COMP9334
Capacity Planning for Computer Systems and Networks

Week 8A: rk-join queues

This lecture

- Web services
  - What is it?
  - Performance analysis
- Fork-join queue
  - Markov chain
  - MVA

Web access versus Web services

(a) Web access

(b) Composite web service for travel

Web service performance issues

- Metrics
  - Response time
  - Throughput
  - Availability
- Performance analysis method
  - Operational an
  - Markov chain

Web service flow graph

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V_a,V_h,V_c: Relative Visit Ratio

Every request to the travel site generates on average V_a requests to the Airline web service etc.

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$$X_{TA} = \text{Throughput of travel site}$$

$$X_a = \text{Throughput of airline Web service}$$

$$X_a \geq V_a \times X_{TA}$$

Similarly,

$$X_a \geq V_a \times X_{TA}$$

$$X_h \geq V_h \times X_{TA}$$

Xh = Throughput of hotel web service

Xc = Throughput of car rental web service

- Can you find an upper bound o ughput of the travel site

$$X_{TA} \leq$$

Example:

Xa = 20 requests/s
Xh = 15 requests/s
Xc = 10 requests/s
Va = 4, Vh = 2, Vc = 1

The airline web service is the bottleneck of the travel web site.

More complex web service graphs

What is the bound on throughput of web service A?

Bound on the throughput of web service A is:

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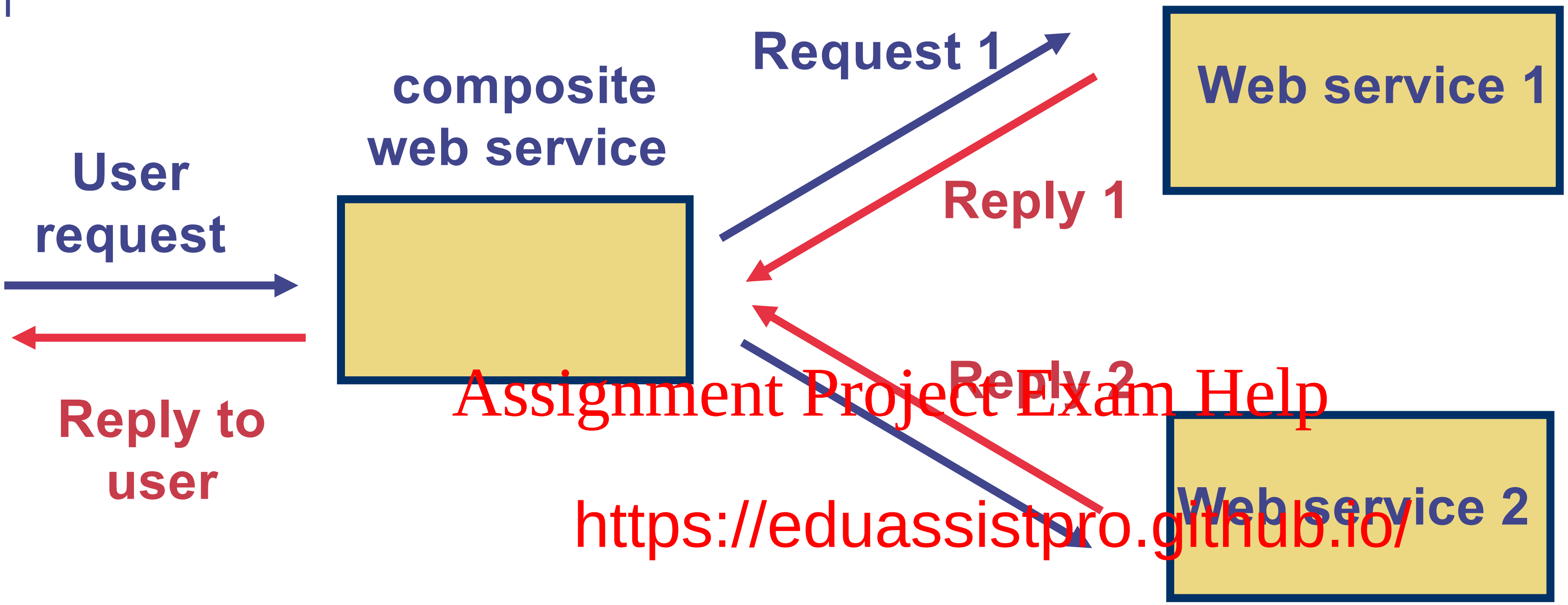
Response time analysis

- The bottleneck analysis only gives an upper bound on the throughput
- Can we find the response time?
  - Markov chain
  - Approximate MVA

