Tutorial
Distributed Systems (IN2259)

SAMPLE SOLUTION: EXERCISES ON PUBLISH/SUBSCRIBE

EXERCISE 1 Distributed Routing

Figure 1.1 illustrates a pub/sub network composed of one publisher, three subscribers, and five brokers. Each node has an ID, and each link is labeled. Depending on the routing model used, different brokers will send and receive different messages and store different types of data.

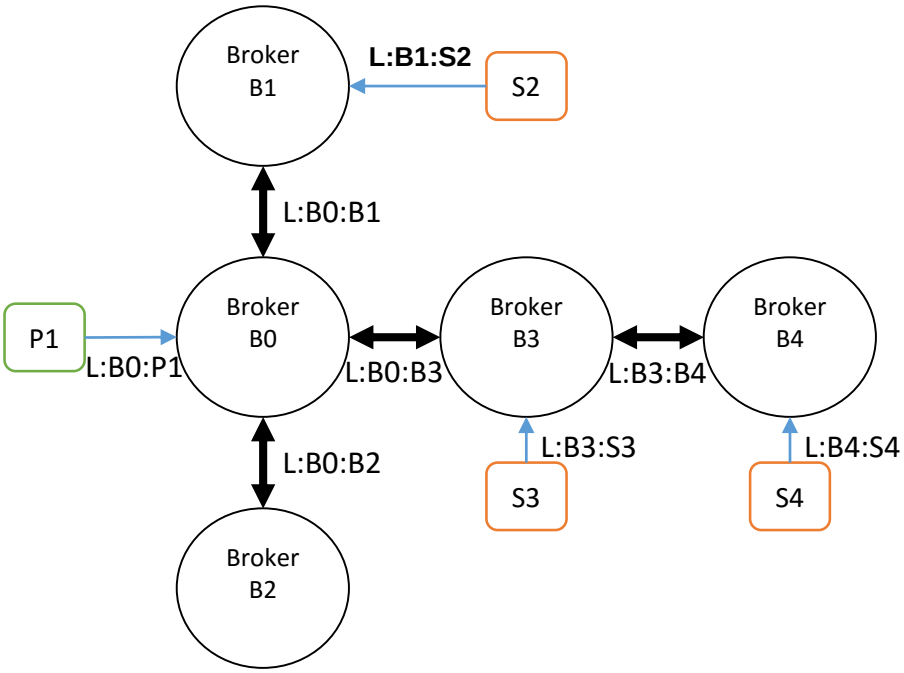

Figure 1.1: Example network

(a) In an advertisement-based routing model, show what type of data is stored by each broker. Describe what happens when $P1$ advertises, then $S2$ sends a matching subscription. Suppose subscription covering is not enabled, show what happens after $S3$ sends the same subscription as $S2$.

Solution: In an advertisement-based routing model, each broker stores a Subscription Routing Table (SRT) and a Publication Routing Table (PRT). Fig. 1.2 illustrates the example. $P1$'s advertisement is flooded to all brokers, who store it in the SRT. $S2$'s subscription follows the reverse path to reach the edge broker attached to $P1$ and is stored in the PRT at brokers $B1$ and $B0$. Subscription $S3$ reaches broker $B0$ and is stored in the PRT of $B3$ and $B0$.

(b) In a subscription-based routing model, show what type of data is stored by each broker. Describe what happens when $S3$ sends a matching subscription. Suppose subscription covering is enabled, show what happens after $S4$ sends the same subscription as $S3$.

