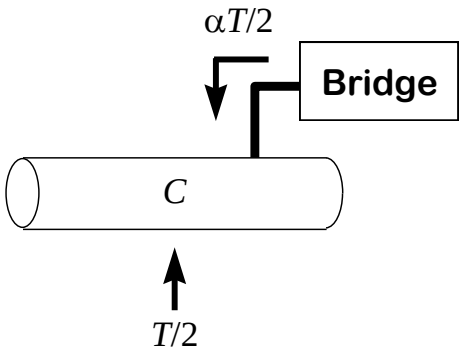
EE384A Homework Assignment 1 Solution
Transparent Bridging

Question 1

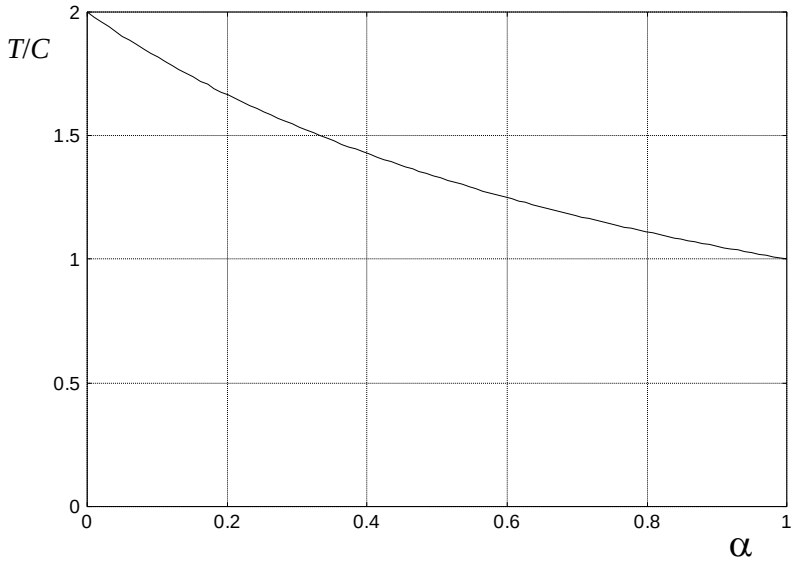
(a) Derive the maximum value of T as a function of C and α. Sketch a plot of maximum T/C as a function of α, for $0 \le \alpha \le 1$.

The traffic on each segment has two components: $T/2$ bits/second generated by the stations in the segment, and $\alpha T/2$ from the bridge, as depicted below:



Since the segment capacity is C, we must have $T/2 + \alpha T/2 \le C$. Therefore, the maximum value of T supported by the network happens when the above inequality becomes an equality:

$$\frac{T}{C} = \frac{2}{1+\alpha}$$



(b) Discuss the maximum value of T when $\alpha = 0$ and $\alpha = 1$.

The situation where $\alpha = 0$ corresponds to the case whereby all the traffic from each segment stays local to that segment, and no traffic crosses the bridge. In this case, $T = 2C$; by using a bridge and separating the two communities, we doubled the network capacity from the scenario where all the stations shared the same segment. If the traffic is localized (i.e., most of the traffic tends to stay within a certain group of machines), properly deploying bridges can increase the network capacity. The other extreme is $\alpha = 1$, when stations in one segment only talk to stations in the other segment. In this case, $T = C$, because all traffic from one segment crosses over to the other segment, and there is no gain in overall network capacity when a bridge is deployed.

Another interesting case is $\alpha = 0.5$, which means that each station is equally likely to talk to any other station. For this case, $T = 1.333C$; the bridge will improve the overall network capacity by 33.3%.

Question 2.1

At startup, all the bridges believe that they are the root bridge, and will exchange configuration BPDUs with neighboring bridges to compute the spanning tree. Configuration BPDUs are subsequently sent by the root bridge at regular intervals (the "hello time"). We assume that the bridges are synchronized and the unit of time is the hello time. The BPDU exchanges are shown in the figures below. To make it easier to follow the procedure, a second table has been added, showing, per bridge, the received BPDUs.