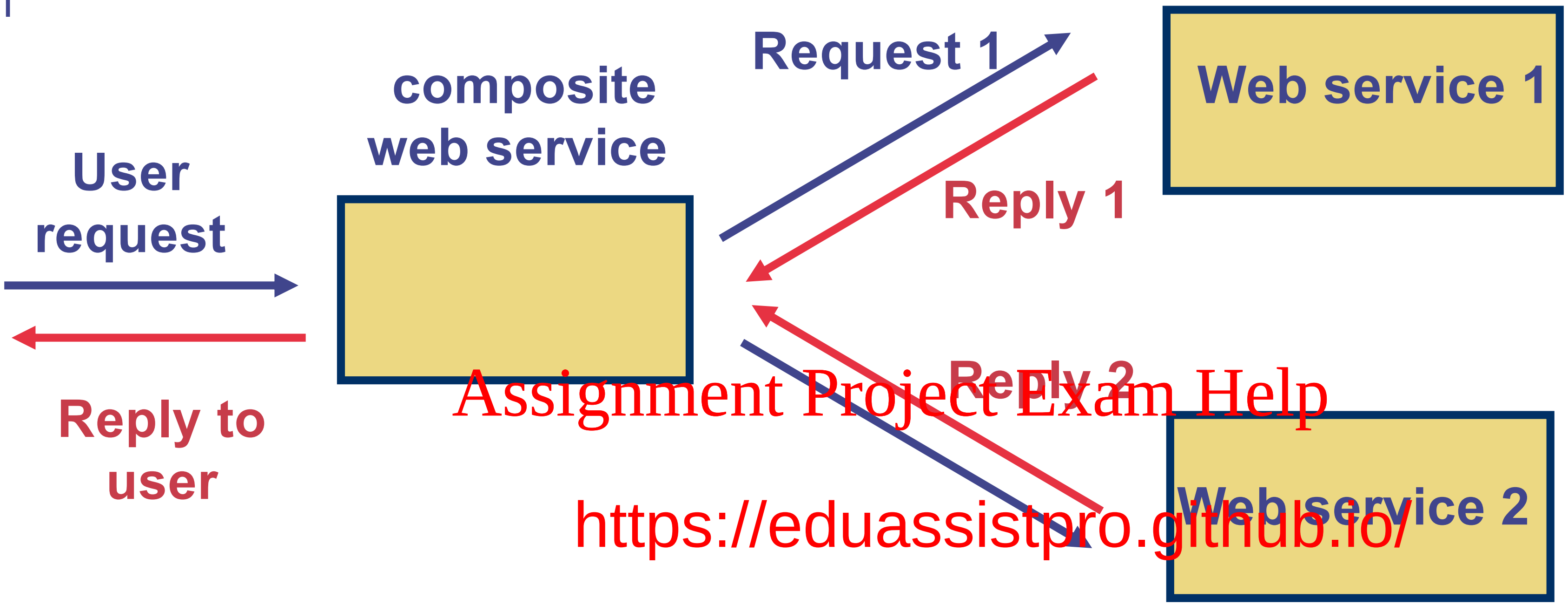
- We begin with a

A simple web service scenario (1)



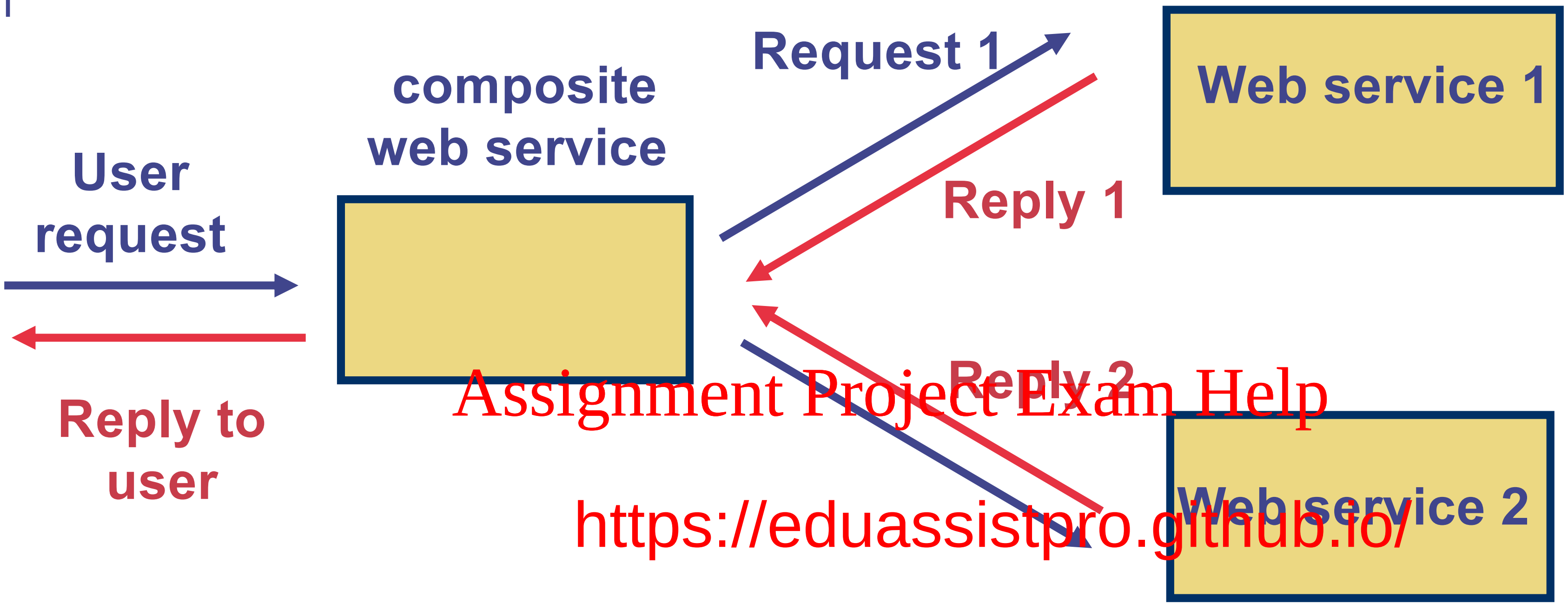
- A composite web service uses two
- Sequence of events
  1. Composite web service receives a user request
  2. Composite web service sends Request 1 and Request 2
  3. The web services reply *independently*
     - *That is, Reply 1 and Reply 2 may arrive at different times*
  4. After the composite web service receives *both* replies, it responds to the user

