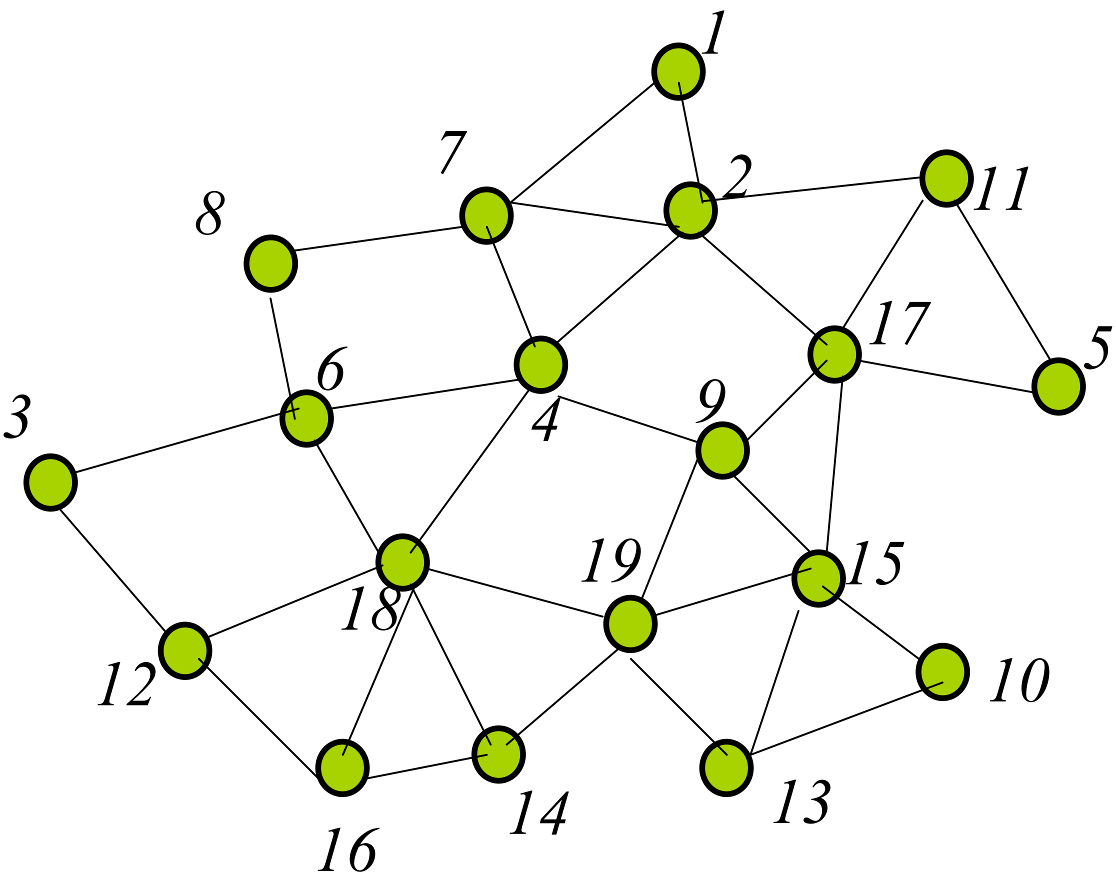
Wireless Ad Hoc Networking: Quiz 1, October 17, 2011

Closed book exam, 120 minutes

Name: ___________________________ Student number: _________________________________

1. (15 marks) Apply the generalized covering rule to determine which nodes do not belong to the connected dominating set. For each such node, list the neighbors that cover it. Node A is covered by neighboring nodes B, C, … if B, C, … are connected (that is, create connected subgraph), any neighbor of A is neighbor of (at least) one of B, C,.. and key(A) < min (key(B), key(C),…). Use key=ID, ordered numericaly (1<2<3<…). Node A is also considered covered is it does not have two unconnected neighbors.