Configuration messages at first exchange of BPDUs (before receiving)

Bridge B1	Configuration BPDU	Port State
Port 1	B1.0.B1.1	Designated Port (DP)
Port 2	B1.0.B1.2	Designated Port (DP)

Bridge B2	Configuration BPDU	Port State
Port 1	B2.0.B2.1	DP
Port 2	B2.0.B2.2	DP

Bridge B3	Configuration BPDU	Port State
Port 1	B3.0.B3.1	DP
Port 2	B3.0.B3.2	DP

Bridge B4	Configuration BPDU	Port State
Port 1	B4.0.B4.1	DP
Port 2	B4.0.B4.2	DP
Port 3	B4.0.B4.3	DP

Bridge B5	Configuration BPDU	Port State
Port 1	B5.0.B5.1	DP
Port 2	B5.0.B5.2	DP

Bridge B6	Configuration BPDU	Port State
Port 1	B6.0.B6.1	DP
Port 2	B6.0.B6.2	DP

Bridge B7	Configuration BPDU	Port State
Port 1	B7.0.B7.1	DP
Port 2	B7.0.B7.2	DP
Port 3	B7.0.B7.3	DP

Sent and Received BPDUs at the end of the first iteration, after receive

Bridge B1	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.0.B1.1	B2.0.B2.2	B3.0.B3.1	B4.0.B4.2
Port 2	B1.0.B1.2	B3.0.B3.2	B5.0.B5.1	
Bridge B2	**Sent BPDU**	**Received BPDUs**		
Port 1	B2.0.B2.1	B4.0.B4.1		
Port 2	B2.0.B2.2	B1.0.B1.1	B3.0.B3.1	B4.0.B4.2
Bridge B3	**Sent BPDU**	**Received BPDUs**		
Port 1	B3.0.B3.1	B2.0.B2.2	B1.0.B1.1	B4.0.B4.2
Port 2	B3.0.B3.2	B1.0.B1.2	B5.0.B5.1	
Bridge B4	**Sent BPDU**	**Received BPDUs**		
Port 1	B4.0.B4.1	B2.0.B2.1		
Port 2	B4.0.B4.2	B2.0.B2.2	B3.0.B3.1	B1.0.B1.1
Port 3	B4.0.B4.3	B6.0.B6.1		
Bridge B5	**Sent BPDU**	**Received BPDUs**		
Port 1	B5.0.B5.1	B1.0.B1.2	B3.0.B3.2	
Port 2	B5.0.B5.2	B7.0.B7.1		
Bridge B6	**Sent BPDU**	**Received BPDUs**		
Port 1	B6.0.B6.1	B4.0.B4.3		
Port 2	B6.0.B6.2	B7.0.B7.3		
Bridge B7	**Sent BPDU**	**Received BPDUs**		
Port 1	B7.0.B7.1	B5.0.B5.2		
Port 2	B7.0.B7.2			
Port 3	B7.0.B7.3	B6.0.B6.2		

Configuration messages at second exchange of BPDUs

Bridge B1	Configuration BPDU	Port State
Port 1	B1.0.B1.1	DP
Port 2	B1.0.B1.2	DP

Bridge B2	Configuration BPDU	Port State
Port 1	B1.1.B2.1	DP
Port 2	----	RP

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP
Port 2	----	Blocked

Bridge B4	Configuration BPDU	Port State
Port 1	B1.1.B4.1	DP
Port 2	----	RP
Port 3	B1.1.B4.3	DP

Bridge B5	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.1.B5.2	DP

Bridge B6	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B4.1.B6.2	DP

Bridge B7	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B5.1.B7.2	DP
Port 3	B5.1.B7.3	DP

Sent and Received BPDUs at the end of the second iteration, after receive

Bridge B1	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.0.B1.1			
Port 2	B1.0.B1.2			
Bridge B2	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.1.B2.1	B1.1.B4.1		
Port 2	----	B1.0.B1.1		
Bridge B3	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.0.B1.1		
Port 2	----	B1.0.B1.2		
Bridge B4	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.1.B4.1	B1.1.B2.1		
Port 2	----	B1.0.B1.1		
Port 3	B1.1.B4.3			
Bridge B5	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.0.B1.2		
Port 2	B1.1.B5.2			
Bridge B6	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B4.3		
Port 2	B4.1.B6.2	B5.1.B7.3		
Bridge B7	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B5.2		
Port 2	B5.1.B7.2			
Port 3	B5.1.B7.3	B4.1.B6.2		

Configuration messages at third exchange of BPDUs

Bridge B1	Configuration BPDU	Port State
Port 1	B1.0.B1.1	DP
Port 2	B1.0.B1.2	DP

Bridge B2	Configuration BPDU	Port State
Port 1	B1.1.B2.1	DP
Port 2	----	RP

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP
Port 2	----	Blocked

Bridge B4	Configuration BPDU	Port State
Port 1	----	Blocked
Port 2	----	RP
Port 3	B1.1.B4.3	DP