Solution: In a subscription-based routing model, each broker stores a Publication Routing Table (PRT). Fig. 1.3 illustrates the example. $S3$'s subscription is flooded and reach all brokers, who store it in the PRT. Subscription $S4$ is stored at $B4$ and then forwarded to $B3$. This is because even though $S4$ is covered by $S3$, $B3$ is the next hop to reach $S3$ from $B4$. This means that at $B3$, $S3$ and $S4$ do not share the same next hop and it must therefore be propagated to

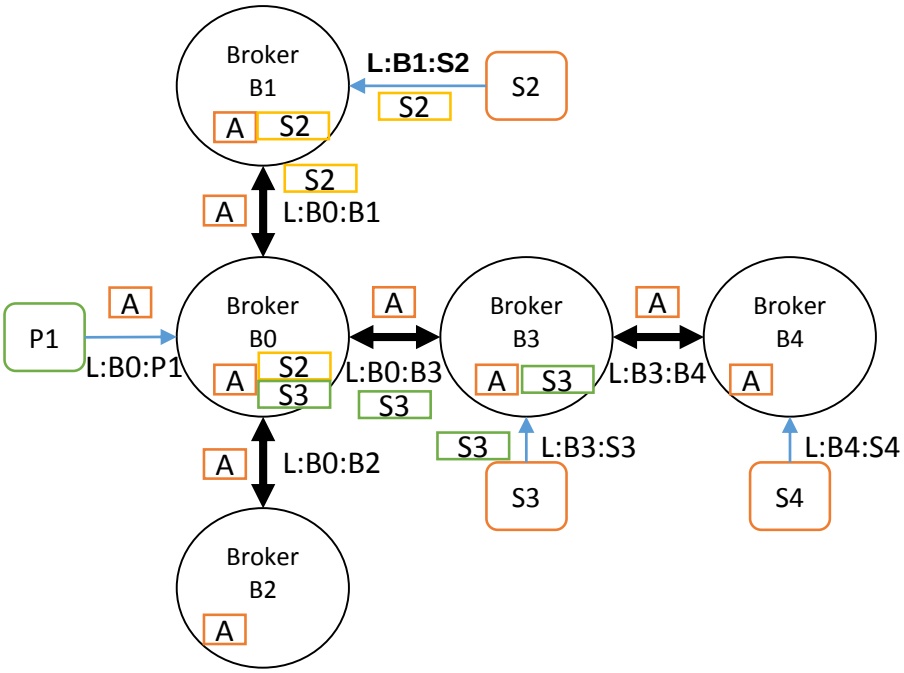

Figure 1.2: Solution (advertisement-based)

$B3$. At $B3$ however, forward propagation to $B0$ is unnecessary because the next hop for $S3$ and $S4$ at $B0$ would be the same ($B3$). Therefore, the covering optimization takes effect.