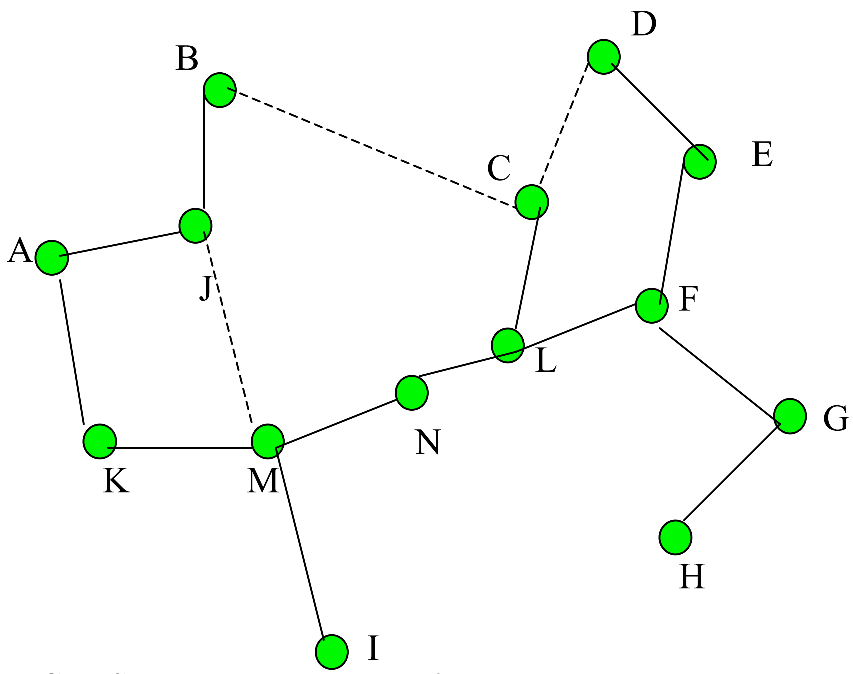
No two disconnected neighbors: 1, 5, 10

11 covered by 17, 13 covered by 15, 14 covered by 18 and 19, 16 covered by 18

2 covered by 4,7,9,11,17

DS nodes: 3,4,6,7,8,9,12,15,17,18,19.

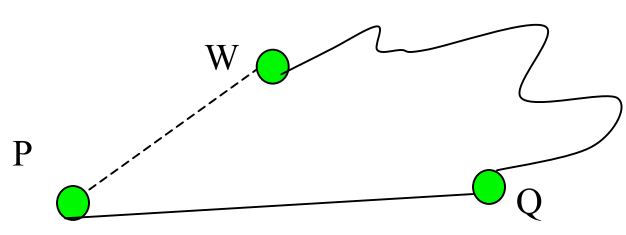
2. (5+5+10 marks) a) An edge UV belongs to Relative Neighborhood Graph (RNG) of a set S if and only if |UV| is not the longest edge in any triangle UVW (that is, either |UV|≤|UW| or |UV|≤|VW|). Draw RNG for the network below. Simply draw/list edges that you believe are in the RNG.