Bridge B5	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.1.B5.2	DP

Bridge B6	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.2.B6.2	DP

Bridge B7	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.2.B7.2	DP
Port 3	B1.2.B7.3	DP

Sent and Received BPDUs at the end of the third iteration, after receive

Bridge B1	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.0.B1.1			
Port 2	B1.0.B1.2			
Bridge B2	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.1.B2.1			
Port 2	----	B1.0.B1.1		
Bridge B3	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.0.B1.1		
Port 2	----	B1.0.B1.2		
Bridge B4	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B2.1		
Port 2	----	B1.0.B1.1		
Port 3	B1.1.B4.3			
Bridge B5	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.0.B1.2		
Port 2	B1.1.B5.2			
Bridge B6	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B4.3		
Port 2	B1.2.B6.2	B1.2.B7.3		
Bridge B7	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B5.2		
Port 2	B1.2.B7.2			
Port 3	B1.2.B7.3	B1.2.B6.2		

Configuration messages at fourth exchange of BPDUs

Bridge B1	Configuration BPDU	Port State
Port 1	B1.0.B1.1	DP
Port 2	B1.0.B1.2	DP

Bridge B2	Configuration BPDU	Port State
Port 1	B1.1.B2.1	DP
Port 2	----	RP

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP
Port 2	----	Blocked

Bridge B4	Configuration BPDU	Port State
Port 1	----	Blocked
Port 2	----	RP
Port 3	B1.1.B4.3	DP

Bridge B5	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.1.B5.2	DP

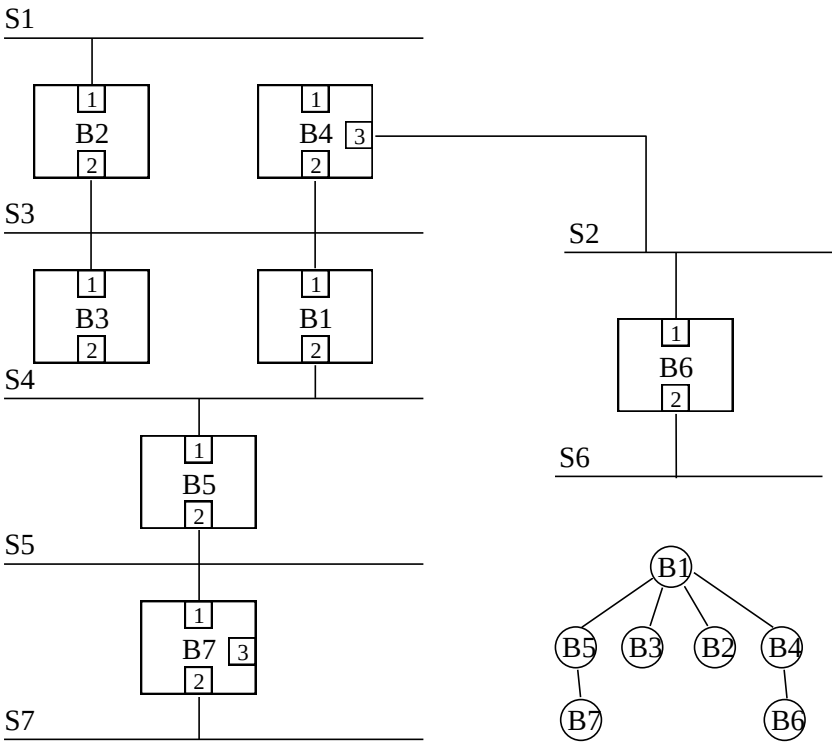
Bridge B6	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.2.B6.2	DP

Bridge B7	Configuration BPDU	Port State
Port 1	----	RP
Port 2	B1.2.B7.2	DP
Port 3	----	Blocked

