CSC 2232: Topics in Computer System Performance and Reliability

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WHO AM I

WHAT IS THIS CLASS ABOUT?

System performance & reliability

- Is one fast server better or two slow servers?
- How many data replicas do I need for reliability?
- How do I generate/simulate realistic workloads?
- What is the impact of workload characteristics?

⇒Methods, tools, back-of-the envelope calculations for system evaluation, simulation & measurement.

⇒Study of recent papers in the area.

LOGISTICS

- Class time: Friday 11am-1pm
  - Can we move to Wed 2-4pm
  - –Does anybody have serious scheduling conflicts?
- Office hours: Wed 4-5pm
  - –Plus open door policy
- Class web page
  - –www.cs.toronto.edu/~bianca/csc2232.html

GRADING

- 30% class participation
  - Participating in class discussion
  - Class presentation of at least one research paper
- 70% class project
  - I will suggest possible projects
  - You can propose your own
  - Final results: Conference style paper
- No exams!

OUTLINE

- Administrivia ✓
- Motivating examples
- Questionnaire

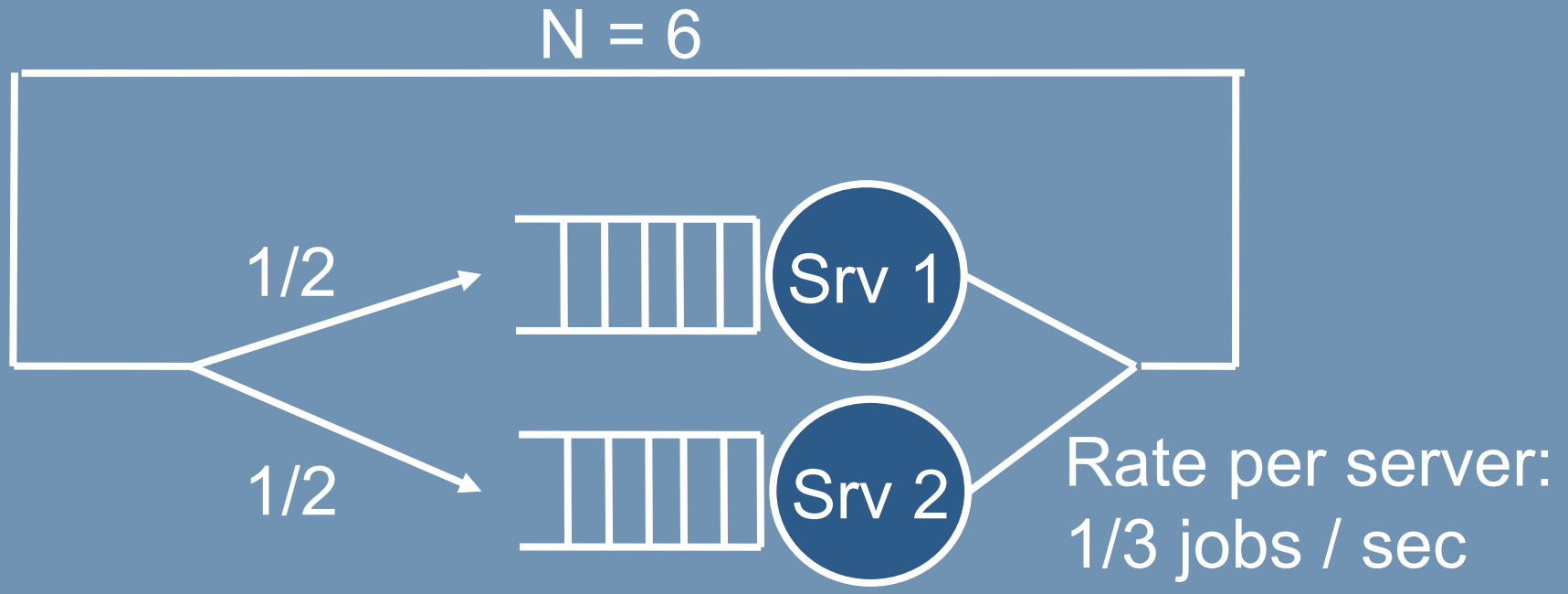
MOTIVATIONAL EXAMPLES / CASE STUDY

- System design is often a *counter-intuitive process*
- Do not expect to understand *everything* in the examples
- Don’t worry if you’re not familiar with all terminology
- Ask questions!

EXAMPLE 1

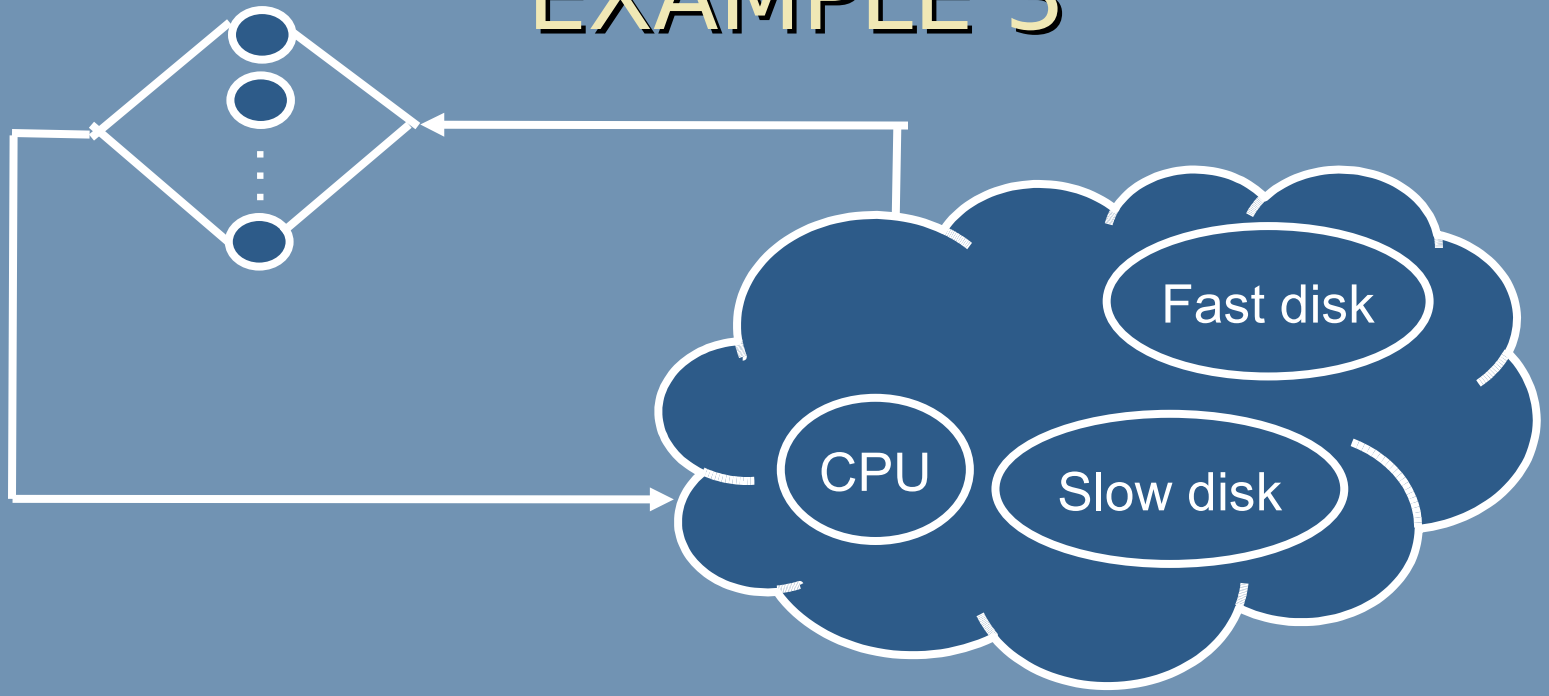
- Question: Assume the arrival rate doubles. By how much do you have to increase CPU speed to keep mean response times the same?
- Does the answer change with PS scheduling instead of FCFS?