All edges in RNG, MST has all edges except 3 dashed edges

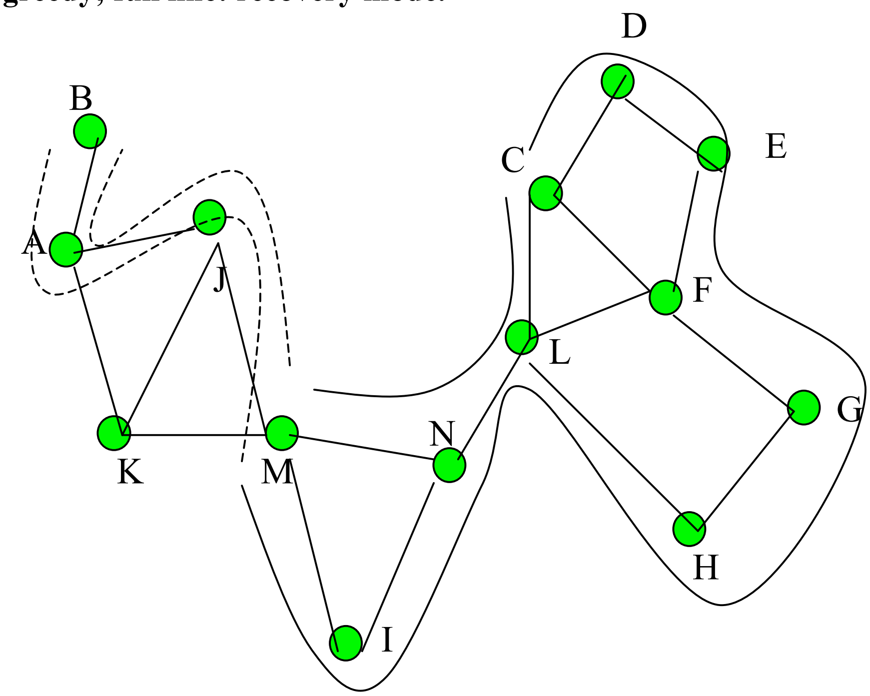
b) The minimal spanning tree (MST) contains selected edges so that the graph is connected and the total sum of selected edges is minimal. Show edges of MST in above example.
c) Prove that MST is a subset of RNG, and therefore RNG is connected.

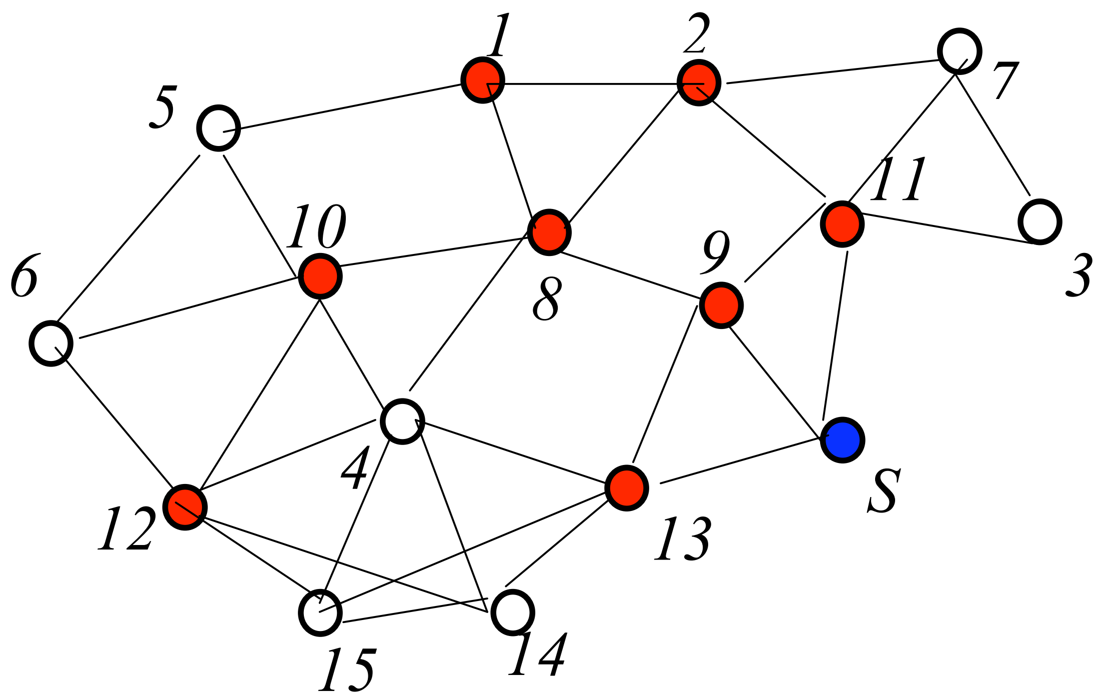
The proof is by contradiction. Suppose that MST is not a subset of RNG. Then there exist an edge PQ which is in MST but not in RNG. Since PQ is not in RNG, there exist a point W so that PQ is longest edge in triangle PQW, so |PW|<PQ| and |QW|<|PQ|. In MST, there exist a path from W to P or Q. MST is a tree, and PQ is in MST, so there are no separate paths from W to Q and W to P, so that none of them contains PQ, since these two path and PQ would then create a cycle, which is not a tree. Suppose that W is connected in MST to Q as closer node (and therefore to P via node Q).
Consider a new tree obtained by removing PQ and adding PW to the current MST. New graph is indeed a tree, as the rest of graph is unaffected, and W, P and Q remain connected without creating a cycle. This new tree would have shorter overall sum of edge lengths because |PW|<|PQ|, which contradicts the definition of MST.