Sent and Received BPDUs at the end of the third iteration, after receive

Bridge B1	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.0.B1.1			
Port 2	B1.0.B1.2			
Bridge B2	**Sent BPDU**	**Received BPDUs**		
Port 1	B1.1.B2.1			
Port 2	----	B1.0.B1.1		
Bridge B3	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.0.B1.1		
Port 2	----	B1.0.B1.2		
Bridge B4	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B2.1		
Port 2	----	B1.0.B1.1		
Port 3	B1.1.B4.3			
Bridge B5	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.0.B1.2		
Port 2	B1.1.B5.2			
Bridge B6	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B4.3		
Port 2	B1.2.B6.2			
Bridge B7	**Sent BPDU**	**Received BPDUs**		
Port 1	----	B1.1.B5.2		
Port 2	B1.2.B7.2			
Port 3	----	B1.2.B6.2		

At this point, steady state has been reached. Note that only one port on each segment (the designated port) transmits bridge hello messages into that segment. The final topology is:

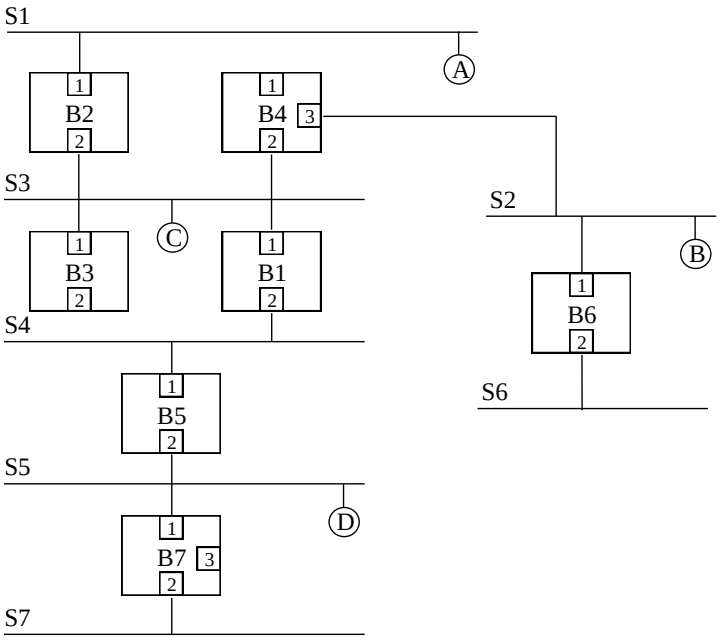


Question 2.2

(a) Station A sends a multicast packet. Bridges have to forward the multicast packet to all forwarding ports; after the packet has propagated through the network, every bridge will know the location of station A. The station caches will look like:

Bridge Number	Station Address	Port Number
B1	A	1
B2	A	1
B3	A	1
B4	A	2
B5	A	1
B6	A	1
B7	A	1

(b) Consider now that station B sends a series of packets to C. Since the location of C is not known (because it has not transmitted yet), the packets are all broadcast across the whole network, causing all the bridges to learn the location of B. When C responds, its response follows the spanning tree to B, because its location is known; the bridges across this path learn the location of C. When D sends a packet to C, some bridges are aware of its location, and some are not. To answer this question, it is useful to draw again the spanning tree, with the stations indicated on it:



The forwarding databases will look like:

Bridge Number	**Station Address**	**Port Number**
B1	A	1
	B	1
	C	1
	D	2
B2	A	1
	B	2
	C	2
	D	2
B3	A	1
	B	1
	C	1
	D	1
B4	A	2
	B	3
	C	2
	D	2
B5	A	1
	B	1
	D	2
B6	A	1
	B	1
	C	1
B7	A	1
	B	1
	D	1

The total number of transmissions is:

- Multicast from A: 7 transmissions.
- Packets from B to C: 7 transmissions per packet, 5 of them being unnecessary (to S1, S4, S5, S6 and S7).
- Packet from C to B: 2 transmissions, 0 unnecessary.
- Packet from D to C: 4 transmissions, 1 unnecessary (to S7).

Question 2.3

Solution of this question follows in the same lines as question 2.1.