EXAMPLE 2



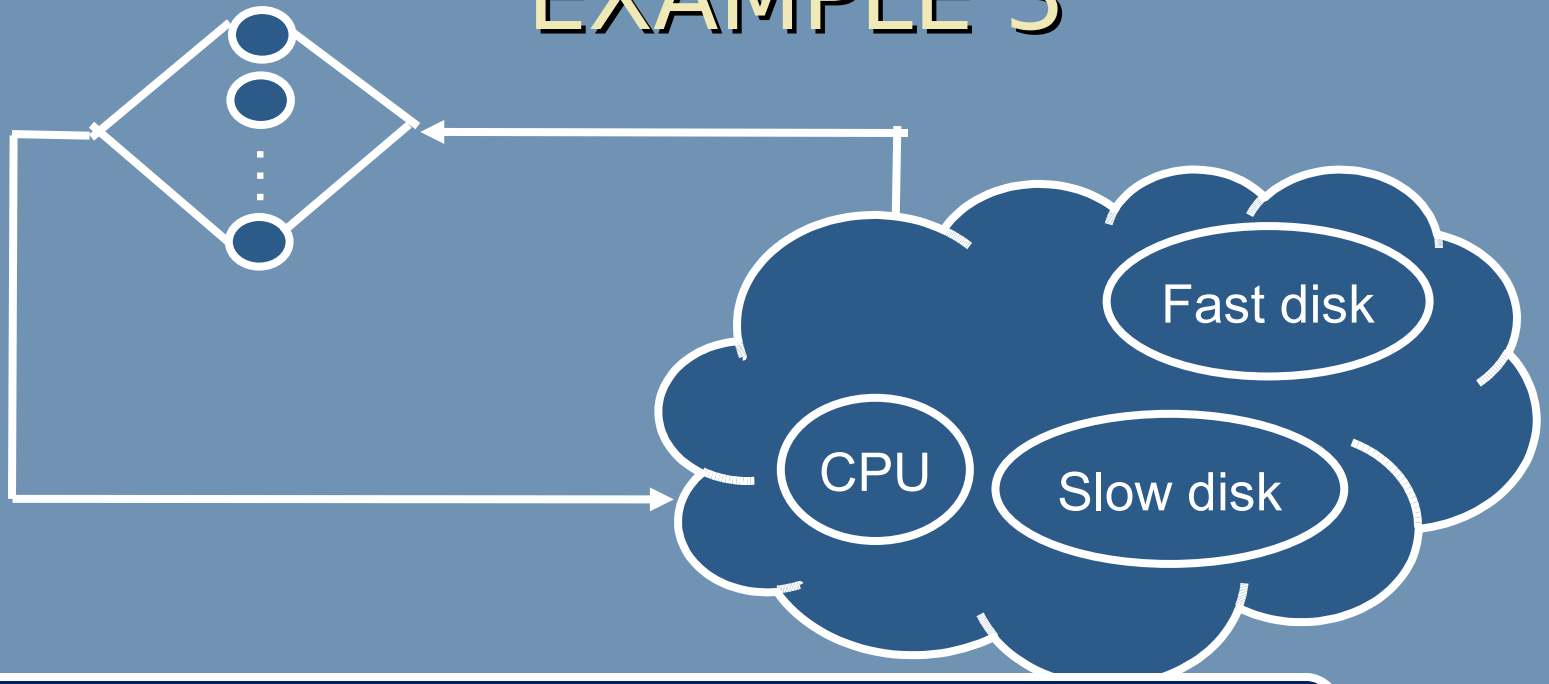
- Question: Server 1 is replaced with a server twice as fast.
- Does this change affect mean response time?
- Does this change affect throughput?

EXAMPLE 3



- Question: Which of the following changes is most effective in increasing throughput?
  - Replace CPU with one twice as fast?
  - Balance load between fast & slow disk?
  - Buy second fast disk?

EXAMPLE 3

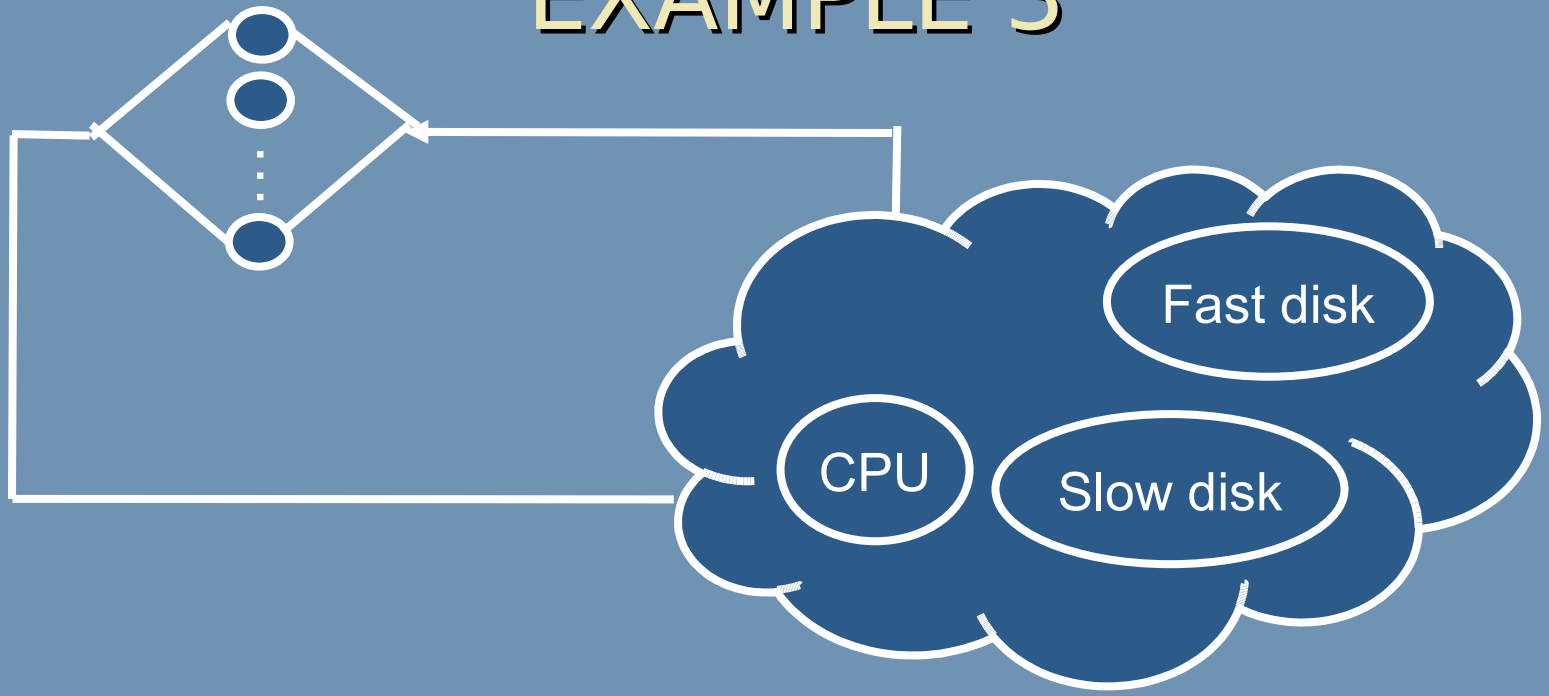


most effective

Measurements:

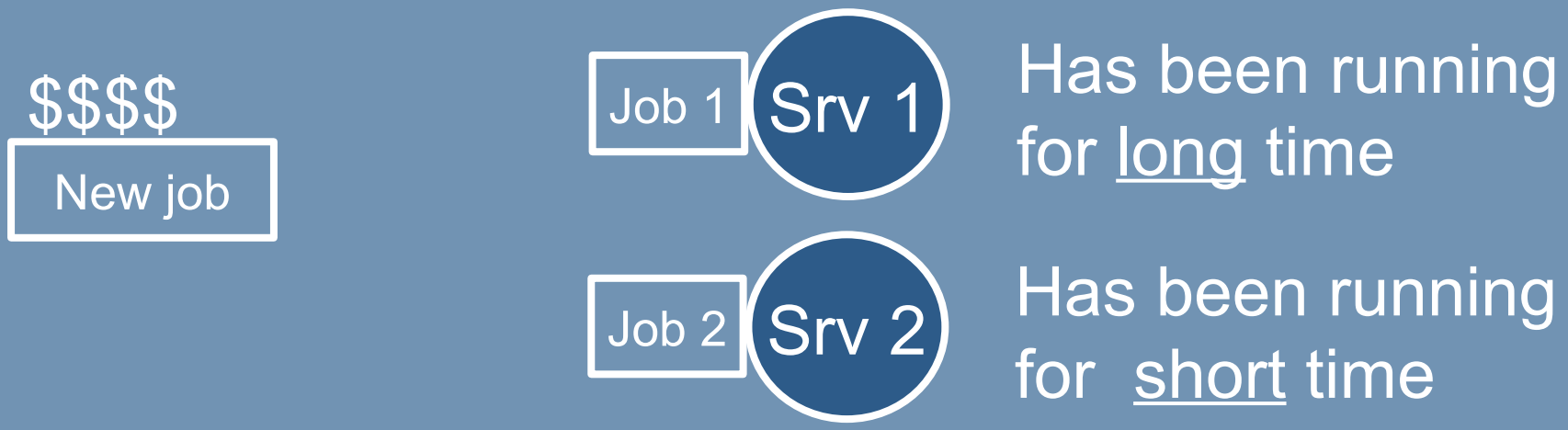
- time each device is busy
- number of completions per device
- total number completions
- mean “think time” between sending jobs

EXAMPLE 3



- We can solve this problem with simple back-of-the-envelope bound analysis
  - No math is necessary!
  - No assumptions on distributions
  - No knowledge of full network topology necessary

EXAMPLE 4



- Question: Which job is closer to completion, job 1 or job 2?

