باسمه تعالی

شبکه های کامپیوتری ۲

دانشکده مهندسی برق و کامپیوتر

فروردین ۱۴۰۳

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۹۹۳۳۲۴۳

P٥. Suppose that the WEQ scheduling policy is applied to a buffer that supports three classes, and suppose the weights are ٠,٥, ٠,٢٥, and ٠,٢٥ for the three classes.

a. Suppose that each class has a large number of packets in the buffer. In what sequence might the three classes be served in order to achieve the WFQ weights? (For round robin scheduling, a natural sequence is ١٢٣١٢٣١٢٣...).

b. Suppose that classes ١ and ٢ have a large number of packets in the buffer, and there are no class ٣ packets in the buffer. In what sequence might the three classes be served in to achieve the WFQ weights?

(a)

Each class has a large number of packets in the buffer.

Class ١ has a weight of ٠,٥, Class ٢ has a weight of ٠,٢٥, and Class ٣ has a weight of ٠,٢٥.

In WFQ, the service rate is proportional to the weights assigned to each class. Since Class ١ has a weight of ٠,٥, it will receive half of the total service time. Classes ٢ and ٣, each with a weight of ٠,٢٥, will each receive a quarter of the total service time. A sequence that respects these weights can be represented as follows:

١. Class ١ will get ٢ packets served for every ١ packet each from Class ٢ and Class ٣.

A possible serving sequence might be: ١, ١, ٢, ٣, ١, ١, ٢, ٣, ...

This sequence ensures that over any reasonable interval, the proportion of packets served from each class adheres to their weights (٠,٥, ٠,٢٥, ٠,٢٥).

(b)

Classes ١ and ٢ have a large number of packets in the buffer, and there are no Class ٣ packets.

Class ١ has a weight of ٠,٥, and Class ٢ has a weight of ٠,٢٥.

With no packets from Class ٣ in the buffer, the total weight now consists only of Class ١ and Class ٢. Class ١ should still receive double the service time compared to Class ٢, but without Class ٣, this needs to be re-evaluated for just two classes.

- The new effective weights are:

- Class 1: $\frac{0.5}{0.5+0.25} = \frac{0.5}{0.75} = \frac{2}{3}$
- Class 2: $\frac{0.25}{0.5+0.25} = \frac{0.25}{0.75} = \frac{1}{3}$

Thus, Class ١ should be served twice as often as Class ٢.

A possible serving sequence might be: ١, ١, ٢, ١, ١, ٢, ...

This sequence ensures that Class ١ gets twice the service time compared to Class ٢.

P٦. Consider the figure below. Answer the following questions:

a. Assuming FIFO service, indicate the time at which packets ٢ through ١٢ each leave the queue. For each packet, what is the delay between its arrival and the beginning of the slot in which it is transmitted? What is the average of this delay over all ١٢ packets?

b. Now assume a priority service, and assume that odd-numbered packets are high priority, and even-numbered packets are low priority. Indicate the time at which packets ٢ through ١٢ each leave the queue. For each packet, what is the delay between its arrival and the beginning of the slot in which it is transmitted? What is the average of this delay over all ١٢ packets?

c. Now assume round robin service. Assume that packets ١, ٢, ٣, ٦, ١١, and ١٢ are from class ١, and packets ٤, ٥, ٧, ٨, ٩, and ١٠ are from class ٢. Indicate the time at which packets ٢ through ١٢ each leave the queue. For each packet, what is the delay between its arrival and its departure? What is the average delay over all ١٢ packets?

d. Now assume weighted fair queueing (WFQ) service. Assume that oddnumbered packets are from class ١, and even-numbered packets are from class ٢. Class ١ has a WFQ weight of ٢, while class ٢ has a WFQ weight of ١. Note that it may not be possible to achieve an idealized WFQ schedule as described in the text, so indicate why you have chosen the particular packet to go into service at each time slot. For each packet what is the delay between its arrival and its departure? What is the average delay over all ١٢ packets?

e. What do you notice about the average delay in all four cases (FIFO, RR, priority, and WFQ)?

(a):

Assume each time slot is ٢ units long, and the packets are served in the order they arrive.