A simple web service scenario (2)



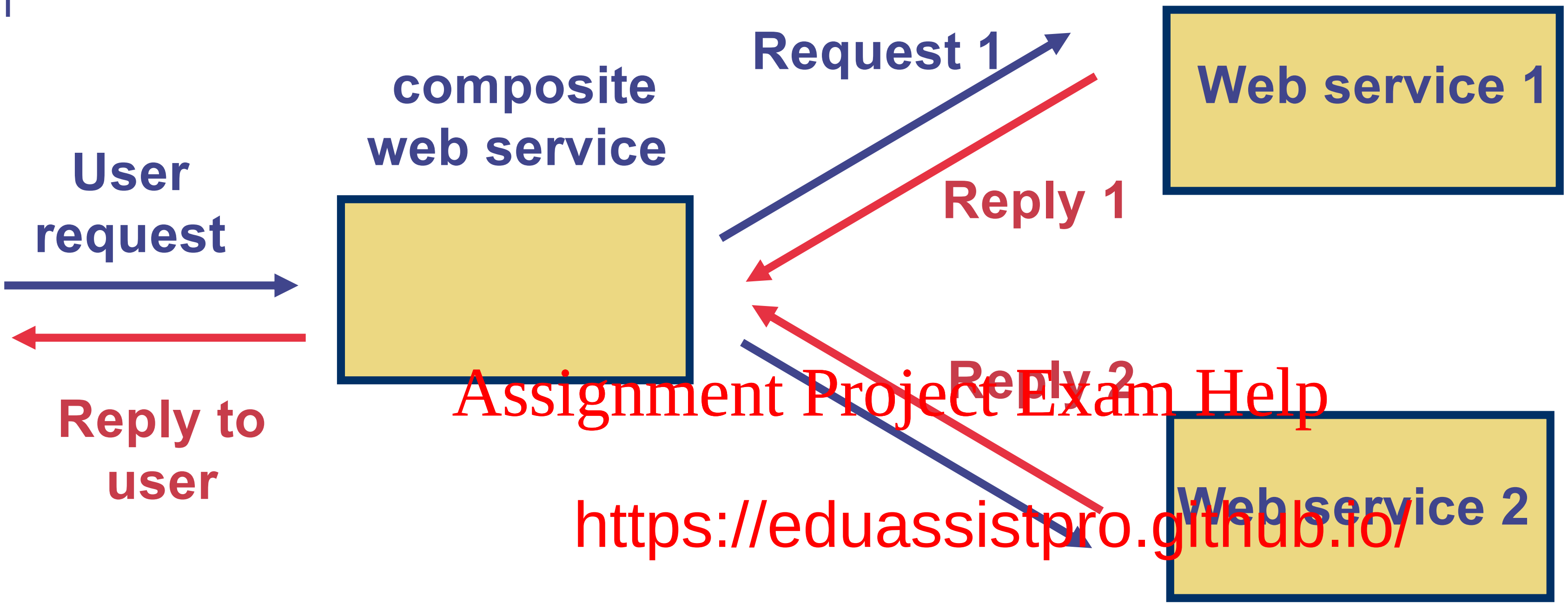
- Recall the definition of respons
- Response time of Web Service 1
  = Time at which composite web service receives Reply 1 *minus*
  Time at which composite web service sends Request 1
- Similarly for Web Service 2.

A simple web service scenario (3)



- Assuming that:
  - Web service 1 has a response time distribution of
    - 0.2s with probability 0.5
    - 0.3s with probability 0.5
  - Web service 2 has a response time distribution of
    - 0.2s with probability 0.5
    - 0.3s with probability 0.5
- What is the average time that the composite web service has to wait until both replies are returned?

A simple web service scenario (4)



- What if the service time distribution
  - Web service 1 has a response time distribution of
    - 0.2s with probability 0.5
    - 0.3s with probability 0.5
  - Web service 2 has a response time distribution of
    - 0.2s with probability 0.5
    - 0.5s with probability 0.5
- What is the average time that the composite web service has to wait until both replies are returned?

Analysis scenario

- Lesson learnt: Slow web services can become the bottleneck for composite web service

- We consider Composite Web Services (illustration next slide)

  - With parallel in

  - Web services service time of S (exponentially distributed)

  - Web service N has a mean ser ~~g x S~~ $\frac{1}{\alpha}$ **x S** (exponentially distributed)
  - The next service step can only be completed after all these N steps have been completed.

Note that if $\alpha < 1$, then server N is slower than the other (N-1) servers.