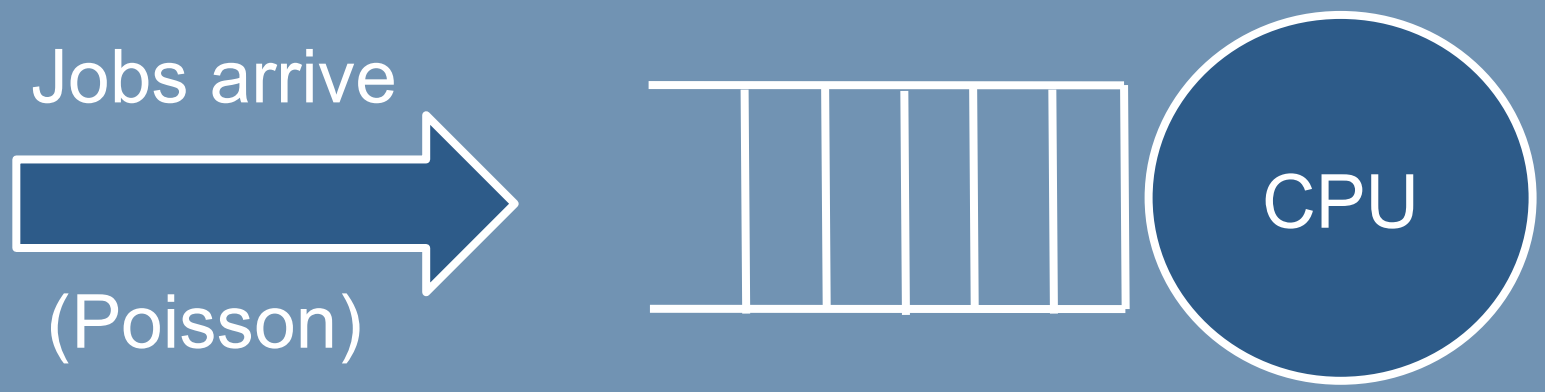
EXAMPLE 5

Has been running non-stop for 1 year

Has just crashed and been fixed yesterday

- Question: Which server will fail first?

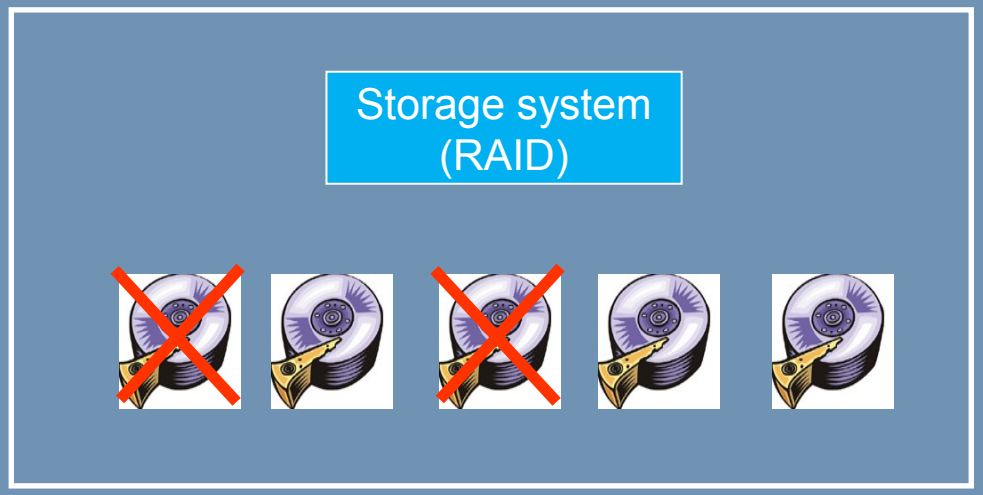
EXAMPLE 6



- Question: Which non-preemptive service order will result in lowest mean response time:
  - FCFS
  - LCFS = Last-Come-First-Serve
  - Random

SOME EXAMPLES FROM MY OWN RESEARCH

Probability of losing data in a RAID?

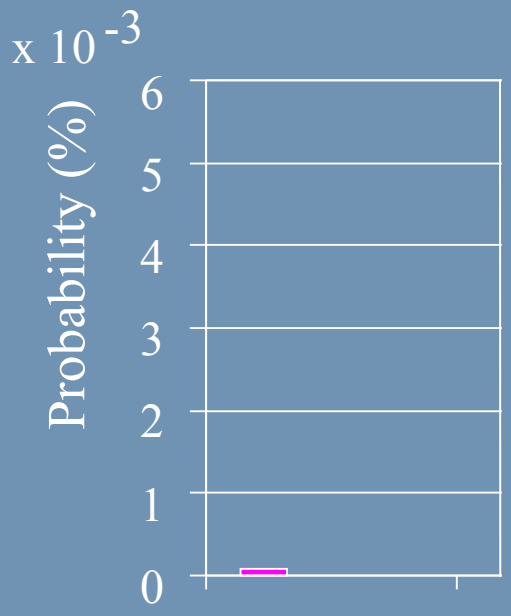


- Depends on probability that after one drive fails, a second drive fails while reconstructing data.

Estimating probability of data loss

- Need probability of second failure during reconstruction

Standard approach: Use datasheet MTTF and exponential distr.



Estimating probability of data loss

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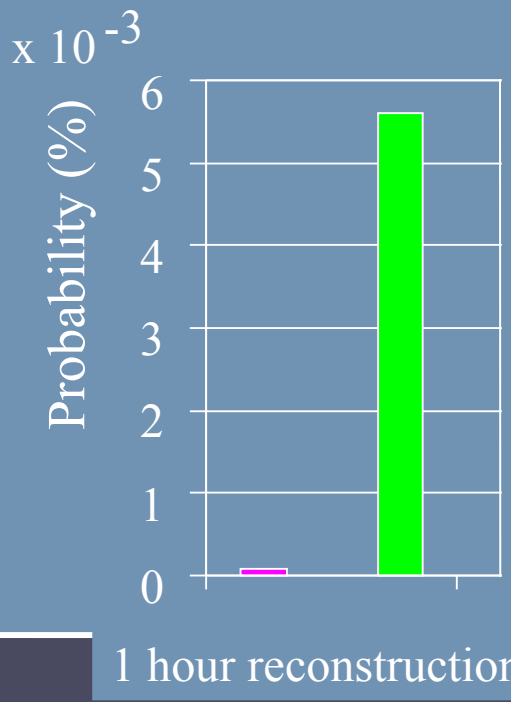
Standard approach: Use datasheet MTTF and exponential distr.

Estimate based on data



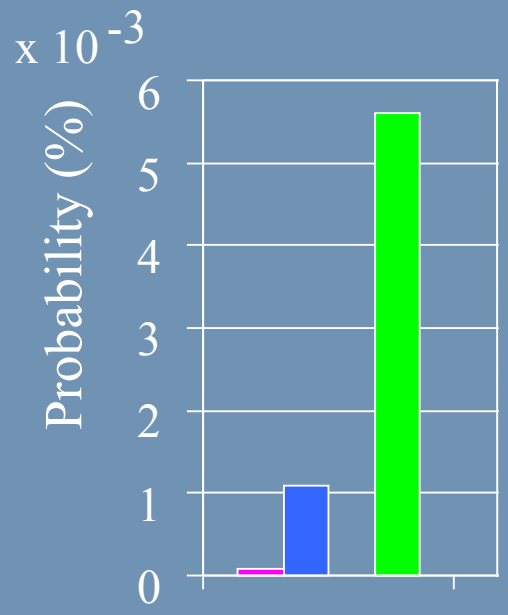
Estimating probability of data loss

- Need probability of second failure during reconstruction

Standard approach: Use datasheet MTTF and exponential distr.

Use measured MTTF and exponential distribution

Estimate based on data



Estimating probability of data loss

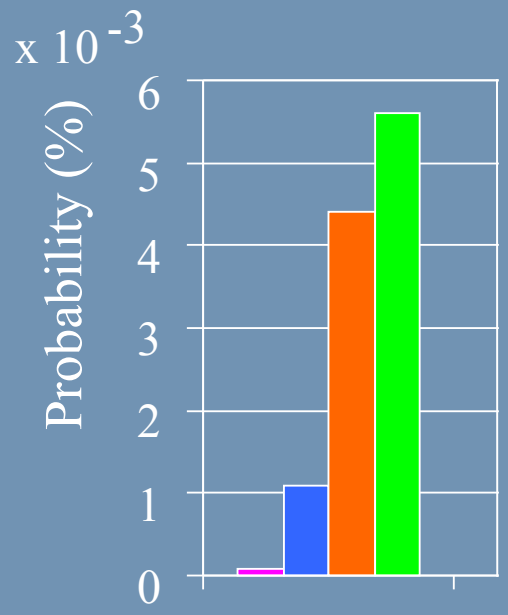
- Need probability of second failure during reconstruction

Standard approach: Use datasheet MTTF and exponential distr.