3. (10 marks) Show two recovery paths (by right-hand and left-hand rules) when recovery starts from node C and message is destined for node B. Extend both and show greedy-face-greedy routing steps.

dashed: greedy; full line: recovery mode.



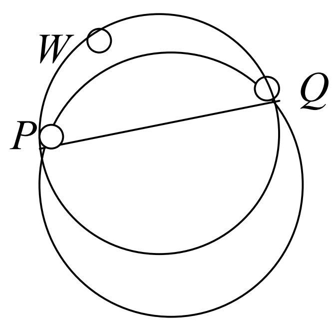


4. (15 marks) Follow **neighbor elimination and dominating set** based broadcasting on above figure, with S as the source node, and nodes 12, 10, 1, 8, 13, 2, 9 and 11 being in the dominating set. The key for timeout comparisons is *(timeout, ID);* that is, if timeouts are same, node with lower ID number will transmit first. For timeout, use formula *timeout=1/(number of uncovered neighbors)*. List nodes that will retransmit in the process, in the order of retransmissions. After each transmission, list which nodes have timeouts and how long are they.

S transmits: 9: 1/1, 13: 1/3, 11: 1/3
11 transmits: 9: 1/1-1/3, 13: 0. 2: ½
13 transmits: 9: 2/3, 2: ½
2 transmits: 9: 2/3-1/2=1/6, 1: 1/1. 8:1/3
9 transmits: 8: ½=1/6=1/3, 1: 1-1/6=5/6
8 transmits: 10: 1/3, 1: 5/6-1/3=1/2
10 transmits: 12: 1/2, 1: ½-1/3=1/6
1 transmits: 12: 1/2-1/6=1/3
12 transmits

5. (6+6 marks) Gabriel graph GG(S) contains an edge (U,V) if ad only if the disk with diameter (U,V) contains no other point from the same network.
Sweep circle based recovery mode for georouting is based on rolling a ball of diameter r (r is the transmission radius) from the point where recovery mode starts until a node closer to destination is reached. It is the same algorithm as explained in the class except that rolling ball replaces Gabriel graph as planar graph selected for recovery. Figure bellow shows how a rolling ball traverses the whole graph and returns to the original position. While rolling, all nodes in the graph remain outside the boll, and ball rotates around the next point hit during traversal.
Show that some edges during roling ball traversal may not belong to the Gabriel graph. Use this figure, and show which traversed edges do not belong to Gabriel graph, and briefly argue why/how this can happen (I suggest to draw a separate figure bellow to show this clearly).

Three dges that are not in Gabriel graph are indicated in the Figure. This can happen because radius r/2 of ralling ball is normally larger that the edge length PQ. Assume PQ is fixed and r increases. Then at some point W (which makes PQ not to be in gabriel graph) will also be ouside rolling ball. This means that rolling ball will trverse PQ and 'miss' point w, and PQ is then not in Gabriel graph.