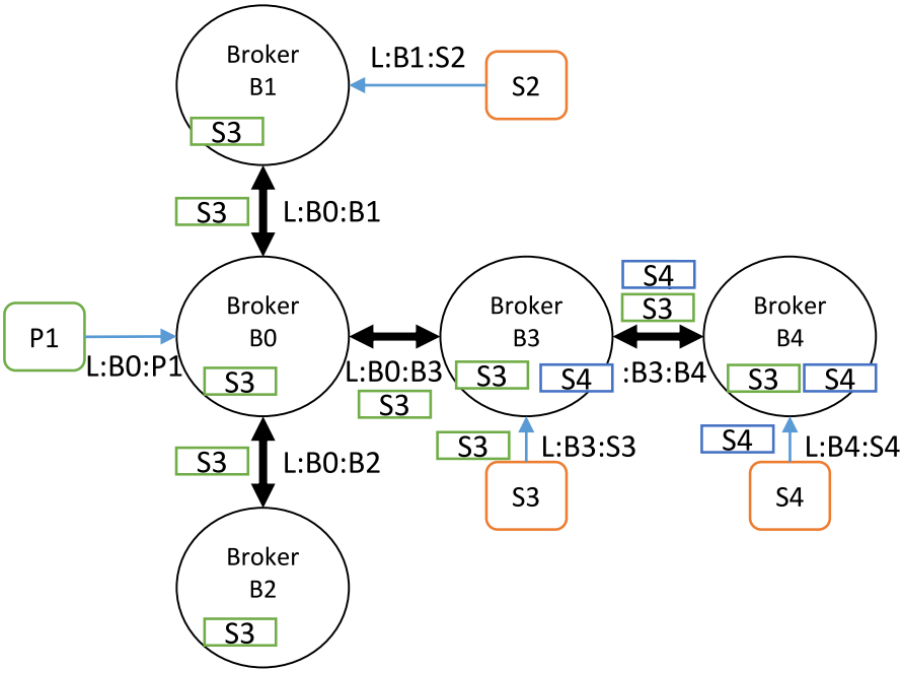

Figure 1.3: Solution (subscription-based)

(c) In a rendezvous-based routing model using Bloom filters with link IDs (see labels), show what type of data is stored by each broker, where $B2$ is the rendezvous broker. Suppose subscribers $S2-4$ have already subscribed. Show what happens when $P1$ sends a publication P which matches $S2$ and $S3$. Assume there are no false positives with the Bloom Filter.

Solution: In a rendezvous-based routing model using Bloom filters with link IDs, each broker knows the next-hop

information to reach the rendezvous broker $B2$. $B2$ also has knowledge of all subscriptions and the topology of the overlay (including all link IDs). Fig. 1.4 illustrates the example. $P1$ sends the publication, which is first forwarded to rendezvous broker $B2$. $B2$ then computes the delivery tree to reach both $S2$ and $S3$, which consists of link IDs: $\{L:B0:B2, L:B0:B1, L:B1:S2, L:B0:B3, L:B3:S3\}$. This information is inserted into the Bloom Filter (P, BF). Each broker which receives P, BF verifies every outgoing link and check if it is inside the Bloom Filter. Assuming there are no false positives, the publication will be traverse brokers $B2, B0, B1, B3$ to reach subscribers $S2, S3$.

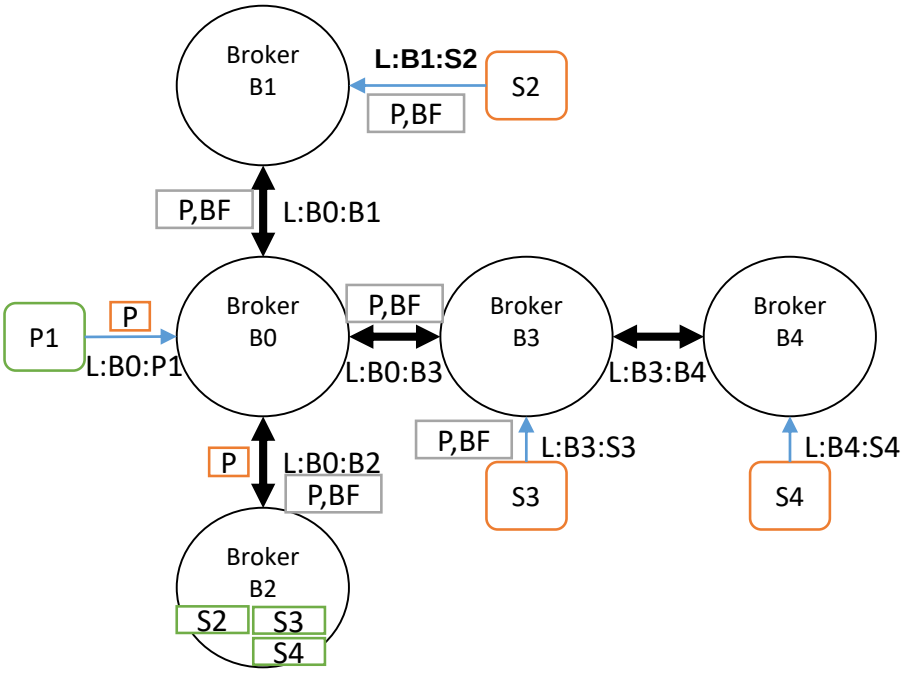

Figure 1.4: Solution (rendezvous-based)