Servers 1 to N-1 : mean response time = S

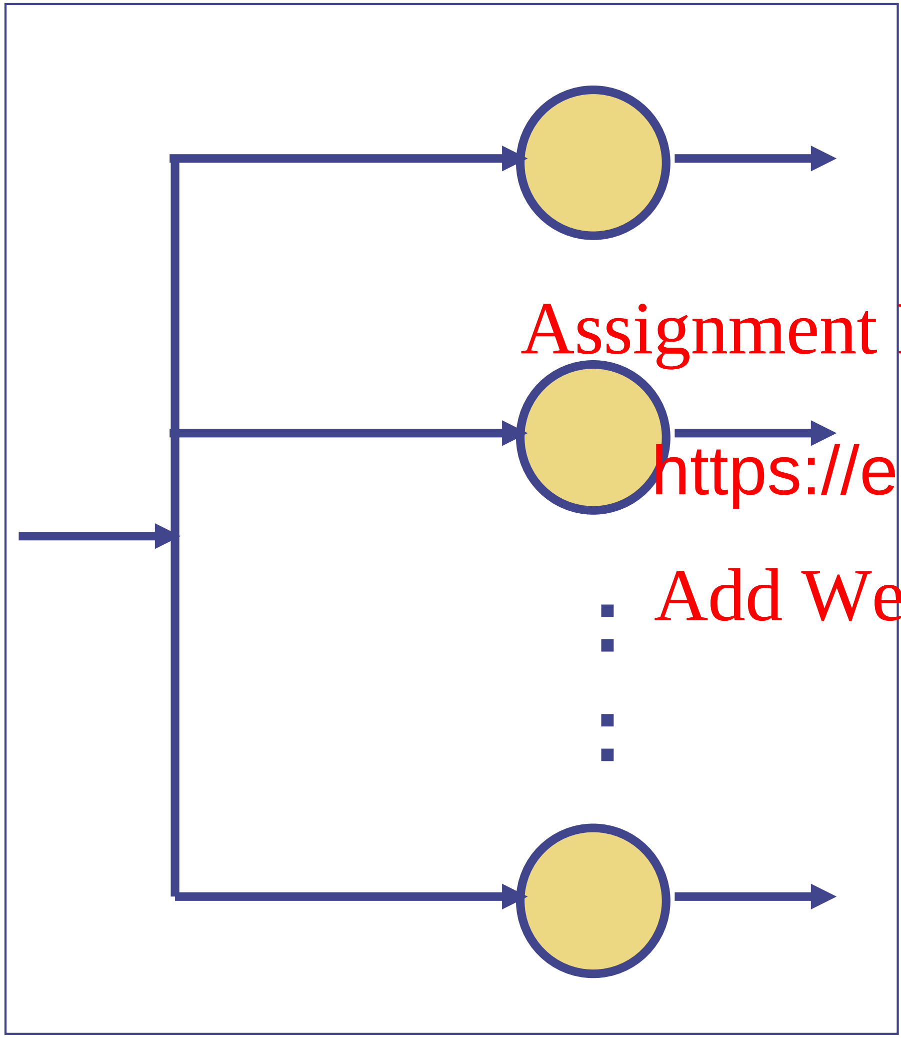
Server N: mean response time = $\cancel{\alpha \times S}$ $\boxed{\frac{1}{\alpha} \times S}$

Fork-join system

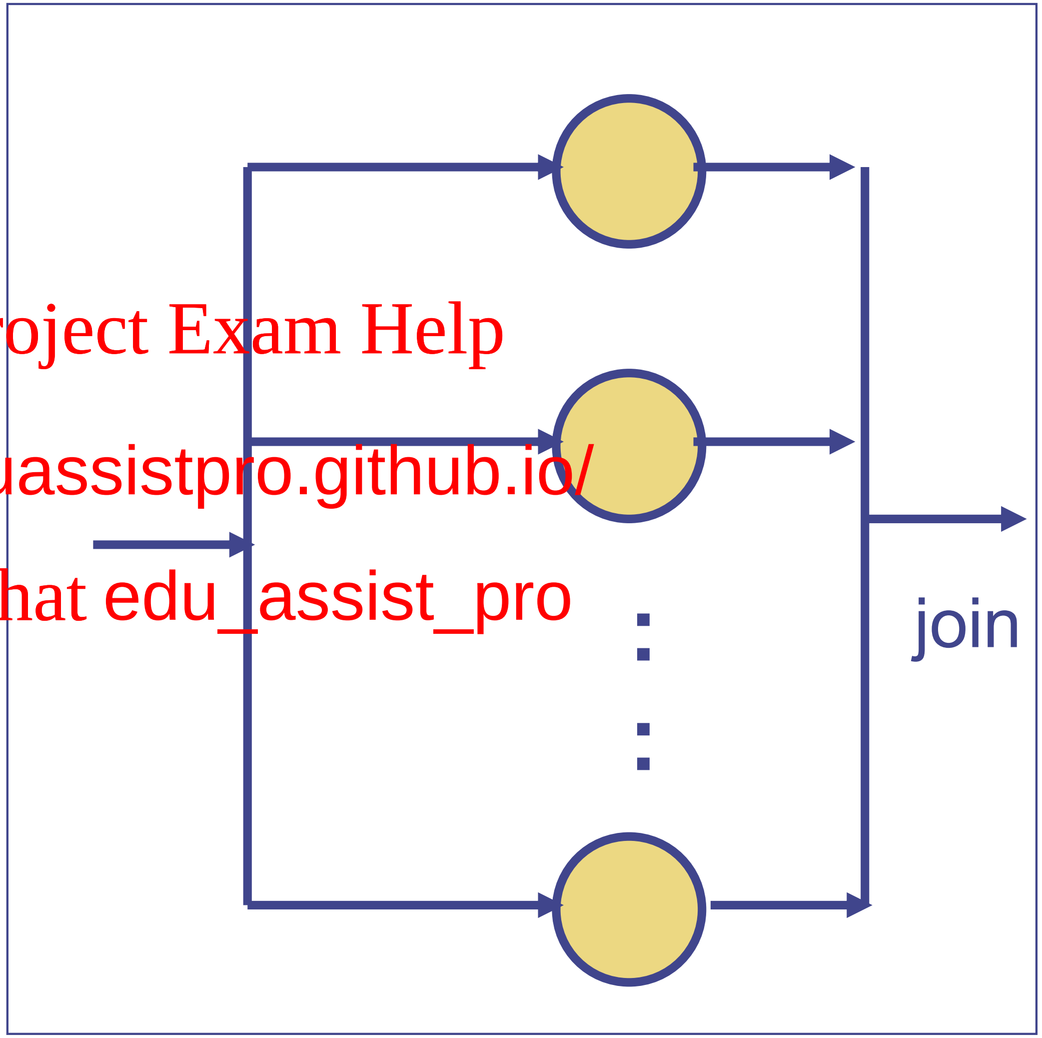
- The type of system described earlier is known as fork-join system
  - Fork is referring to the parallel invocation
  - All services must complete at the joining point before the next service can start