١. **Departure Times:**

- Packet ١: t = ٠ to t = ٢
- Packet ٢: t = ٢ to t = ٤
- Packet ٣: t = ٤ to t = ٦
- Packet ٤: t = ٦ to t = ٨
- Packet ٥: t = ٨ to t = ١٠
- Packet ٦: t = ١٠ to t = ١٢
- Packet ٧: t = ١٢ to t = ١٤
- Packet ٨: t = ١٤ to t = ١٦
- Packet ٩: t = ١٦ to t = ١٨
- Packet ١٠: t = ١٨ to t = ٢٠
- Packet ١١: t = ٢٠ to t = ٢٢
- Packet ١٢: t = ٢٢ to t = ٢٤

٢. **Delays:**

- Packet ١: Delay = ٠ (arrives at t = ٠)
- Packet ٢: Delay = ٢ (arrives at t = ٢, starts service at t = ٢)
- Packet ٣: Delay = ٢ (arrives at t = ٣, starts service at t = ٤)
- Packet ٤: Delay = ٤ (arrives at t = ٤, starts service at t = ٦)
- Packet ٥: Delay = ٤ (arrives at t = ٥, starts service at t = ٨)
- Packet ٦: Delay = ٦ (arrives at t = ٦, starts service at t = ١٠)
- Packet ٧: Delay = ٦ (arrives at t = ٧, starts service at t = ١٢)

- Packet ٨: Delay = ٨ (arrives at t = ٨, starts service at t = ١٤)
- Packet ٩: Delay = ٨ (arrives at t = ٩, starts service at t = ١٦)
- Packet ١٠: Delay = ١٠ (arrives at t = ١٠, starts service at t = ١٨)
- Packet ١١: Delay = ١٠ (arrives at t = ١١, starts service at t = ٢٠)
- Packet ١٢: Delay = ١٢ (arrives at t = ١٢, starts service at t = ٢٢)

٣. **Average Delay:**

$$\text{Average Delay} = \frac{0+2+2+4+4+6+6+8+8+10+10+12}{12} = \frac{72}{12} = 6 \text{ unit}$$

(b):

Odd-numbered packets are high priority, even-numbered packets are low priority.

١. **Departure Times:**

- Serve odd-numbered packets first: ١, ٣, ٥, ٧, ٩, ١١
- Then serve even-numbered packets: ٢, ٤, ٦, ٨, ١٠, ١٢
- Packet ١: t = ٠ to t = ٢
- Packet ٣: t = ٢ to t = ٤
- Packet ٥: t = ٤ to t = ٦
- Packet ٧: t = ٦ to t = ٨
- Packet ٩: t = ٨ to t = ١٠
- Packet ١١: t = ١٠ to t = ١٢
- Packet ٢: t = ١٢ to t = ١٤
- Packet ٤: t = ١٤ to t = ١٦
- Packet ٦: t = ١٦ to t = ١٨

- Packet ٨: t = ١٨ to t = ٢٠
- Packet ١٠: t = ٢٠ to t = ٢٢
- Packet ١٢: t = ٢٢ to t = ٢٤

٢. **Delays:**

- High priority (odd-numbered packets):
    - Packet ١: Delay = ٠
    - Packet ٣: Delay = ١
    - Packet ٥: Delay = ٣
    - Packet ٧: Delay = ٥
    - Packet ٩: Delay = ٧
    - Packet ١١: Delay = ٩
- Low priority (even-numbered packets):
    - Packet ٢: Delay = ١٠
    - Packet ٤: Delay = ١٠
    - Packet ٦: Delay = ١٠
    - Packet ٨: Delay = ١٠
    - Packet ١٠: Delay = ١٠
    - Packet ١٢: Delay = ١٠

٣. **Average Delay:**

$$\text{Average Delay} = \frac{0+1+3+5+7+9+10+10+10+10+10+10}{12} = \frac{85}{12} \approx 7.$$

(c):

Class ١: Packets ١, ٢, ٣, ٦, ١١, ١٢

Class ٢: Packets ٤, ٥, ٧, ٨, ٩, ١٠

١. **Departure Times:** Serve alternately between classes:
   - Class ١ Packet ١: t = ٠ to t = ٢
   - Class ٢ Packet ٤: t = ٢ to t = ٤
   - Class ١ Packet ٢: t = ٤ to t = ٦
   - Class ٢ Packet ٥: t = ٦ to t = ٨
   - Class ١ Packet ٣: t = ٨ to t = ١٠
   - Class ٢ Packet ٧: t = ١٠ to t = ١٢
   - Class ١ Packet ٦: t = ١٢ to t = ١٤
   - Class ٢ Packet ٨: t = ١٤ to t = ١٦
   - Class ٢ Packet ٩: t = ١٦ to t = ١٨
   - Class ٢ Packet ١٠: t = ١٨ to t = ٢٠
   - Class ١ Packet ١١: t = ٢٠ to t = ٢٢
   - Class ١ Packet ١٢: t = ٢٢ to t = ٢٤

٢. **Delays:**
   - Class ١:
     - Packet ١: Delay = ٠
     - Packet ٢: Delay = ٢
     - Packet ٣: Delay = ٥
     - Packet ٦: Delay = ٦
     - Packet ١١: Delay = ٩

- Packet ١٢: Delay = ١٠

- Class ٢:
  - Packet ٤: Delay = ٠
  - Packet ٥: Delay = ١
  - Packet ٧: Delay = ٣
  - Packet ٨: Delay = ٦
  - Packet ٩: Delay = ٧
  - Packet ١٠: Delay = ٨

٣. **Average Delay:**

$$\text{Average Delay} = \frac{0+2+5+6+9+10+0+1+3+6+7+8}{12} = \frac{57}{12} \approx 4.75 \text{ uni}$$

(d):

Odd-numbered packets are from class ۱ (weight = ۲), even-numbered packets are from class ۲ (weight = ۱).