Use measured MTTF and exponential distribution

Use measured MTTF and Weibull distribution

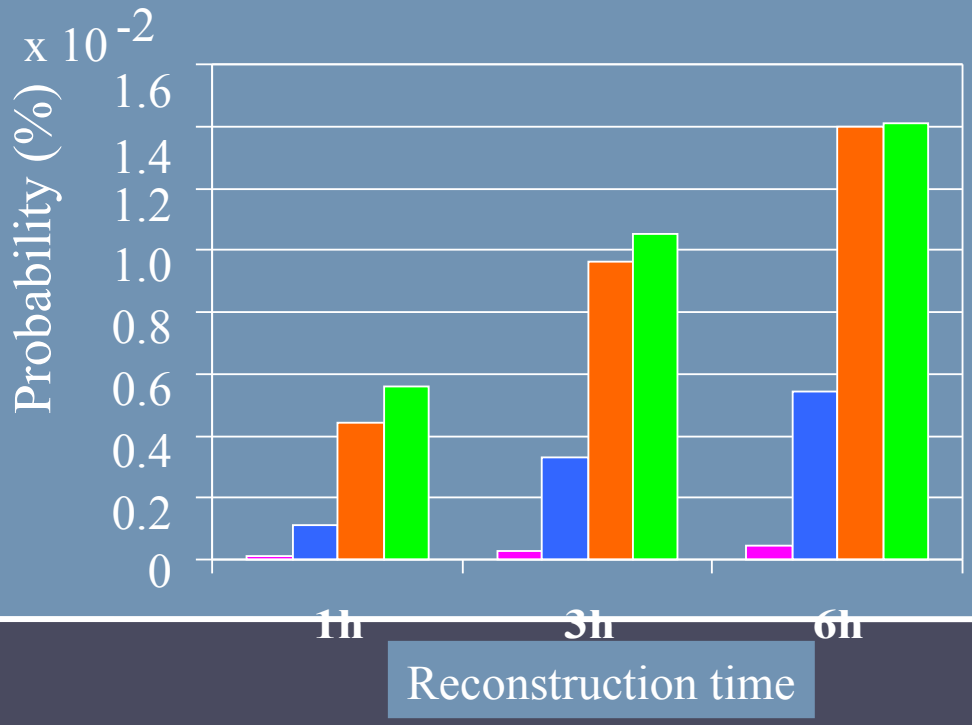
Estimate based on data



Estimating probability of data loss

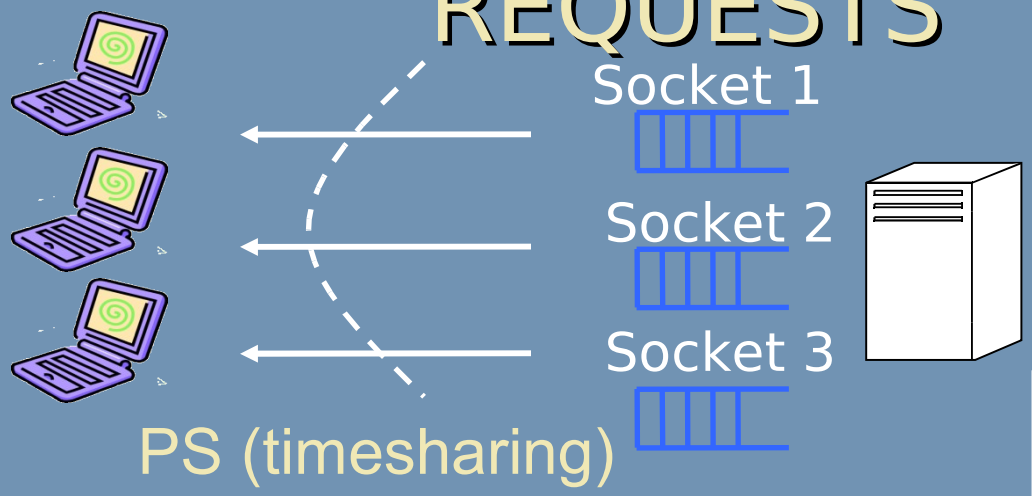
- Need probability of second failure during reconstruction

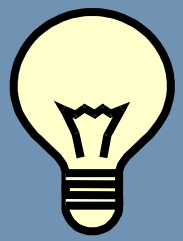
- Standard approach: Use datasheet MTTF and exponential distr.
- Use measured MTTF and exponential distribution
- Use measured MTTF and Weibull distribution
- Estimate based on data



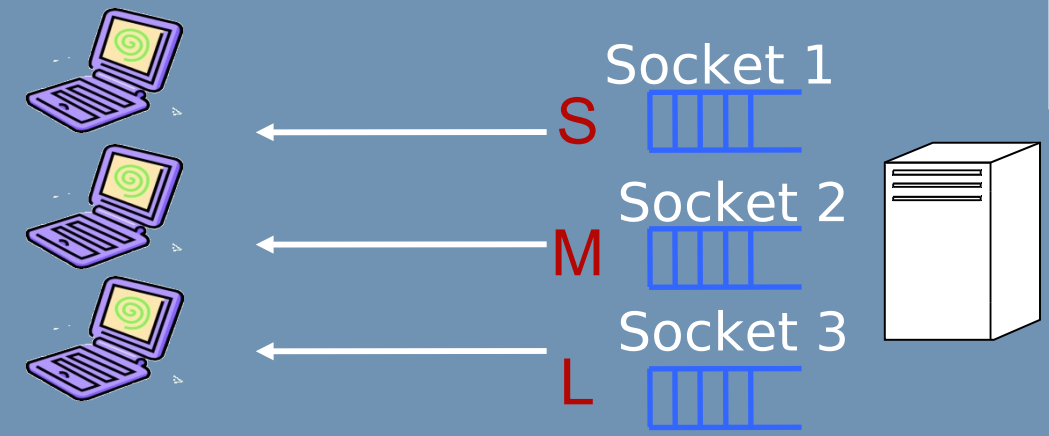
EXAMPLE 2

SCHEDULING STATIC WEB REQUESTS

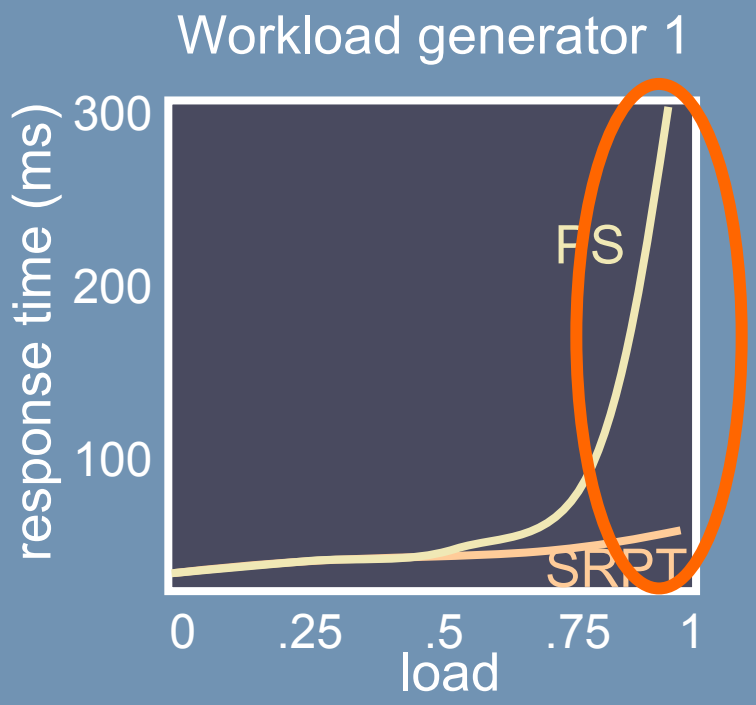


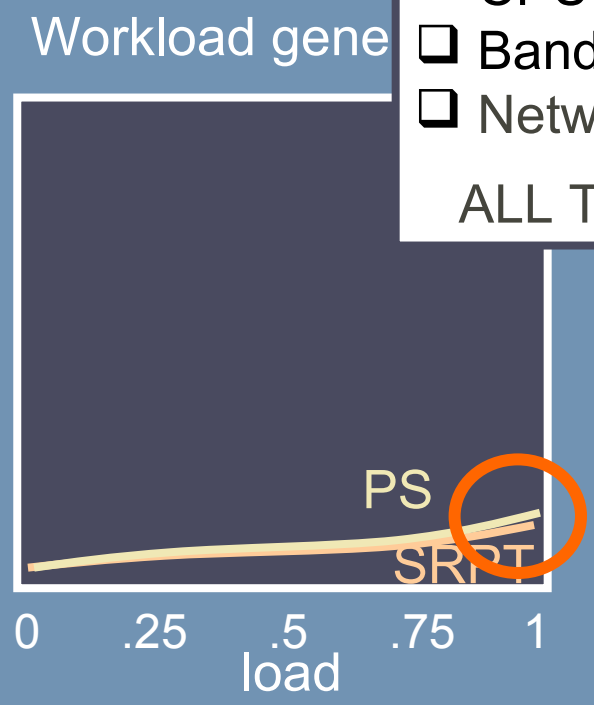


Size-based scheduling for better response times.