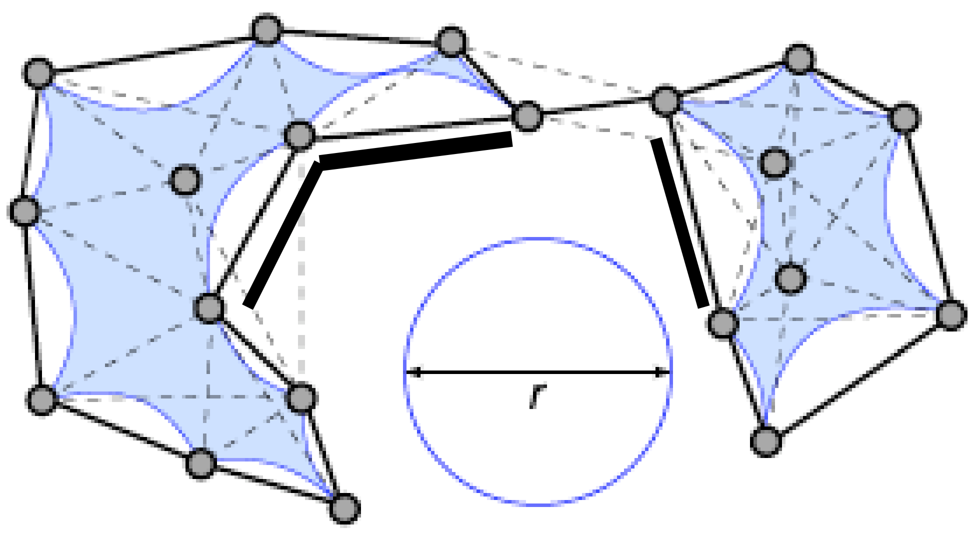
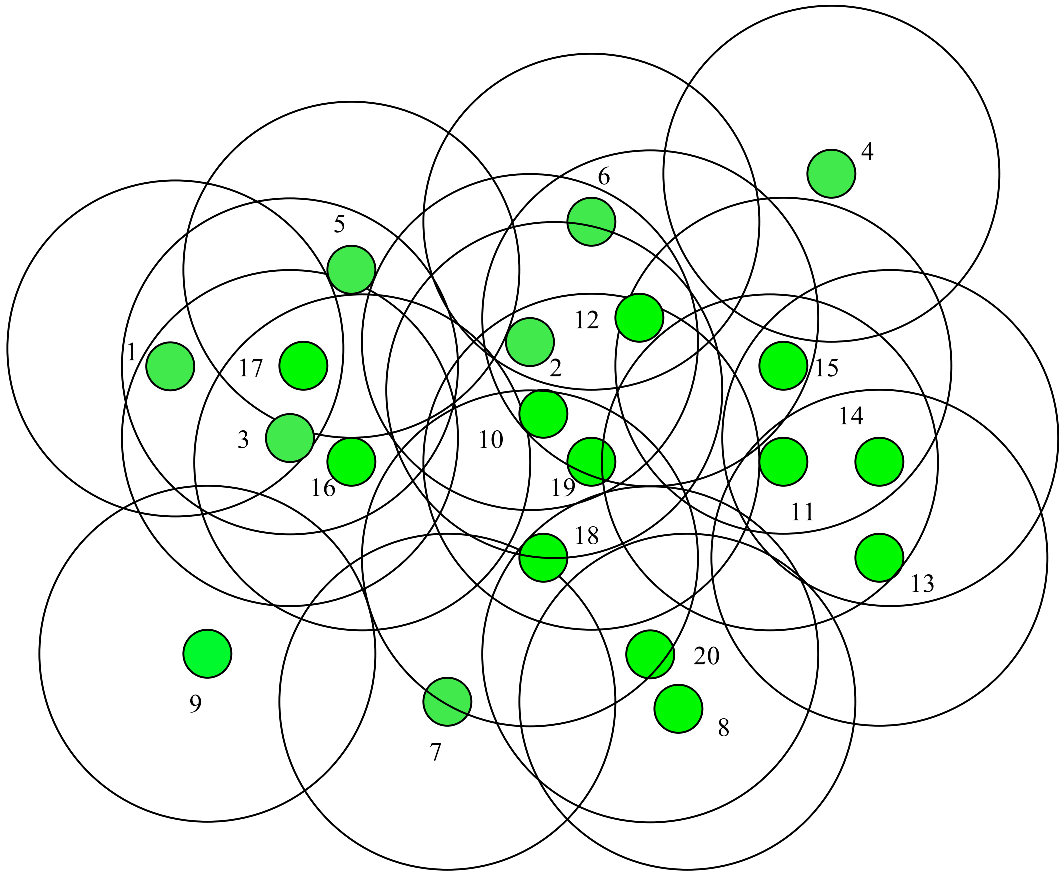