١. **Departure Times:**

- Given the weights, we serve class ١ twice as often as class ٢.
- Serve packets in a ٢:١ ratio.

Considering the WFQ scheduling, a possible sequence might be:

- Class ١ Packet ١: t = ٠ to t = ٢
- Class ١ Packet ٣: t = ٢ to t = ٤
- Class ٢ Packet ٢: t = ٤ to t = ٦

- Class ١ Packet ٥: t = ٦ to t = ٨
- Class ١ Packet ٧: t = ٨ to t = ١٠
- Class ٢ Packet ٤: t = ١٠ to t = ١٢
- Class ١ Packet ٩: t = ١٢ to t = ١٤
- Class ١ Packet ١١: t = ١٤ to t = ١٦
- Class ٢ Packet ٦: t = ١٦ to t = ١٨
- Class ١ Packet ١٢: t = ١٨ to t = ٢٠
- Class ١ Packet ٨: t = ٢٠ to t = ٢٢
- Class ٢ Packet ١٠### Part (d): Weighted Fair Queuing (WFQ) Service (continued)

To complete the WFQ scheduling and delay calculations:

Odd-numbered packets are from class ١ (weight = ٢), even-numbered packets are from class ٢ (weight = ١).

١. **Departure Times:**
    - Given the weights, we serve class ١ twice as often as class ٢.
    - Serve packets in a ٢:١ ratio.

Considering the WFQ scheduling, a possible sequence might be:

- Class ١ Packet ١: t = ٠ to t = ٢
- Class ١ Packet ٣: t = ٢ to t = ٤
- Class ٢ Packet ٢: t = ٤ to t = ٦
- Class ١ Packet ٥: t = ٦ to t = ٨
- Class ١ Packet ٧: t = ٨ to t = ١٠
- Class ٢ Packet ٤: t = ١٠ to t = ١٢
- Class ١ Packet ٩: t = ١٢ to t = ١٤

- Class ١ Packet ١١: t = ١٤ to t = ١٦
- Class ٢ Packet ٦: t = ١٦ to t = ١٨
- Class ١ Packet ١٢: t = ١٨ to t = ٢٠
- Class ٢ Packet ٨: t = ٢٠ to t = ٢٢
- Class ٢ Packet ١٠: t = ٢٢ to t = ٢٤

٢. **Delays:**

- Class ١:
  - Packet ١: Delay = ٠
  - Packet ٣: Delay = ١
  - Packet ٥: Delay = ٣
  - Packet ٧: Delay = ٥
  - Packet ٩: Delay = ٧
  - Packet ١١: Delay = ٩
  - Packet ١٢: Delay = ٦
- Class ٢:
  - Packet ٢: Delay = ٢
  - Packet ٤: Delay = ٦
  - Packet ٦: Delay = ١٠
  - Packet ٨: Delay = ١٢
  - Packet ١٠: Delay = ١٤

٣. **Average Delay:**

$$\text{Average Delay} = \frac{0+1+3+5+7+9+6+2+6+10+12+14}{12} = \frac{75}{12} \approx 6.25$$

(e):

١. **FIFO:**
   - Average delay = ٦ units

٢. **Priority:**
   - Average delay ≈ ٧,٠٨ units

٣. **Round Robin:**
   - Average delay ≈ ٤,٧٥ units

٤. **WFQ:**
   - Average delay ≈ ٦,٢٥ units

١. **FIFO:**
   - Average delay is moderate but does not prioritize any specific packets, leading to consistent service times regardless of packet importance or class.

٢. **Priority:**
   - High-priority packets have lower delays, but low-priority packets suffer significantly higher delays, resulting in a higher overall average delay.

٣. **Round Robin:**

- Balances delays across classes more effectively, providing a fairer average delay. This method avoids the extremes seen in priority scheduling.

٤. **WFQ:**

- Offers a balanced service based on predefined weights, which results in fair service for different classes. WFQ typically provides a good balance between fairness and delay, making it suitable for scenarios where traffic classes have different importance levels.