You’ve seen parallel processing before:

M/M/m queue



Fork-join queue



What is the difference between these two queueing networks?

Servers 1 to N-1 : mean response time = S

Server N: mean response time = $\cancel{\alpha \text{ x } S}$ $\leftarrow$ $\boxed{\frac{1}{\alpha} \text{ x } S}$

- We want to understand how α affects the response time of the composite web services
- Let T(α) = response time as a function of α

What is T(1)?

- In this case, all constituent web services have the same response time distribution
- If all mean response times are exponentially distributed with mean S

$$H_N = \text{ } N\text{-th harmonic number}$$

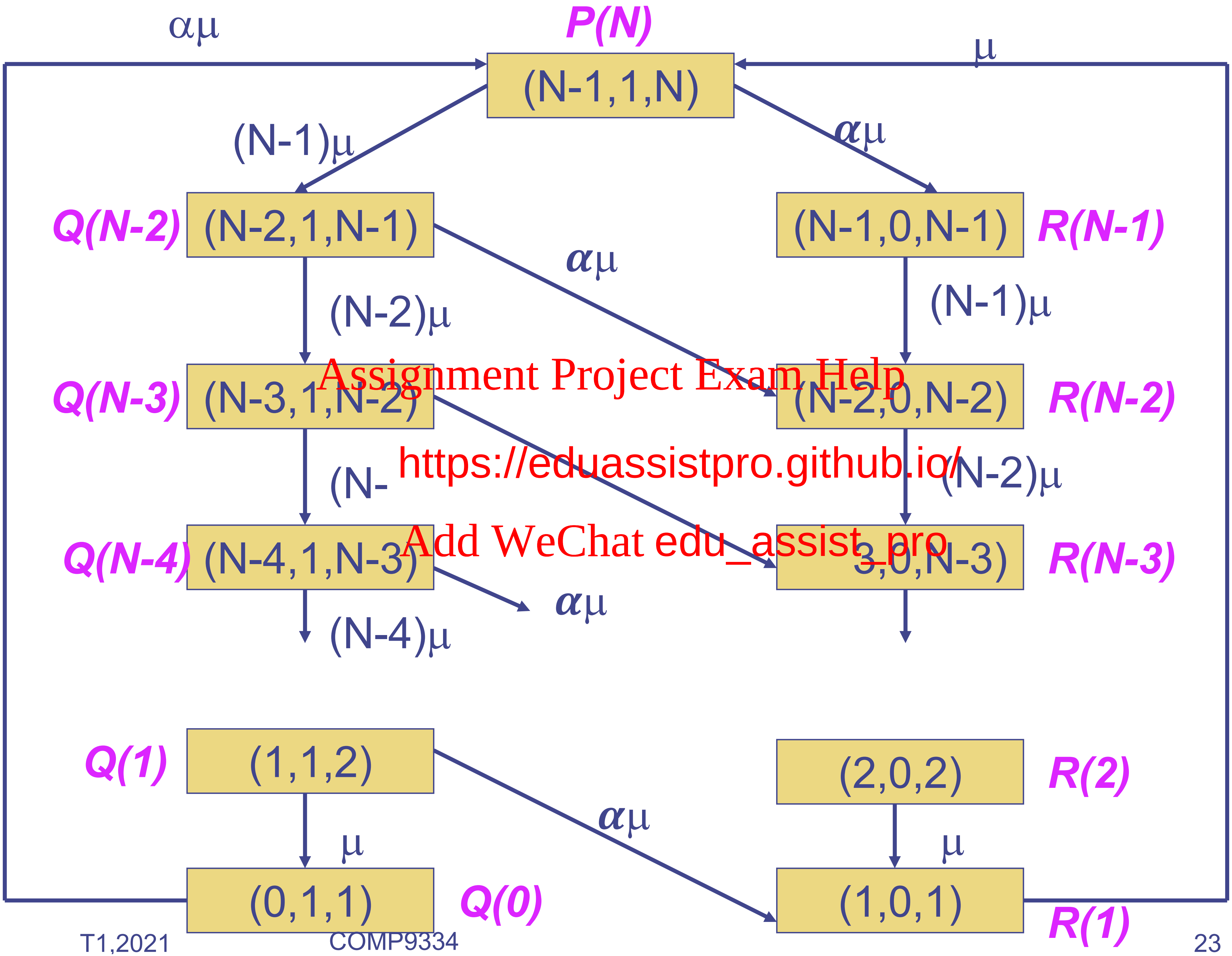
(We will explain how this is obtained later.)