STATIC WEB WORKLOA
APACHE/LINUX





WHY?

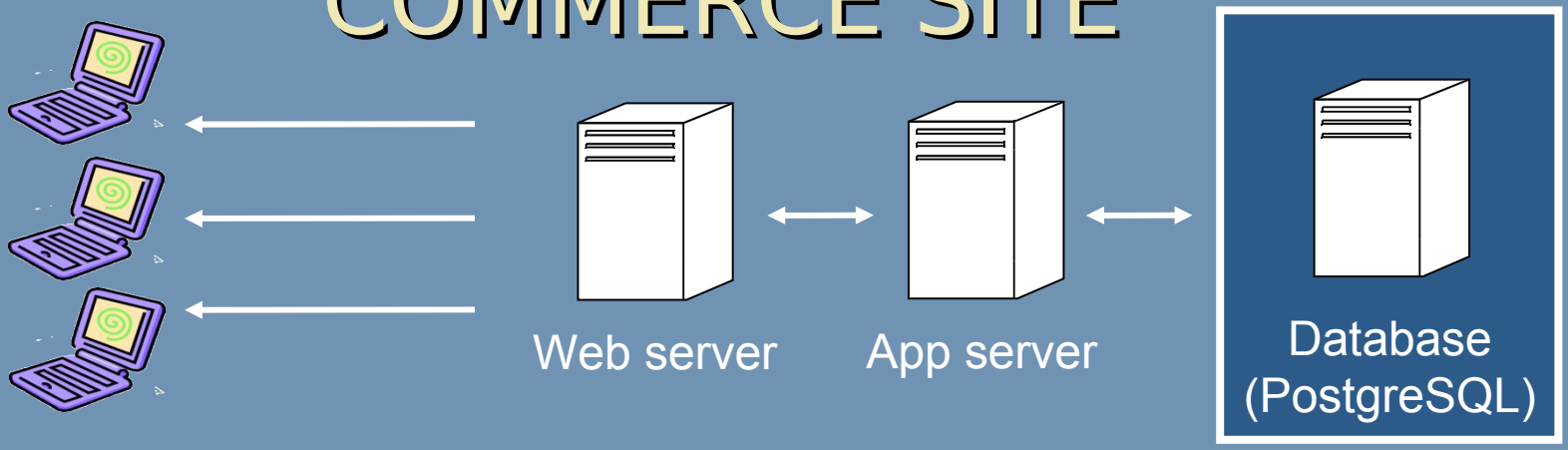
- ❑ Mean file size
- ❑ File size distribution
- ❑ Access pattern
- ❑ Request rate
- ❑ CPU utilization
- ❑ Bandwidth
- ❑ Network effects

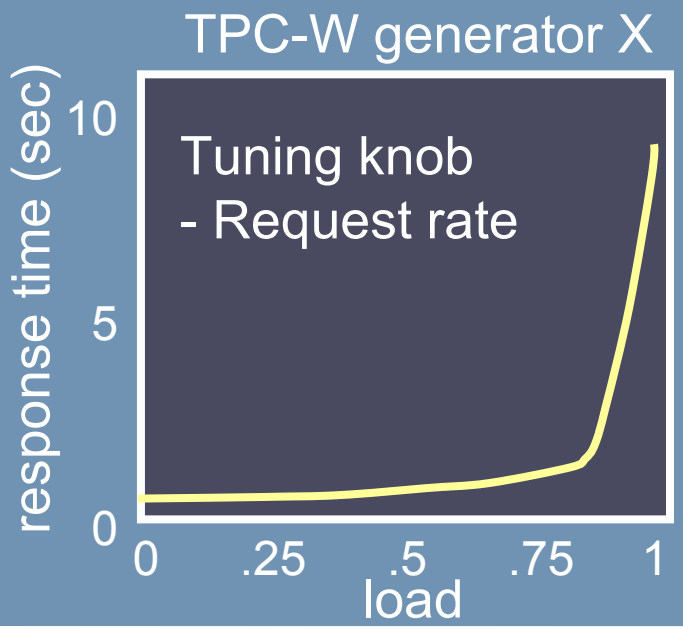
ALL THE SAME!

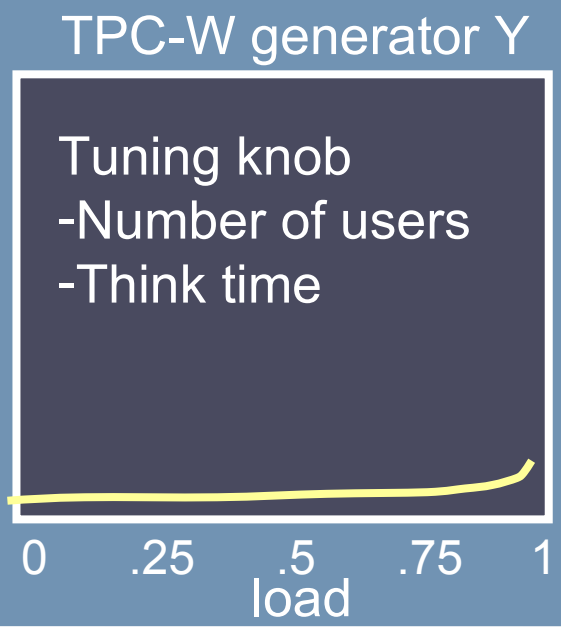
Tuning knob
- Request rate

Tuning knob
-Number of users
-Think time

DATABASE BACKEND OF E-COMMERCE SITE

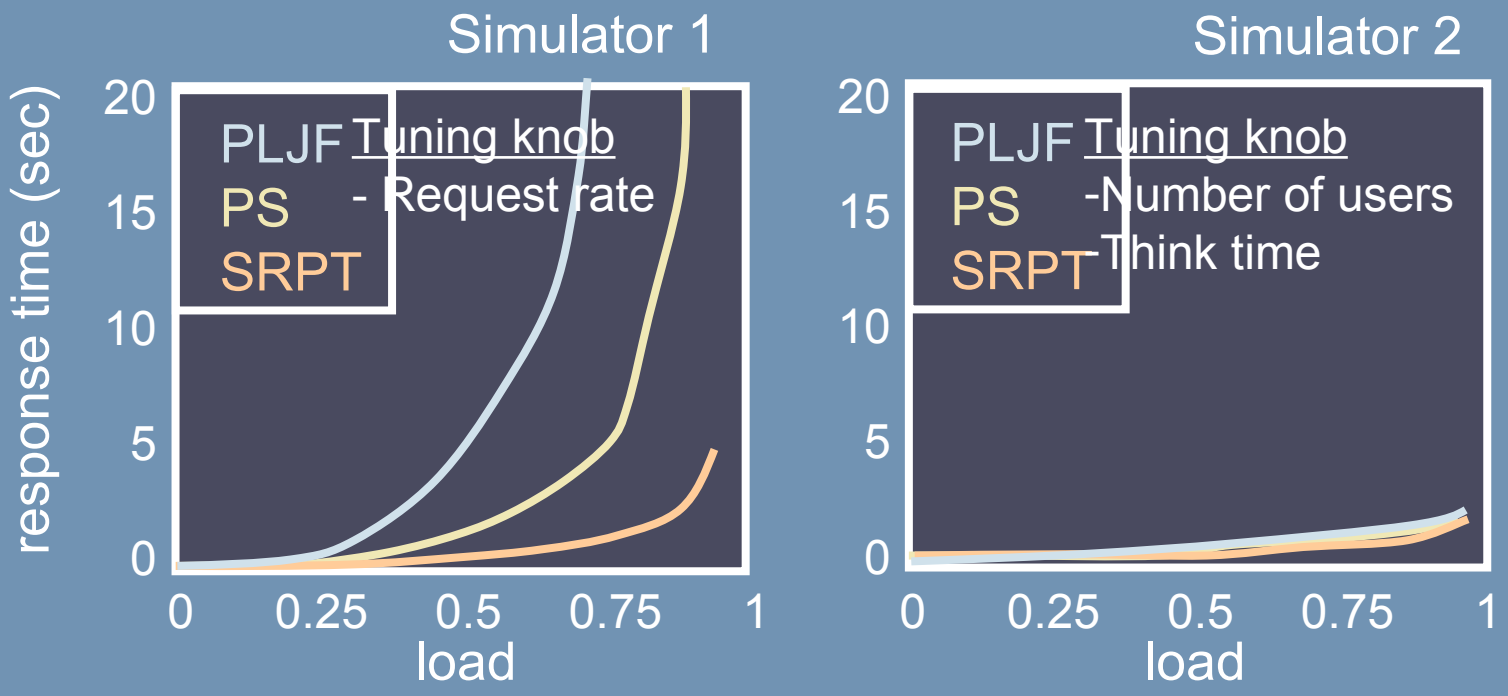




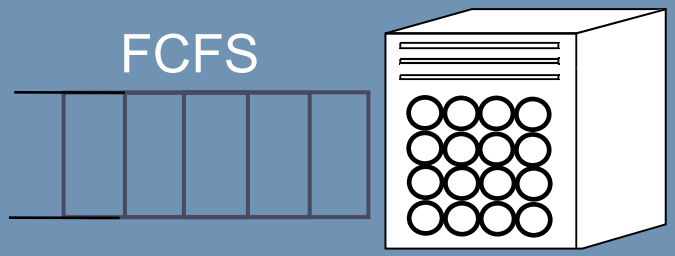


ONLINE AUCTION SITE – SIMULATION

- Based on trace from top-10 online auctioning site.