EXERCISE 2 Publish/subscribe - content-based matching

Figure 2.5 shows the overlay broker network for an advertisement-based publish/subscribe system. The brokers serve as the contact point for any client of the system; they receive subscriptions and publications and forward them to their destination. In order to route the messages, the brokers maintain two routing tables: Subscription Routing Table (SRT) and Publication Routing Table (PRT)(see Figure 2.6). Now, consider a stock trading application providing information about all kinds of stocks. A stock consists of a tuple of following properties: stock symbol, stock price and stock trend (e.g., $[s,=,MSFT]$, $[p,<,128]$, $[t,=,+8]$).

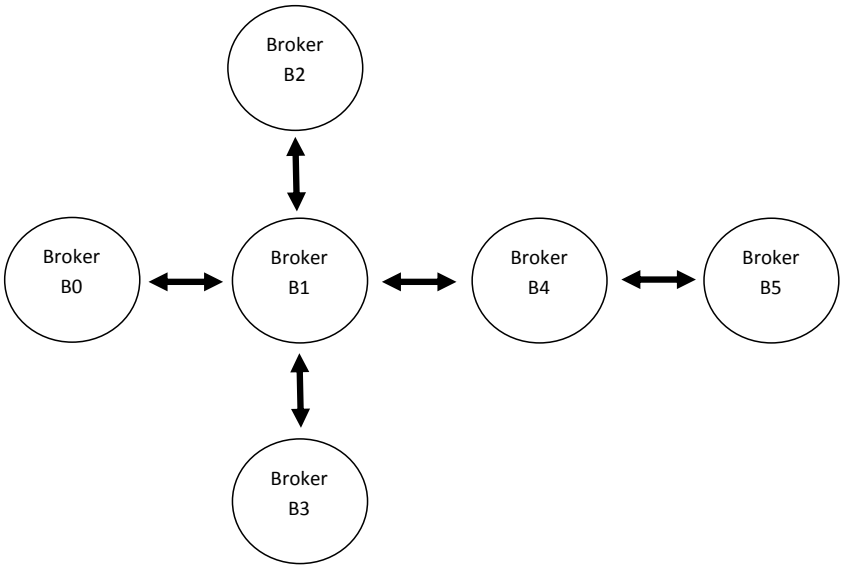

Figure 2.5: Broker overlay

(a) The publishers flood the network with their advertisements to inform potential subscribers. Update the routing tables.

1. Publisher p_1 connects to broker b_0 and advertises $[s,=,AAPL][p,=,*][t,=,*]$
2. p_2 connects to b_2 and advertises $[s,=,GOOG][p,=,*][t,=,*]$
3. p_3 connects to b_4 and advertises $[s,=,AMZ][p,=,*][t,=,*]]$

(b) The subscribers issue their subscriptions to the brokers. Route the subscriptions and update the routing tables accordingly. Assume subscription covering is disabled.

1. Subscriber s_1 connects to broker b_3 and subscribes to $[s,=,AAPL][p,>,100]$
2. s_2 connects to b_5 and subscribes to $[s,=,AAPL],[t,>,+20]$
3. s_3 connects to b_4 and subscribes to $[s,=,GOOG],[p,<,50]$
4. s_4 connects to b_3 and subscribes to $[s,=,GOOG],[p,>,40],[t,>,+10]$
5. s_5 connects to b_3 and subscribes to $[s,=,AMZ],[p,>,35]$

(c) Describe changes, if any, to the above if subscription covering is enabled.
Solution: No changes, there are no covering relationships between any pair of subscriptions.

(d) The publishers publish the following events. Specify the routing path and the set of receivers (e.g. $\{p_1,b_0,b_1,\{b_3,s_1\}||\{b_4,b_5,s_2\}\} \rightarrow s_1,s_2$).

