TUM I 13
Chair of Application and Middleware Systems
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Tutorial

Distributed Systems (IN2259)

EXERCISES ON PEER-TO-PEER SYSTEMS

EXERCISE 1 - Chord

Let C be the Chord ring given in Figure 1.1. The network contains eight peers (blue points), each of which is mapped to a node $N_i \in C$ by a base hash function, e.g., SHA-1, with bit-string length $m = 5$. Key k is assigned to the first peer whose identifier is equal to or follows k within C. For instance, in Figure 1.1, key K_8 is assigned to the peer at node N_{10}. The *successor* function receives as input an integer $i \in \{0, \ldots, 2^m - 1\}$ and returns the closest peer node N_j such that $j \geq i$.

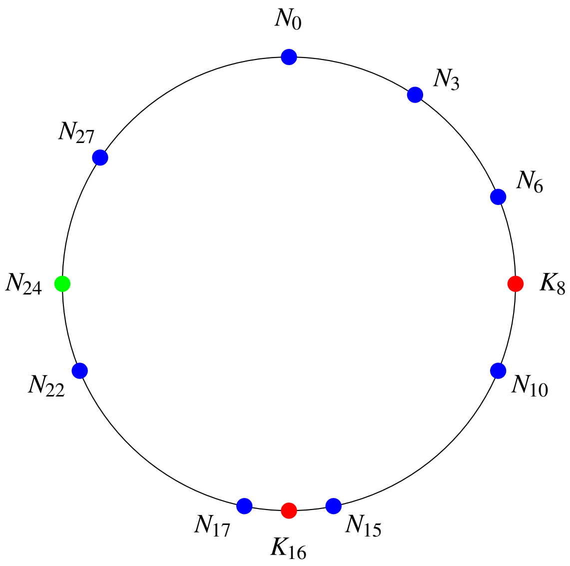

Figure 1.1: Chord ring.

(a) Suppose that every peer node stores only a reference to its successor node, e.g. at N_3, $successor(3) = N_6$. Give an asymptotic upper bound on the number of hops you would need to look for a key k in the worst case. Which operations do you need to perform when a peer joins/leaves the ring? What if we also reference to a predecessor node?

(b) From now on, consider the standard Chord implementation where peer nodes store a finger table. Fill in the finger table of the peer at node N_3 in Figure 1.2. Will N_3 have a reference to all the other peers?

Peer ID	Successor

Figure 1.2: Finger table for node N_3.

(c) By looking at the finger table you just filled in, can you directly determine the peer responsible for an arbitrary key $k \in C$? Show how you would search for K_{16} from N_3.

(d) Suppose a new peer wants to join the network, and it is mapped to node N_{24} (in green). Show all the changes that are necessary to perform such an operation. How much do these changes cost?

(e) Now suppose that the peer at node N_0 leaves C. Write down the updates needed and discuss the cost of this operation.

(f) When peers fail, it is possible that a peer does not know its new successor anymore, and this could lead to an incorrect lookup. How would you approach this problem? Assume that peer failures occur independently with probability p.

Exercise 2 - Content Addressable Network

For simplicity, in this exercise we see a CAN as a d-dimensional unit cube $[0,1]^d$ instead of a d-dimensional torus. However, remember that, in a real CAN, the sides should wrap around.

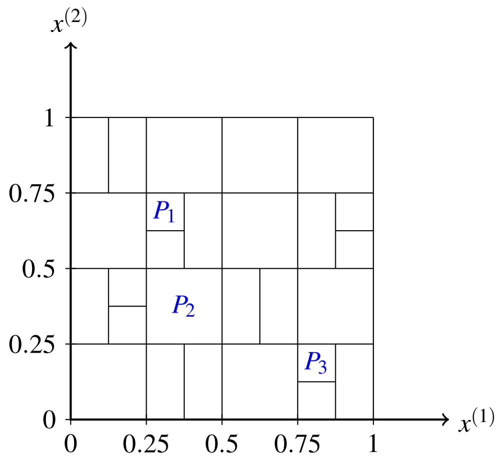

Figure 2.3: 2D CAN

(a) Suppose peer P lying in a d-dimensional CAN responsible for virtual coordinate zone $(x_1, x_2, \ldots, x_d)$ such that $x_i \in [x^{(i)}_{min}, x^{(i)}_{max}]$ for each dimension $i \in \{1, \ldots, d\}$, where min, max refer to the minimum and maximum interval end-point, respectively. For example, in Figure 2.3, peer P_1 would be responsible for all the points (x_1, x_2) whose $x_1 \in [0.25, 0.375]$ and $x_2 \in [0.625, 0.75]$. Peer P needs to search for a key k mapped to the point $\mathbf{y} = (y_1, y_2, \ldots, y_d)$ of the CAN. Specify a greedy algorithm that forwards the request to the nearest neighbour peer to $\mathbf{y}$ in pseudo-code. What is the time complexity of your algorithm assuming a d dimensional space that is partitioned into n equal zones?

(b) Draw the path determined by the search algorithm from Part (a) in the CAN given in Figure 2.3 to route from $P_1([0.25, 0.375], [0.625, 0.75])$ to $\mathbf{x} = (0.4, 0.3)$ and $\mathbf{y} = (0.8, 0.2)$. Who are the peers responsible for these two points?

Exercise 3 - Gnutella

To answer the following questions, assume the topology of a Gnutella network shown in Figure 3.4 where all peers maintain state information about messages they have already sent or received. Supposed that all messages are sent and received in a synchronized, round-based manner.

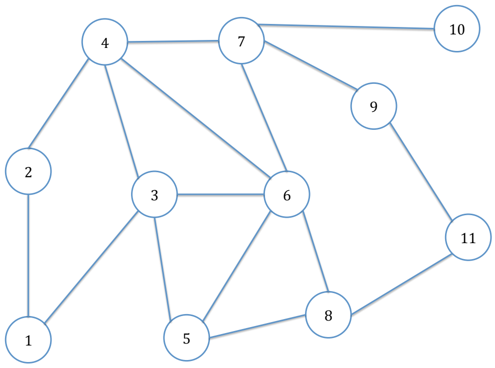

Figure 3.4: Gnutella network.

(a) Peer 1 attempts to search for a key k using a $TTL = 3$. Note down all QUERY messages that are sent throughout the network until the TTL expires. Specify the respective round, the sender, the receiver and the TTL attached to each message.

(b) Assume that peers 2, 5, and 11 have files matching the keyword k. List all QUERYHIT messages that are sent after the search, described above, has been started. Specify round, sender and receiver.

(c) What would happen during the query routing if the peers would not store information about messages that they already received? Describe the problem using an example in the topology given in Figure 3.4.

Exercise 4 - Pastry

Consider the following Pastry network with identifier bit-length $m = 8$ that contains the following nodes:

$$\{\mathbf{0023}, 0113, 0133, 0322, 1002, 1010, \mathbf{1132}, 1223, 2000, 2112, \mathbf{2210}, 2231\}$$

Every node ID $\in \{0,1,2,3\}^4$; hence, $B = 4$, which is the number of rows in the routing table. The leaf set L has size 4.

(a) Specify the routing table and the leaf set of nodes 0023, 1132, 2210 (in bold). The policy for choosing among candidate nodes is a random selection.

(b) Write the Pastry routing algorithm in pseudo-code.

(c) Execute a lookup for key $k = 1000$ from node 2210.