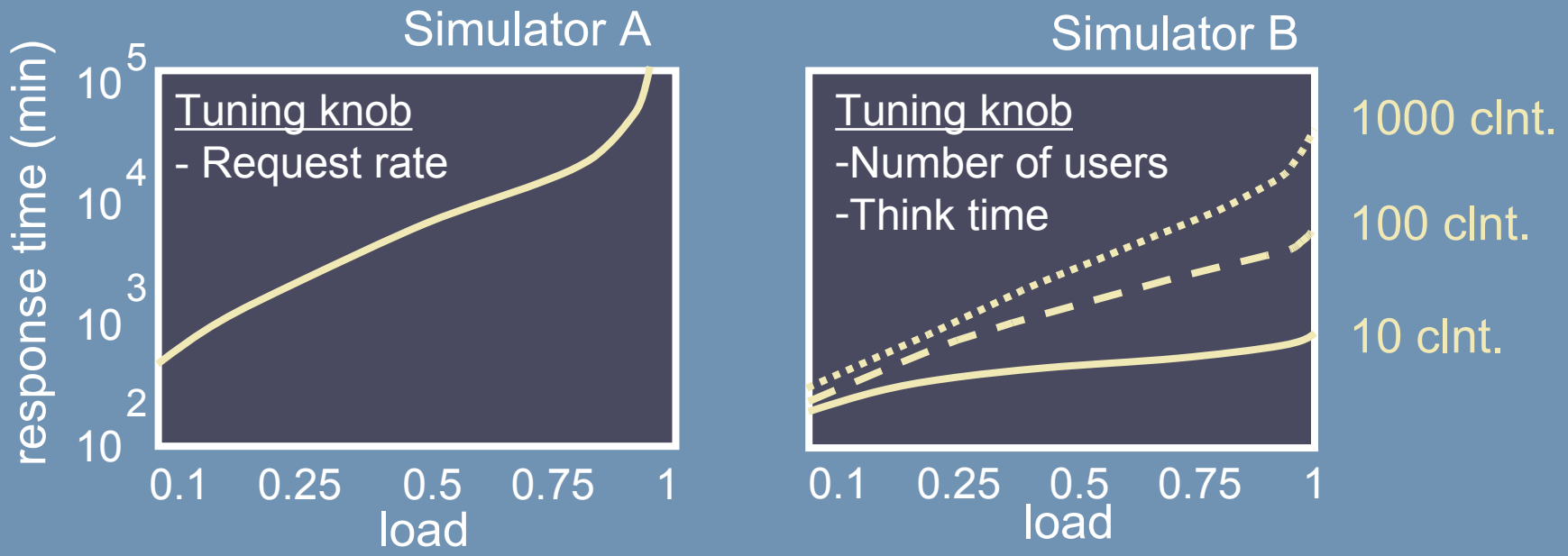


BATCH JOBS AT A SUPERCOMPUTING SITE



Cray J90/C90

- Simulation based on trace from Pittsburgh Supercomputing Center.