Messages sent out at the first exchange

Bridge B0	Configuration BPDU	Port State
Port 1	B0.0.B0.1	DP, listening
Port 2	B0.0.B0.2	DP, listening

Bridge B1	Configuration BPDU	Port State
Port 1	B1.0.B1.1	DP, forwarding
Port 2	B1.0.B1.2	DP, forwarding

Bridge B2	Configuration BPDU	Port State
Port 1	B1.1.B2.1	DP, forwarding
Port 2	----	RP, forwarding

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	----	Blocked

Bridge B4	Configuration BPDU	Port State
Port 1	----	Blocked
Port 2	----	RP, forwarding
Port 3	B1.1.B4.3	DP, forwarding

Bridge B5	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B1.1.B5.2	DP, forwarding

Bridge B6	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B1.2.B6.2	DP, forwarding

Bridge B7	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B1.2.B7.2	DP, forwarding
Port 3	----	Blocked

Messages sent out at the second exchange

Bridge B0	Configuration BPDU	Port State
Port 1	B0.0.B0.1	DP, listening
Port 2	B0.0.B0.2	DP, listening

Bridge B1	Configuration BPDU	Port State
Port 1	B1.0.B1.1	DP, forwarding
Port 2	B1.0.B1.2	DP, forwarding

Bridge B2	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B0.1.B2.2	DP, forwarding

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	----	Blocked

Bridge B4	Configuration BPDU	Port State
Port 1	----	RP, listening
Port 2	B0.1.B4.2	DP, forwarding
Port 3	B0.1.B4.3	DP, forwarding

Bridge B5	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B1.1.B5.2	DP, forwarding

Bridge B6	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B1.2.B6.2	DP, forwarding

Bridge B7	Configuration BPDU	Port State
Port 1	B0.1.B7.1	DP, forwarding
Port 2	----	RP, forwarding
Port 3	B0.1.B7.3	DP, listening

Messages sent out at the third exchange

Bridge B0	Configuration BPDU	Port State
Port 1	B0.0.B0.1	DP, listening
Port 2	B0.0.B0.2	DP, listening

Bridge B1	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B0.2.B1.2	DP, forwarding

Bridge B2	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B0.1.B2.2	DP, forwarding

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	----	Blocked

Bridge B4	Configuration BPDU	Port State
Port 1	----	RP, listening
Port 2	----	Blocked
Port 3	B0.1.B4.3	DP, forwarding

Bridge B5	Configuration BPDU	Port State
Port 1	B0.2.B5.1	DP, forwarding
Port 2	----	RP, forwarding

Bridge B6	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B0.2.B6.2	DP, forwarding

Bridge B7	Configuration BPDU	Port State
Port 1	B0.1.B7.1	DP, forwarding
Port 2	----	RP, forwarding
Port 3	B0.1.B7.3	DP, listening

Messages sent out at the fourth exchange

Bridge B0	Configuration BPDU	Port State
Port 1	B0.0.B0.1	DP, listening
Port 2	B0.0.B0.2	DP, listening

Bridge B1	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B0.2.B1.2	DP, forwarding

Bridge B2	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	B0.1.B2.2	DP, forwarding

Bridge B3	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	----	Blocked

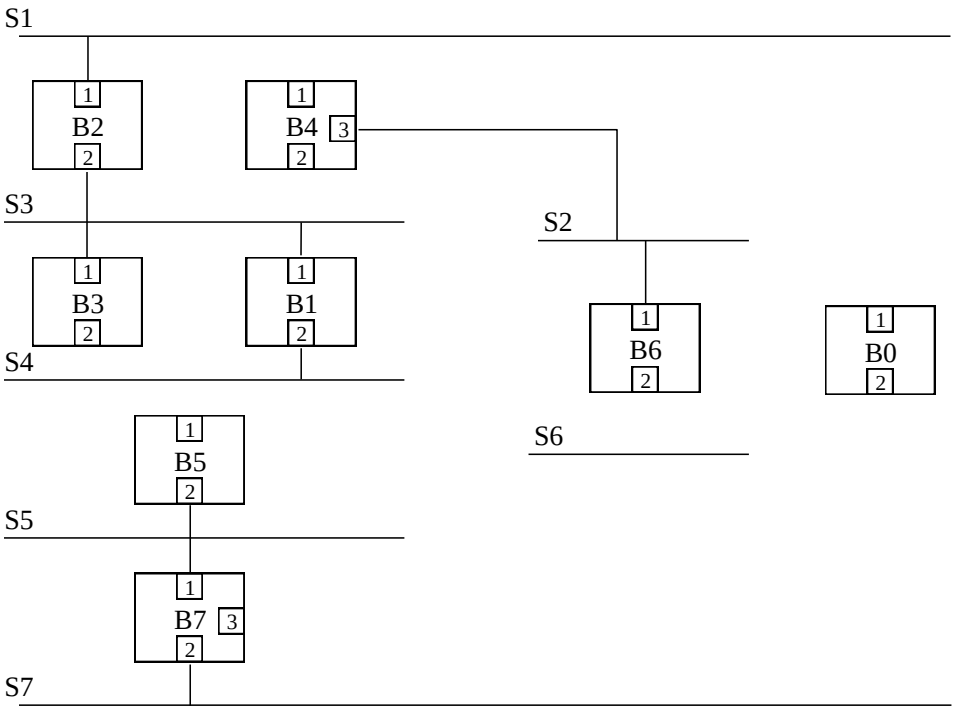
Bridge B4	Configuration BPDU	Port State
Port 1	----	RP, listening
Port 2	----	Blocked
Port 3	B0.1.B4.3	DP, forwarding

