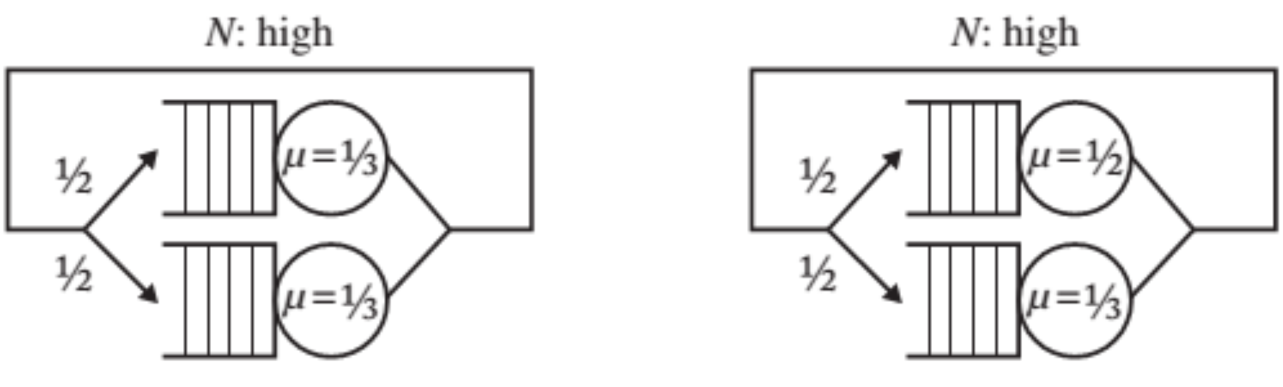
(a) **Original**



(b) **"Improved"**

Modification Analysis

- **Neither throughput nor mean response time changes!**



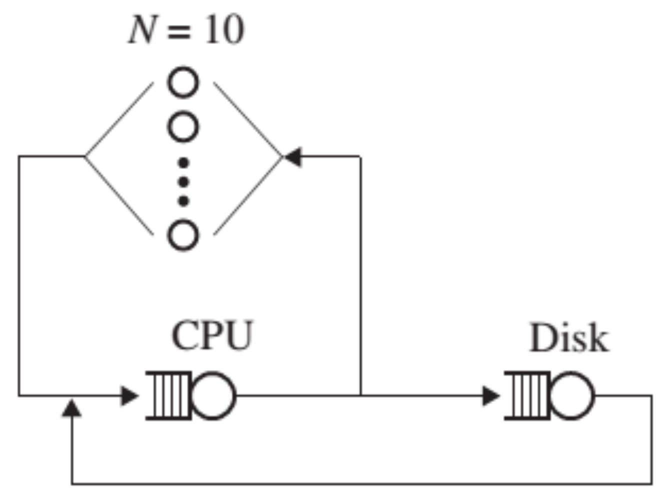
(a) **Original** (b) **"Improved"**

Summary

- D_{max} : **Bottleneck device**
- Key limiting factor to improve system performance
- Improving other devices will have little effect

Example

- $D_{cpu} = 4.6$ and $D_{disk} = 4.0$
- $D_{cpu} = 4.9$ and $D_{disk} = 1.9$



$$N_A^* = \frac{D + \mathbf{E}[Z]}{D_{\max}} = \frac{13.6}{4.6} < 3$$

$$N_B^* = \frac{11.8}{4.9} < 3$$

- For both systems : $N \gg N^*$
- A wins → lower D_{max}

Modification Analysis

- Easy and computation-feasible
- Independent of any assumption such as
    - Distribution of the service time
    - Distribution of the inter-arrival time
    - Scheduling order
- If N is sufficiently far from N*
    - These bounds are sufficient to analyze

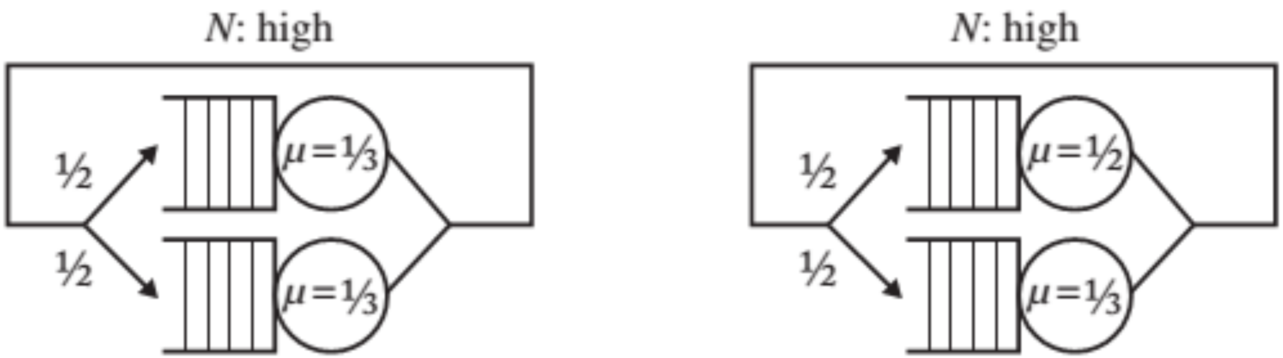
Why don’t they make sense for open networks?

- Because they are not asymptotic bounds in the open case!
- Still : $X \leq \frac{1}{D_{max}}$
  - We know $X = \lambda$
  - So, it is not a tight upper bound
  - The same is true for $E[R]$

- It applies only if
  - Outside arrival rate is high enough that X is close to $\frac{1}{D_{max}}$

Modification Analysis

- **Open Network**
  - **The mean response time, E[T], will certainly improve by speeding up just one of the two devices**



(a) **Original** (b) **"Improved"**