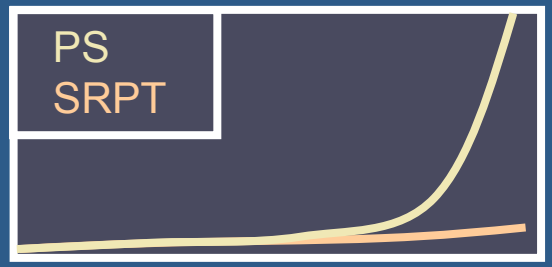
STATIC WEB

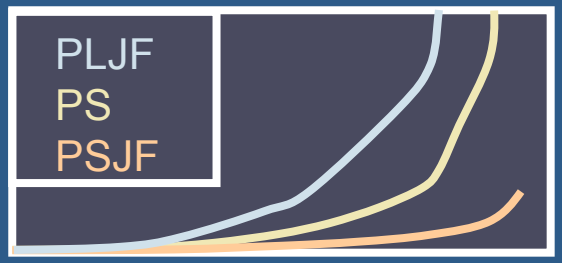
DATABASE BACKEND

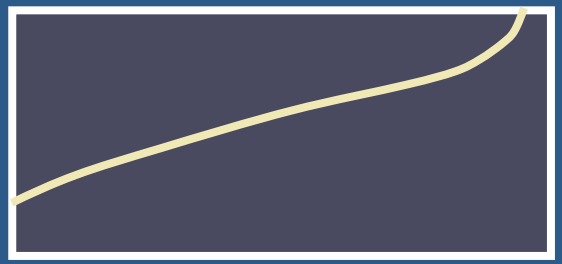
ONLINE AUCTION

SUPER-COMPUTING

OPEN

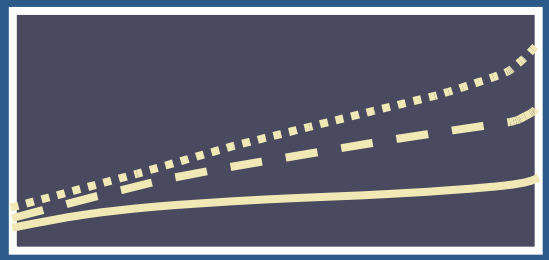






Tuning knob
- Request rate

CLOSED

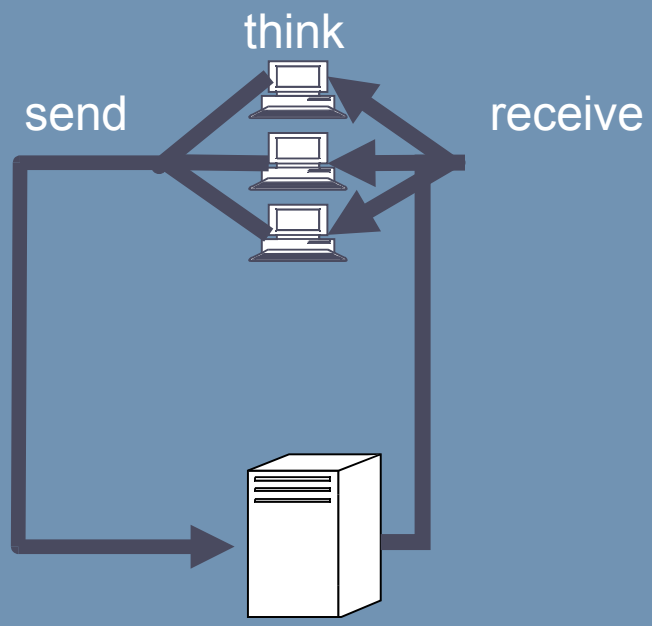


Tuning knob
-Number of users
-Think time

CLOSED SYSTEM MODEL

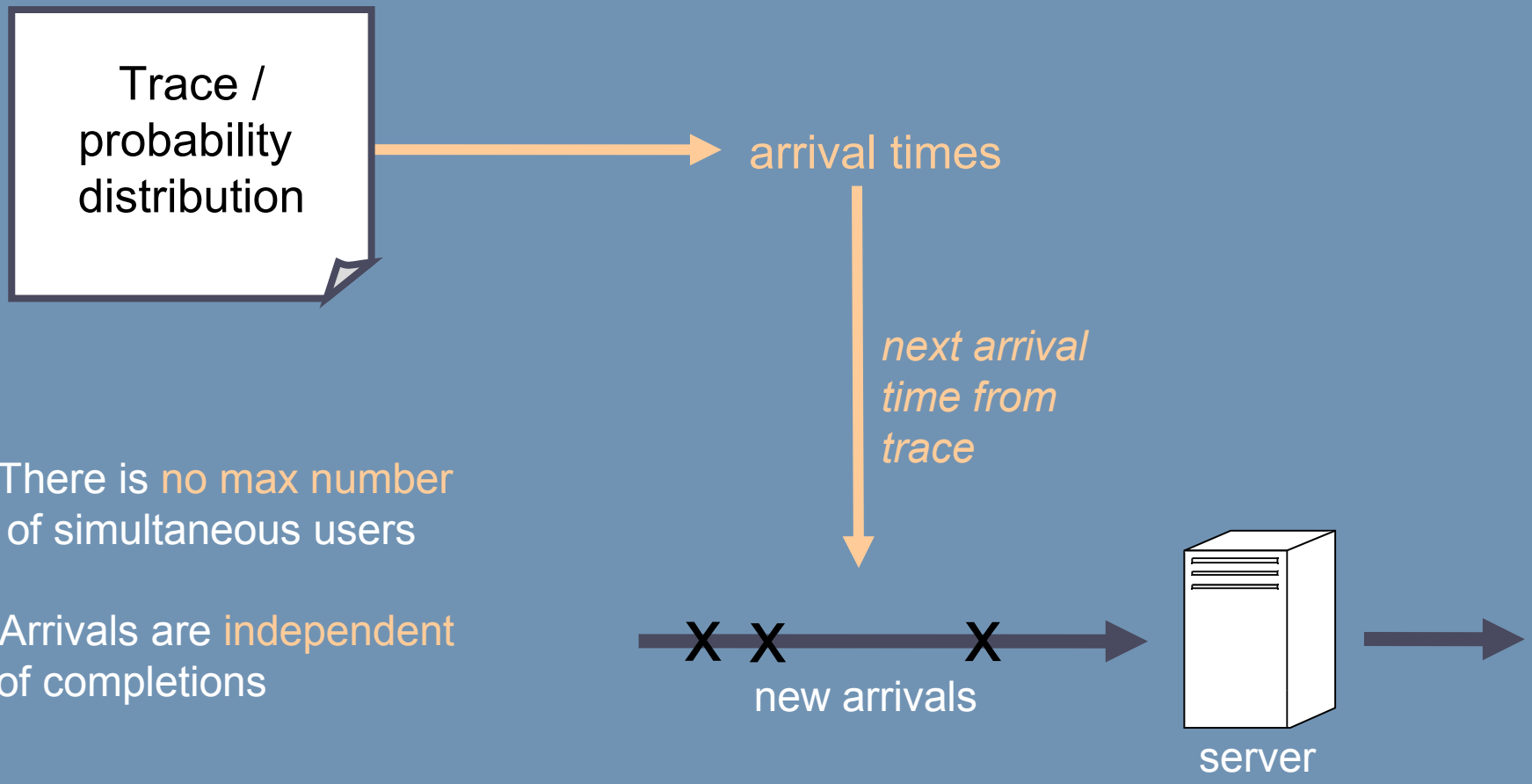
Model of user behavior

User requests web page, receives page, reads page, clicks on new link



- Fixed number of users, called the Multi-Programming-Level (MPL)
- Arrivals triggered by completions.

OPEN SYSTEM MODEL



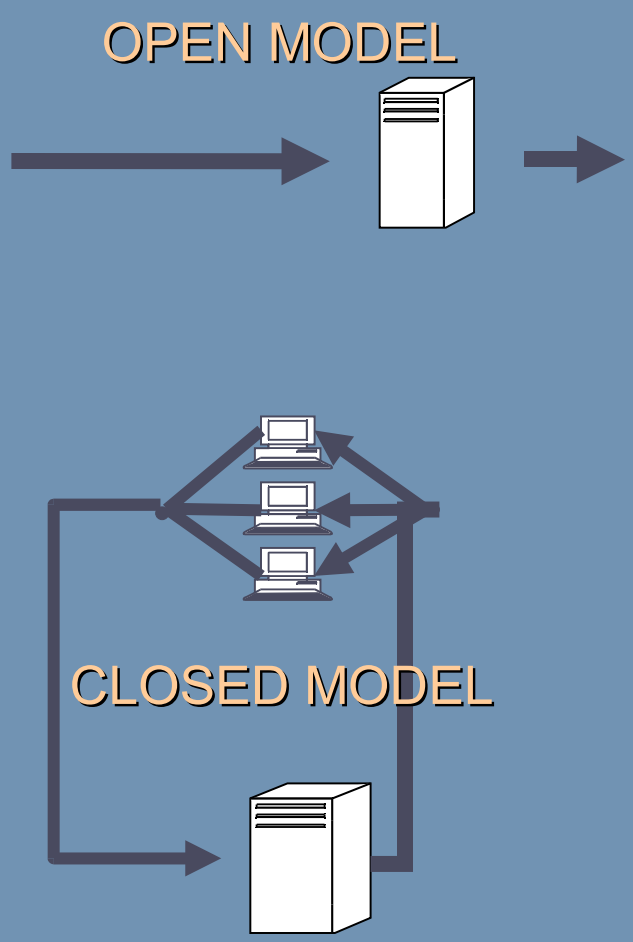
- There is no max number of simultaneous users
- Arrivals are independent of completions

WHICH MODEL DO WORKLOAD GENERATORS USE?

WEB WORKLOAD GENERATORS

- G… urpose u…
- C… n…

Surge
SPECWeb
TPC-W
Sclient
RUBiS
WebBench
Webjamma



WHAT IS KNOWN IN THE LITERATURE?

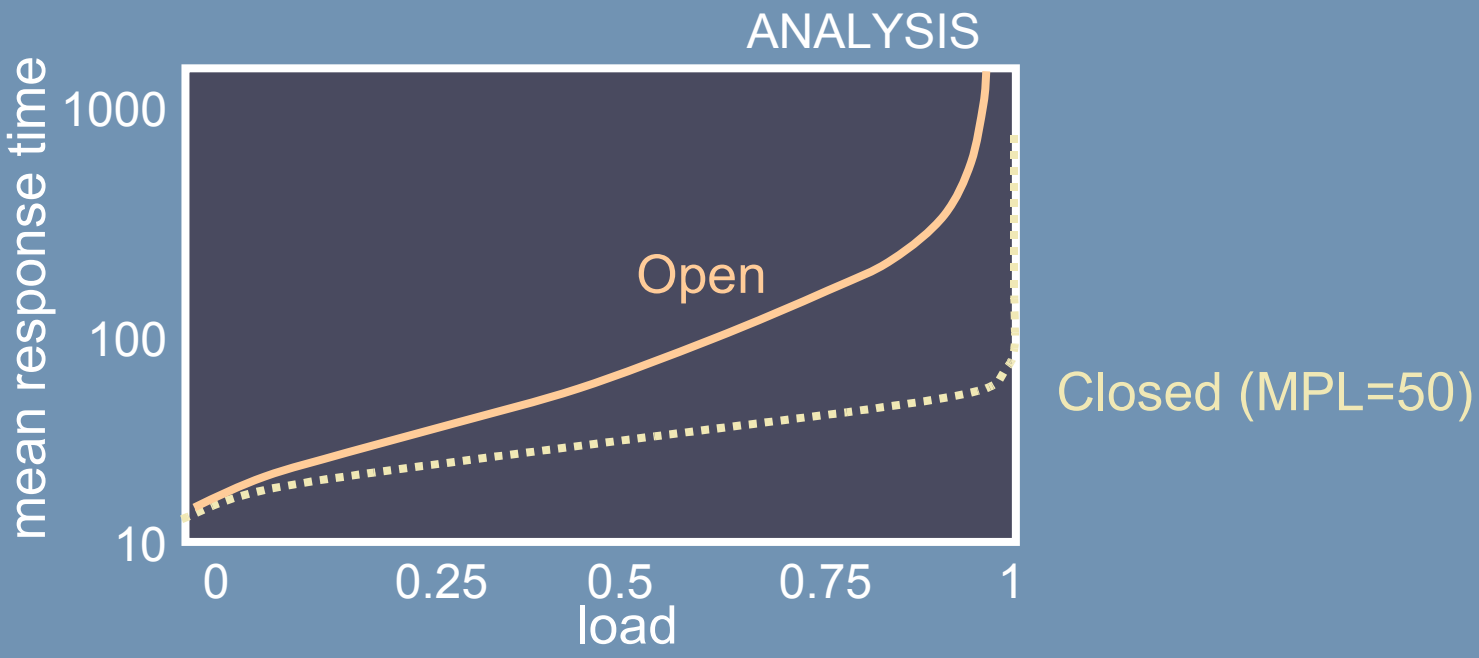
- Very little …
- Limited to FCFS single server queue.
  - Response times under open system higher than under closed [Bondi and Whitt 1986].
  - For MPL -> ∞, closed system converges to open system [Schatte83, Schatte84].

STILL UNANSWERED:

- What is the magnitude in difference of response times?
- What is the speed of convergence?
- How does variability (heavy tails) affect results?
- How are different scheduling disciplines affected?
- …. in practice?