Bridge B5	Configuration BPDU	Port State
Port 1	----	Blocked
Port 2	----	RP, forwarding

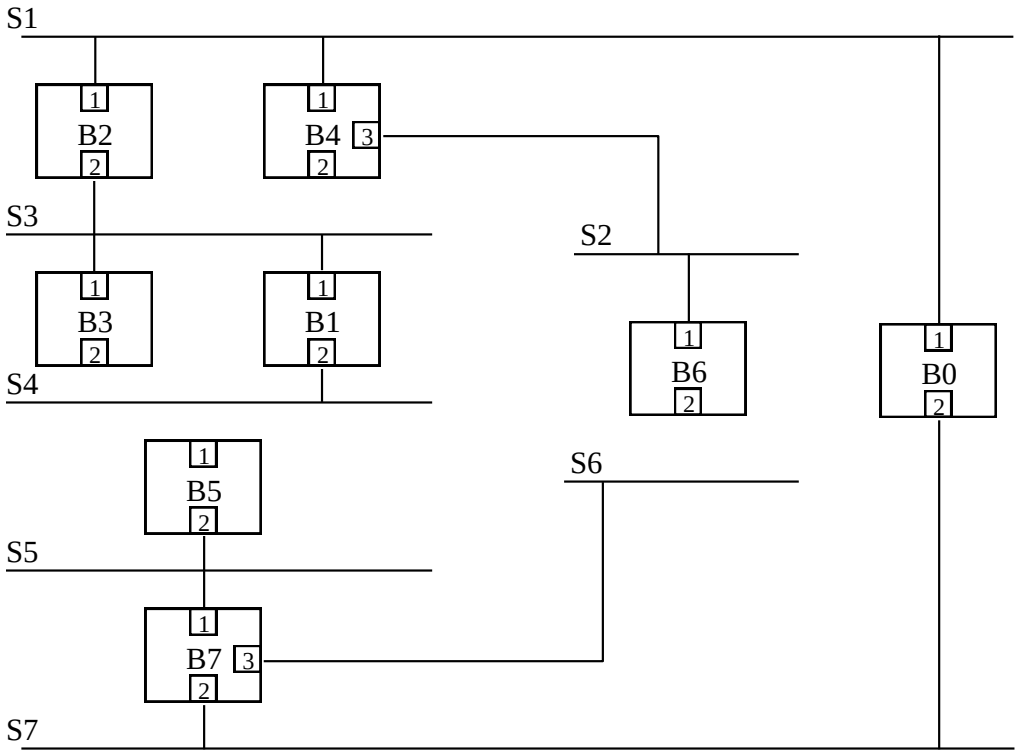
Bridge B6	Configuration BPDU	Port State
Port 1	----	RP, forwarding
Port 2	----	Blocked

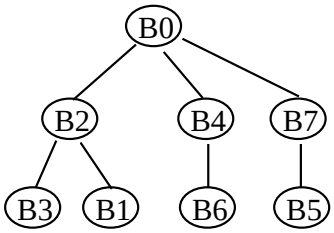
Bridge B7	Configuration BPDU	Port State
Port 1	B0.1.B7.1	DP, forwarding
Port 2	----	RP, forwarding
Port 3	B0.1.B7.3	DP, listening

Steady state has been reached. The topology has been redrawn in the figure below, removing all ports that are either blocked or listening:



From the figure, it is clear that, during this period, the network is disconnected and partitioned into 4 sets: (S1, S3, S4), (S5, S7), (S2) and (S6). After the forward delay elapses, and the listening ports go into the forwarding state, the network is again connected into the following spanning tree:


S1
B2
B4
S3
S2
B3
B1
B6
B0
S4
B5
S6
S5
B7
S7


B0
B2
B4
B7
B3
B1
B6
B5