How about T(α) for $\cancel{\alpha>1}$?

$\boxed{\alpha < 1 \text{ or } \frac{1}{\alpha} > 1}$

- We use Markov chain.
- States (i,j,k)
  - i (i = 0,…,N-1) is the number of web services still running in fast Web services
  - j (j = 0,1) is the number of web services running on the slow Web service
  - k (k = 1,2,..,N) is the number of web services yet to complete

- Define $\mu = \frac{1}{s}$



P(N)
(N-1,1,N)
αμ
μ
(N-1)μ
αμ
Q(N-2)
(N-2,1,N-1)
(N-1,0,N-1)
R(N-1)
αμ
(N-2)μ
(N-1)μ
Q(N-3)
(N-3,1,N-2)
(N-2,0,N-2)
R(N-2)
(N-
(N-2)μ
Q(N-4)
(N-4,1,N-3)
3,0,N-3)
R(N-3)
αμ
(N-4)μ
Q(1)
(1,1,2)
(2,0,2)
R(2)
αμ
μ
μ
(0,1,1)
Q(0)
(1,0,1)
R(1)

$T(\alpha)$

α

α

When α = 1,

$T(\alpha) = H_N S$

α

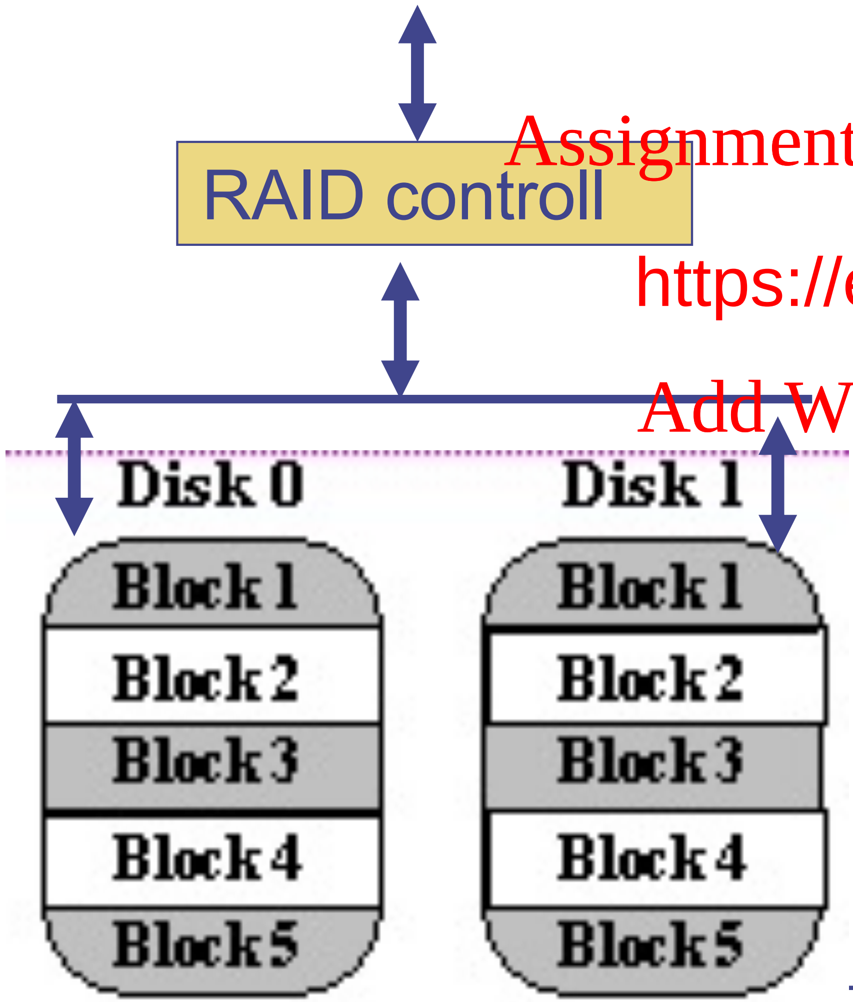
How T(α)/S varies with α?

