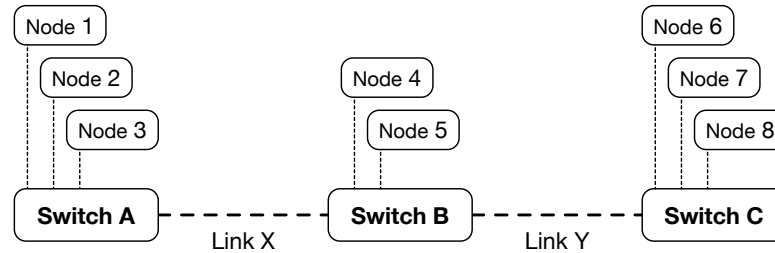


8 Concurrent and Distributed Systems (RNW)

The *Bully Algorithm* allows a set of nodes to elect a unique *leader* in the presence of node failures. For the purposes of this question, assume that: the set of nodes is known in advance by all nodes; each process knows its own identifier; processes fail and restart cleanly; node failure can be reliably detected; and message delivery is reliable unless the destination node has failed. Our network contains eight nodes (1–8), which are connected via three switches (A–C):



- (a) In the absence of node or switch failures, which node will be elected leader using the Bully Algorithm? [1 mark]
- (b) A new Node 9 is added to the network, attached to Switch C. Which node will be elected leader using the Bully Algorithm? [1 mark]
- (c) If there is a network partition between Switches B and C, what node will be elected leader using the Bully Algorithm? [2 marks]
- (d) To address the concern about network partition, the authors of a distributed system introduce a majority rule: for a node to declare itself leader, it must receive OK messages from a majority of nodes (including itself). Which combinations of links can fail while still permitting a successful election, and, for each of those combinations, which node is elected leader? [4 marks]
- (e) One key metric used in evaluating distributed algorithms is the number of messages generated. What is the worst-case cost (using O-notation) in messages with n nodes participating in the Bully Algorithm? Explain why this is the case. [2 marks]
- (f) The Bully Algorithm provides a strong invariant that a node can identify that it is the unique leader in a distributed system. However, that leadership status can be preempted (revoked) without node failure. Explain how this may occur. [4 marks]
- (g) Describe how a distributed application can utilise elected leadership status to safely allocate unique transaction IDs. Explain why this works, considering in particular: (1) the steady state; (2) leader change due to leader crash; and (3) leader change due to leadership revocation. [6 marks]