Figure 2: Unit disk graph with radius r, α-hull (shaded area) and α-shape (solid edges) with $\alpha = -\frac{2}{r}$ of a point set.



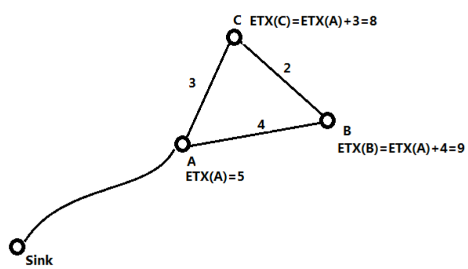
6. (14 marks) Localized sensor area coverage algorithm works as follows. Each sensor selects a random timeout. Suppose that timeouts expire in the order as indicated by numbers: 1,2,3,…,20. Assume also that communication range is much larger than sensing range (so all decisions are received by sensing neighbors). Each transmission contains the position of sensor. At the end of its timeout, if sensing area is not fully covered, sensor decides to be active, and informs neighbors. Otherwise it decides to be passive, but still sends a message to neighbors informing about the decision. This is PN variant. What sensors will at the end be active? Suppose also that at the end there is another round of timeout (use same order) for sensors which decided to be active. Each such sensor will decide to be passive if other active sensors cover its area (some of these active sensors decided their status after given sensor). This is a retreat option (PNR variant). Retreat decisions are communicated to neighbors. Which sensors will retreat in this example?

active: 1,2,3,4,5,6,7,8,9,10,11,13,14,16,18
passive: 12, 15, 17, 19, 20
retreat: 2,3.

7. (14 marks) In proactive routing, routing tables contain the first hop / neighbor toward each destination. Bellman-Ford algorithm is used to periodically update tables. Each node exchanges its routing tables with all its neighbors, and

- the best neighbor N for route from S to D is one that minimizes the cost of link S to N, plus cost of routing from N to D (from routing table in N).

In this figure, the cost of routing from nodes A, B and C to the sink (destination) is indicated as ETX, and initial values are in the figure. Thus ETX is value from routing tables.
Suppose that the quality of link from A to the sink suddenly worsens and becomes equal to 20. Show the ETX values (in corresponding routing tables) for nodes A, B, C in coming iterations, one by one, until it becomes stable.



ETX from A, B, C to sink; note link from A to sink changed to 20, but A believes that C and B provide better paths to sink than direct link until things stabilize.

A	**B**	**C**
5	**9**	**8**
ETX(C)+3=11	**9**	**8**
note: here A chose between 20 (direct), 8+3 (via C) and 9+4 (via B)		
11	**ETX(C)+2=10**	**ETX(B)+2=11**
note: B chose between 11+4 (via A), and 8+2 (via C)		
10+4=11+3=14	**ETX(C)+2=13**	**ETX(B)+2=12**
ETX(C)+3=15	**ETX(C)+2=14**	**ETX(B)+2=15**
14+4=15+3=18	**ETX(C)+2=17**	**ETX(B)+2=16**
ETX(C)+3=19	**ETX(C)+2=18**	**ETX(B)+2=19**
20	**ETX(C)+2=21**	**ETX(B)+2=20**
note: direct link now for A is best		
20	**ETX(C)+2=22**	**ETX(A)+3=ETX(B)+2=23**
20	**ETX(A)+4=24**	**ETX(A)+3=23**
20	**24**	**23**