T(α)/S

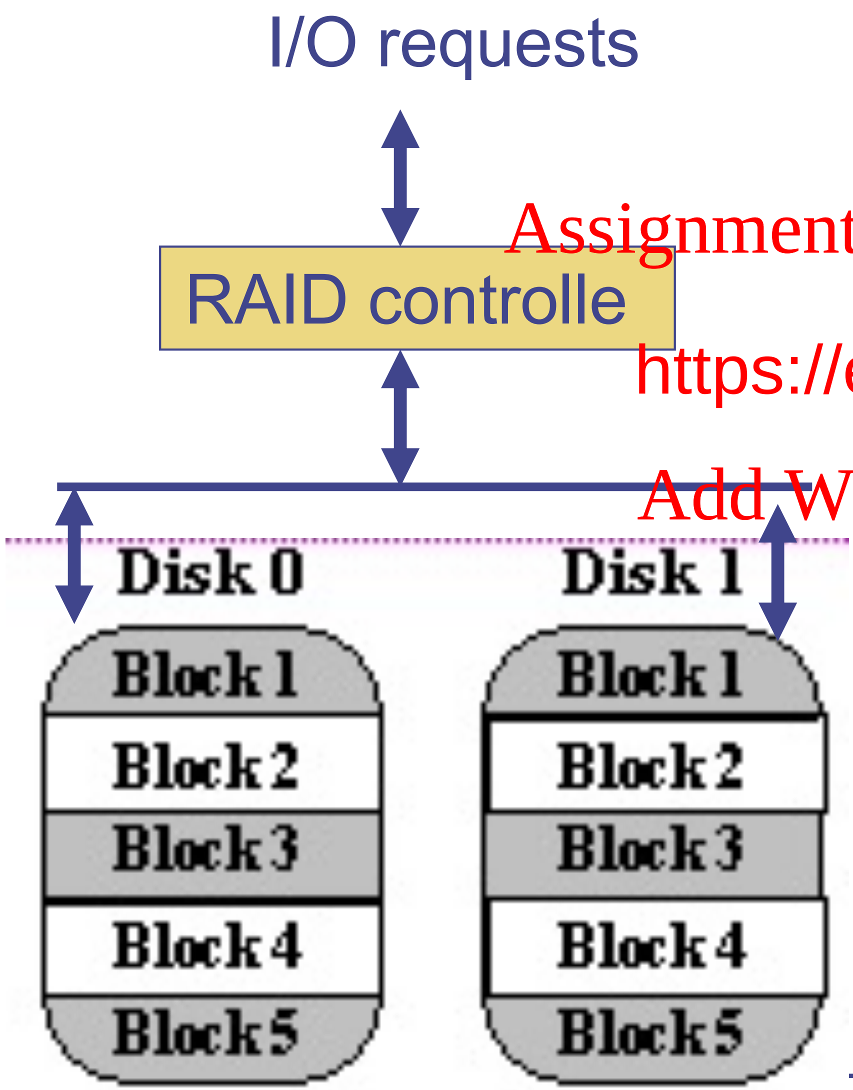
$\cancel{\alpha}$ $\boxed{\frac{1}{\alpha}}$

Other examples of fork-join QNs

- Disk array, e.g. RAID (= Redundant Array of Independent Disks)



f RAID1
sks



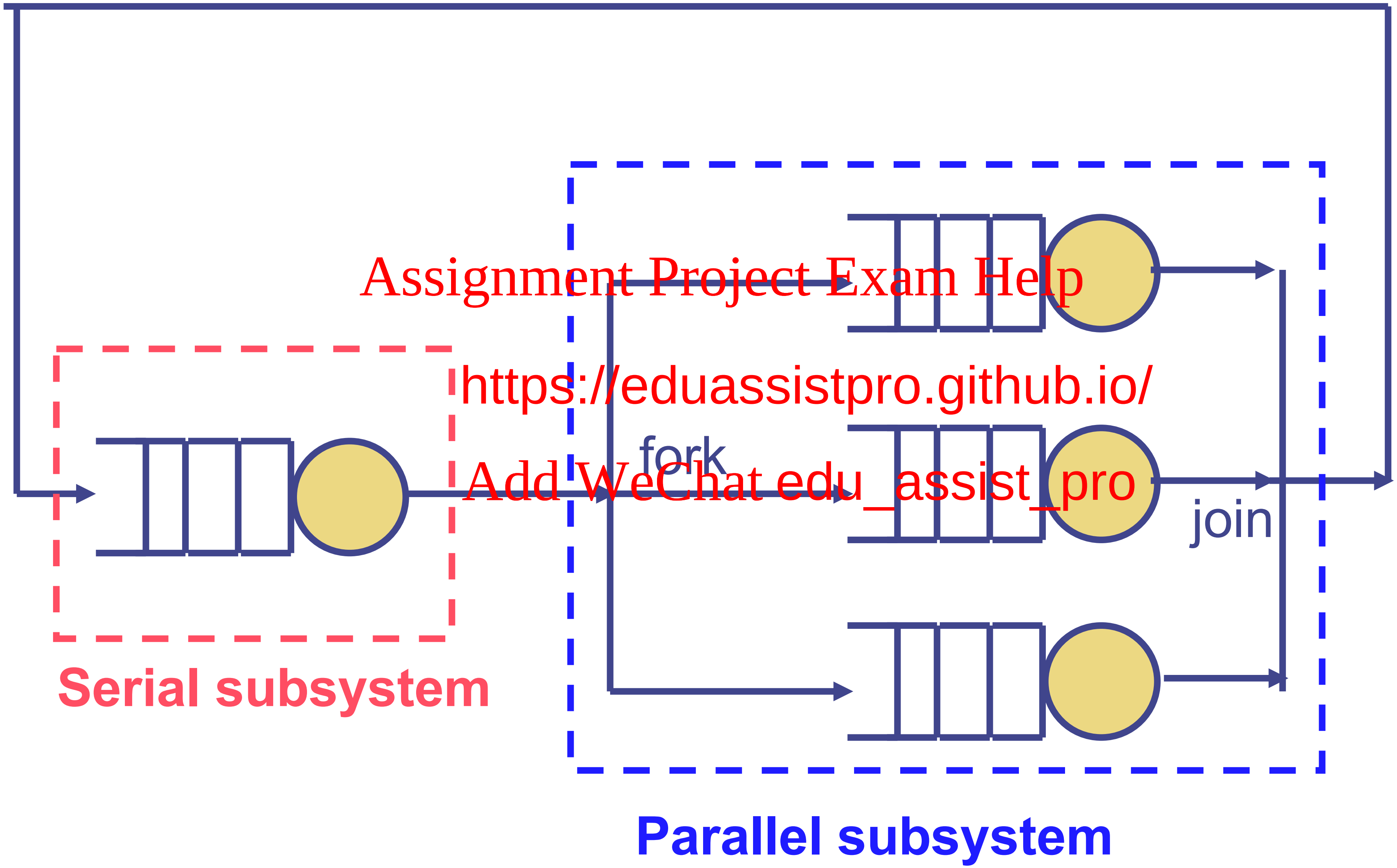
Example 1
Read a file in parallel
1st half of the file from Disk 0
2nd half of the file from Disk 1
Need to wait for both halves of
re the next operation