PRINCIPLES FOR OPEN VS. CLOSED

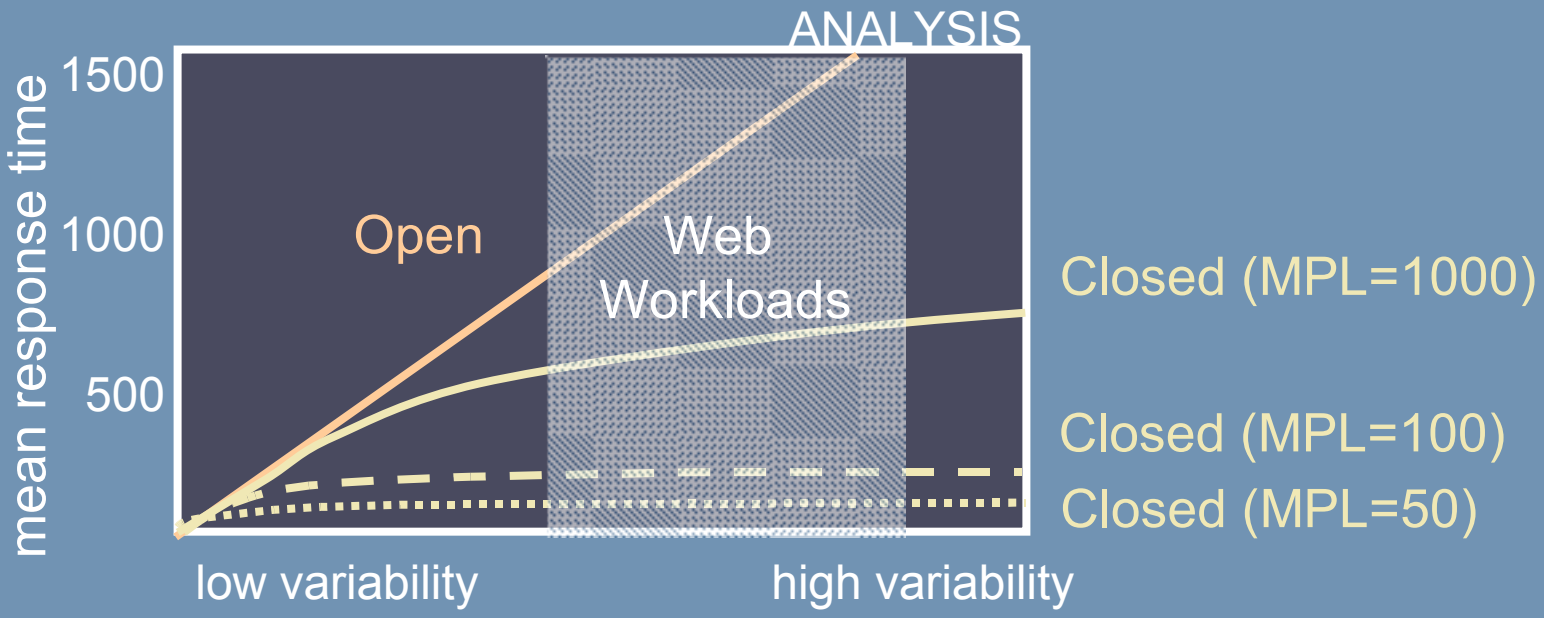
- What is the magnitude in difference of response times?
  - Orders of magnitude!



- Why?
  - *Bounded number of jobs in closed system.*

PRINCIPLES FOR OPEN VS. CLOSED

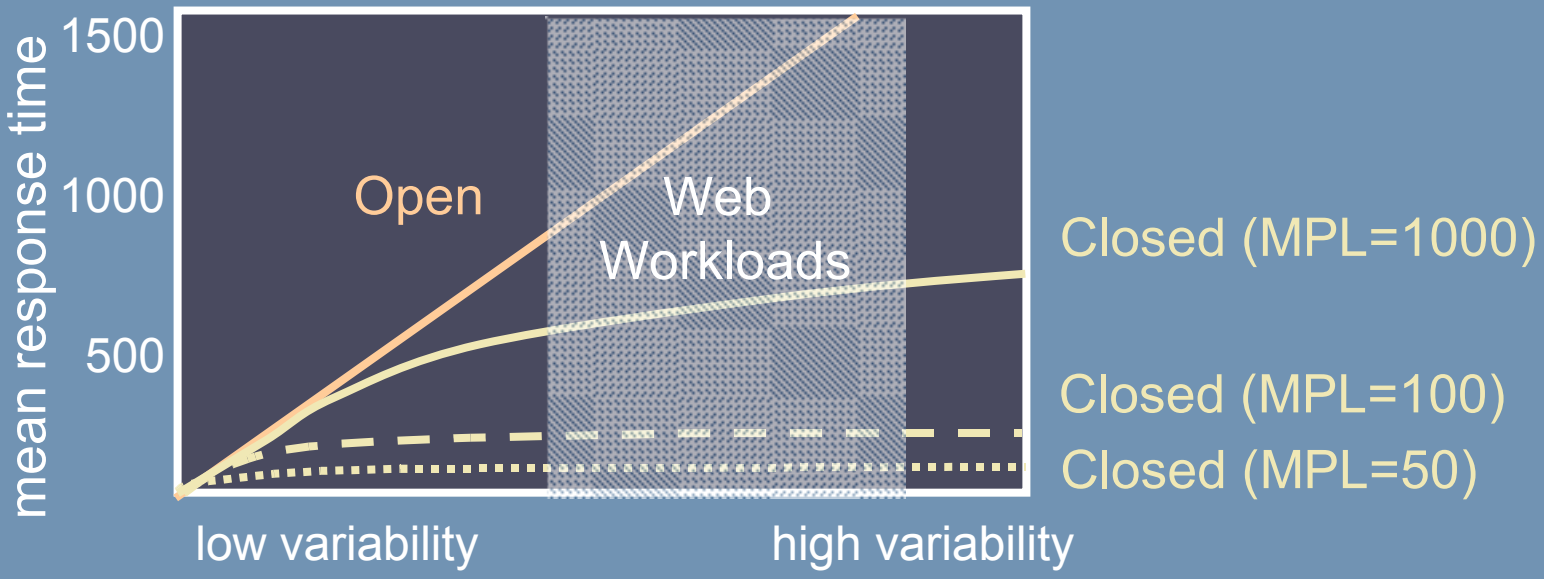
- How does variability affect open/closed response times?
  - Huge effect on open, limited effect on closed system.



- Why?
  - *Dependency between completions and arrivals in closed system reduces burstiness.*

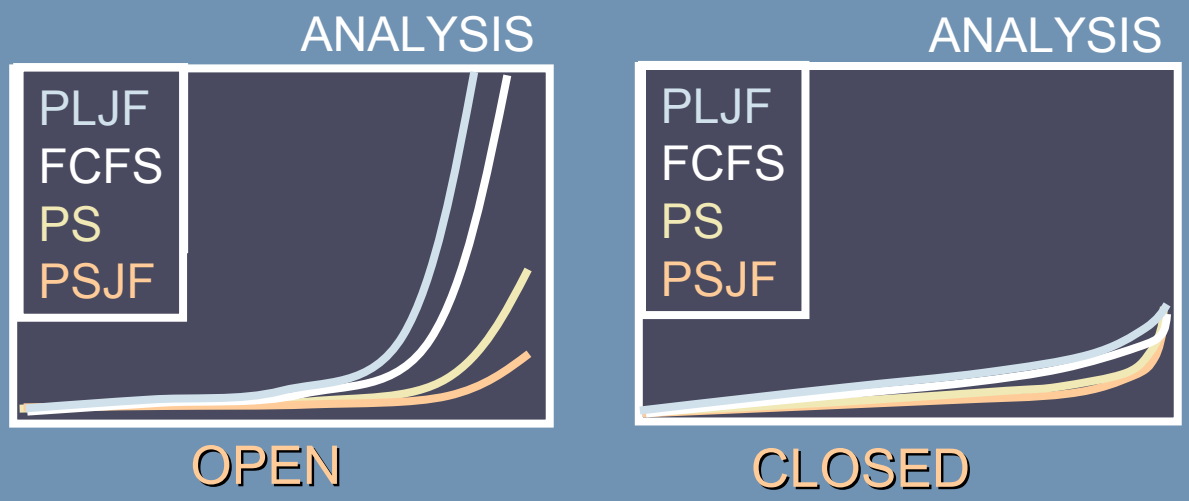
PRINCIPLES FOR OPEN VS. CLOSED

- Can we make closed look like open, by increasing MPL?



PRINCIPLES FOR OPEN VS. CLOSED

- What is the impact of scheduling?
  - Huge in open system, almost none in closed system.



- Why?
  - *Scheduling takes advantage of variability in the system.*
  - *Closed systems reduce the effect of variability.*