1. Publisher p_1 publishes $[s,MSFT],[p,120],[t,-20]$
Solution: $\{\emptyset\} \rightarrow \emptyset$

2. Publisher p_2 publishes $[s, GOOG], [p, 50], [t, +10]$
   Solution: $\{\emptyset\} \rightarrow \emptyset$
3. Publisher p_1 publishes $[s, AAPL], [p, 110], [t, +10]$
   Solution: $\{p_1, b_0, b_1, b_3, s_1\} \rightarrow s_1$
4. Publisher p_3 publishes $[s, AMZ], [p, 60], [t, -5]$
   Solution: $\{p_3, b_4, b_1, b_3, s_5\} \rightarrow s_5$
5. Publisher p_2 publishes $[s, GOOG], [p, 45], [t, +20]$
   Solution: $\{p_2, b_2, b_1, \{b_4, s_3\} || \{b_3, s_4\}\} \rightarrow s_3, s_4$
6. Publisher p_1 publishes $[s, AAPL], [p, 140], [t, +30]$
   Solution: $\{p_1, b_0, b_1, \{b_3, s_1\} || \{b_4, b_5, s_2\}\} \rightarrow s_1, s_2$

Broker B0			
SRT		PRT	

Broker B1			
SRT		PRT	

Broker B2			
SRT		PRT	

Broker B3			
SRT		PRT	

Broker B4			
SRT		PRT	

Broker B5			
SRT		PRT	

Figure 2.6: Routing tables

Broker B0			
SRT		PRT	
[s,=,AAPL][p,=,*][t,=,*]	p1	[s,=,AAPL][p,>,100]	b1
[s,=,GOOG][p,=,*][t,=,*]	b1	[s,=,AAPL], [t,>,+20]	b1
[s,=,AMZ][p,=,*][t,=,*]	b1		

Broker B1			
SRT		PRT	
[s,=,AAPL][p,=,*][t,=,*]	b0	[s,=,AAPL][p,>,100]	b3
[s,=,GOOG][p,=,*][t,=,*]	b2	[s,=,AAPL], [t,>,+20]	b4
[s,=,AMZ][p,=,*][t,=,*]	b4	[s,=,GOOG], [p,<,50]	b4
		[s,=,GOOG], [p,>,40][t,>,+10]	b3
		[s,=,AMZ], [p,>,35]	b3

Broker B2			
SRT		PRT	
[s,=,AAPL][p,=,*][t,=,*]	b1	[s,=,GOOG], [p,<,50]	b1
[s,=,GOOG][p,=,*][t,=,*]	p2	[s,=,GOOG], [p,>,40][t,>,+10]	b1
[s,=,AMZ][p,=,*][t,=,*]	b1		

Broker B3			
SRT		PRT	
[s,=,AAPL][p,=,*][t,=,*]	b1	[s,=,AAPL][p,>,100]	s1
[s,=,GOOG][p,=,*][t,=,*]	b1	[s,=,GOOG], [p,>,40][t,>,+10]	s4
[s,=,AMZ][p,=,*][t,=,*]	b1	[s,=,AMZ], [p,>,35]	s5

Broker B4			
SRT		PRT	
[s,=,AAPL][p,=,*][t,=,*]	b1	[s,=,AAPL], [t,>,+20]	b5
[s,=,GOOG][p,=,*][t,=,*]	b1	[s,=,GOOG], [p,<,50]	s3
[s,=,AMZ][p,=,*][t,=,*]	p3	[s,=,AMZ], [p,>,35]	b1

Broker B5			
SRT		PRT	
[s,=,AAPL][p,=,*][t,=,*]	b4	[s,=,AAPL], [t,>,+20]	s2
[s,=,GOOG][p,=,*][t,=,*]	b4		
[s,=,AMZ][p,=,*][t,=,*]	b4		

Figure 2.7: Routing tables solution