2
Write to disk.
Need to write to both disks (for consistency)
Need to wait for both disks to complete

Fork-join queueing networks

- Exact results are hard to come by
- Approximate solution methods are used

A Queueing network with a fork-join subsystem



Approximate MVA for fork-join queueing networks

- For MVA with fork-join, the basic unit is a subsystem
  - A subsystem can be either a serial subsystem (= a device) or parallel one
    - A serial subsystem is a special case of parallel subsystem
  - In comparison, the basic unit for MVA before is a device

Arrival Theorem for Parallel Subsystems (1)

- Consider a parallel subsystem with *k* parallel service centres
- The average time each job requires at each service centre is S (exponentially distributed)

$\mu = 1/S$

Arrival Theorem for Parallel Subsystems (2)

When there are $n-1$ jobs in the whole QN, the average number of jobs in the subsystem is z. When there're n jobs in the system

One of the
n jobs (customers)

$$\text{Waiting time} = S \times z; \text{ Service time} = S \times H_k$$

$$\Rightarrow \text{Response time} = S \times (H_k + z)$$

Note that if *k* = 1, the subsystem is serial and is identical to a device in MVA analysis that we have seen before.

$$\text{Response time} = S \times (H_1 + z)$$

This is the same arrival theorem that we've seen before.

Notation:

$$I = \text{Number of subsystems in the QN}$$

$$S_i = \text{Avg. service time of a station in subsystem } i$$

$$\bar{n}_i(n) = \text{Avg. \# of jobs at subsystem } i \text{ when there're } n \text{ jobs in the QN}$$

$$V_i = \text{Visit ratio of subsystem } i$$

MVA for fork-join systems:

Mean # jobs in each subsystem $\bar{n}_i(n-1)$

(n-1) jobs in system

n jobs in system

$$R_i(n) = S_i \times (H_{k_i} + \bar{n}_i(n-1))$$

Mean response time $R_i(n)$

Throughput of the system $X_0(n)$

$$\bar{n}_i(n) = V_i \times X_0(n) \times R_i(n)$$

Mean # jobs in each subsystem $\bar{n}_i(n)$

Example

- A system consists of a processor and 2 disk arrays
- Disk arrays operate under synchronous workload
  - Transactions are blocked until I/O are completed

	Service demand	# parallel systems
Processor		
Disk array 1	0.02	
Disk array 2	0.03	

What is the system response time when there are 50 transactions? How many transactions can the system have if the system response time should not exceed 1s?

Exercise

- The MVA algorithm on p.35 assumes that you have both visit ratios V_i and mean service time S_i available
- You may recall that service demand $D_i = V_i * S_i$
- Now, let us assume that you are only given the service demands D_i. That is, you know only D_i but you do not know V_i and S_i. How A algorithm on p.35 so that it can wo e demands only?

References (1)

- Web services
  - D. Mensace et al. Static and Dynamic Processor Scheduling Disciplines in Heterogeneous Parallel Architectures," *Journal of Parallel and Distributed Computing,* Vol. 28 (1), July 1995, pp. 1-18.
  - D. Mensace, "QoS Issues in Web Services," *IEEE Internet Computing*, November/December 2002, Vol. 6, No. 6.
  - D. Mensace, "Resp site Web Services," *IEEE Internet Com* 4, Vol. 8, No. 1
  - D. Mensace, "Composing Web Servic ew," D. Menasce, IEEE Internet Computing, Vol. 8, No. 6, No
  - These papers can be downloaded from the course website (use your CSE password)
    - We didn't cover the last paper but it's well worth a read.
- Derivation of Markov chain on pp. 22-24 is further explained in the file *forkjoin_mc.pdf*

References (2)

- Fork-join MVA
  - Menasce et al.,”Performance by desing”. Section 15.6.
- Addition references outside the scope of this course
  - Tutorial on RAID http://www.slcentral.com/articles/01/1/raid/