Politecnico di Milano
Facoltà di Ingegneria dell'Informazione

WI – Exercises

Wireless Internet

Prof. Antonio Capone

Multiple Access

Exercise 1

- a) Derive the model for the waiting time in polling systems with exhaustive service.
- b) In the case of:
- Transmission time = 3 ms
- Token passing time = 0.8 ms
- Traffic ρ = 0.7
- Number of stations = 10
- Calculate: 1) average waiting time; 2) average cycle duration; 3) average number of packets in the local queue 4) average number of packets transmitted per cycle.

Solution 1

- Part a) see lecture slides
- Part b) :

$$E[W] = \frac{\rho}{2(1-\rho)}T + \frac{M-\rho}{2(1-\rho)}h = 15.9ms$$

$$E[C] = \frac{Mh}{1-\rho} = 26.67ms$$

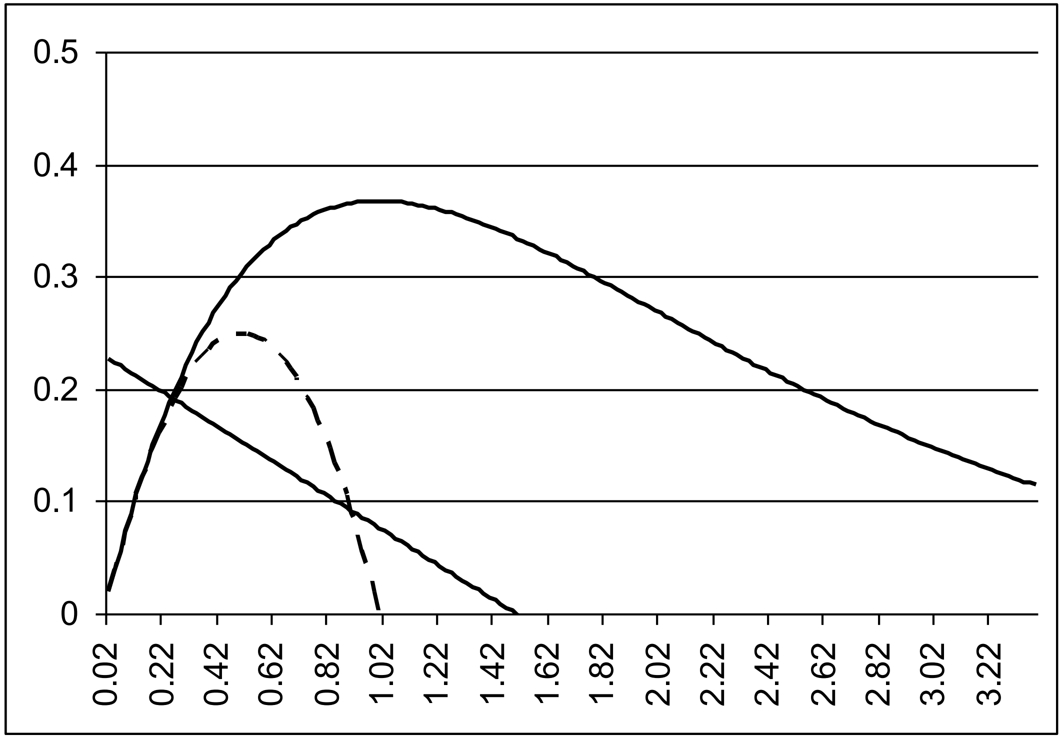
$$E[N_l] = \frac{\lambda E[W]}{M} = 0.37$$

$$Q_c = \frac{E[C] - Mh}{T} = 6.22$$

Exercise 2

- a) Derive the single buffer model for Aloha protocol and comment its possible operational states.
- b) Characterize the behavior of the protocol (number and type of equilibrium states) in the case:
  - M = 50
  - a = 0,004
  - b = 0,03
- c) Estimate the throughput considering numerical values of previous point (suggestion: approximate the throughput curve with its power series of second order).

Solution 2



$$s(g) = ge^{-g} \cong g - g^2$$

$$a(g) = M\alpha + (g - M\alpha)\frac{\alpha}{\beta - \alpha}$$

$$s(g) = a(g)$$

$$s \cong 0.19$$

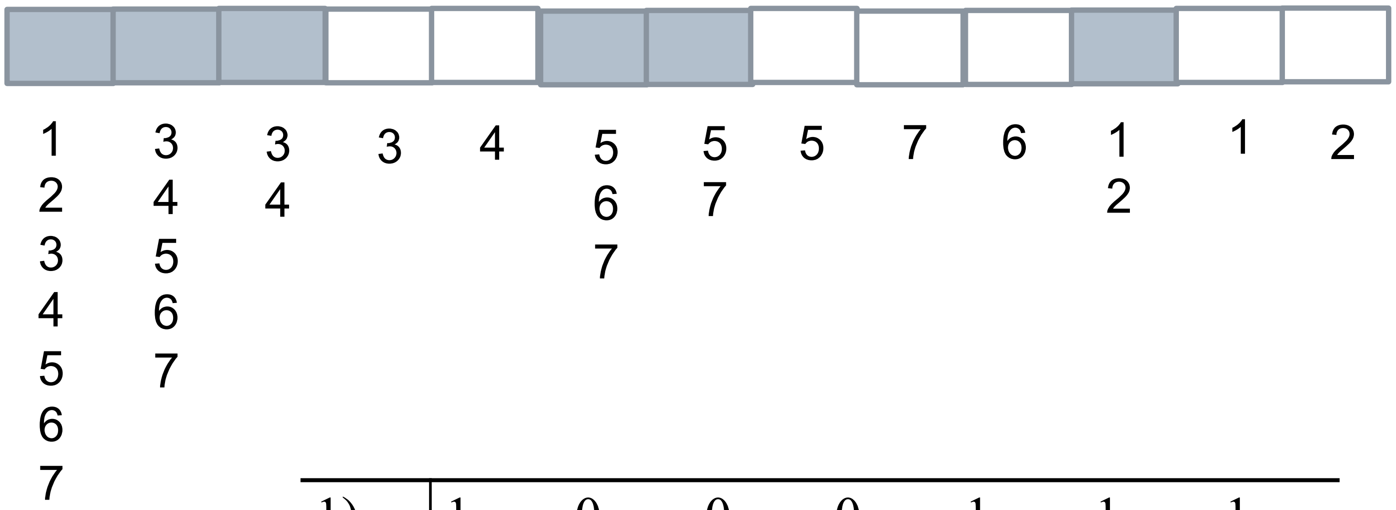
$$g \cong 0.25$$

Exercise 3

- a) Illustrate the collision resolution algorithm based on trees (consider the binary tree).
- b) Describe the evolution of the collision resolution algorithm, slot by slot, in the case of 7 stations that collide together in slot 0, assuming that no other station transmit during collision resolution and that random number generators of different stations provides the following numbers at each function call:

1)	1	0	0	0	1	1	1
2)	1	1	1	1	1	0	0
3)	0	0	0	0	1	1	0
4)	0	0	1	1	0	1	0
5)	0	1	0	0	0	1	1
6)	0	1	1	1	0	0	1
7)	0	1	0	1	0	1	0

Solution 3

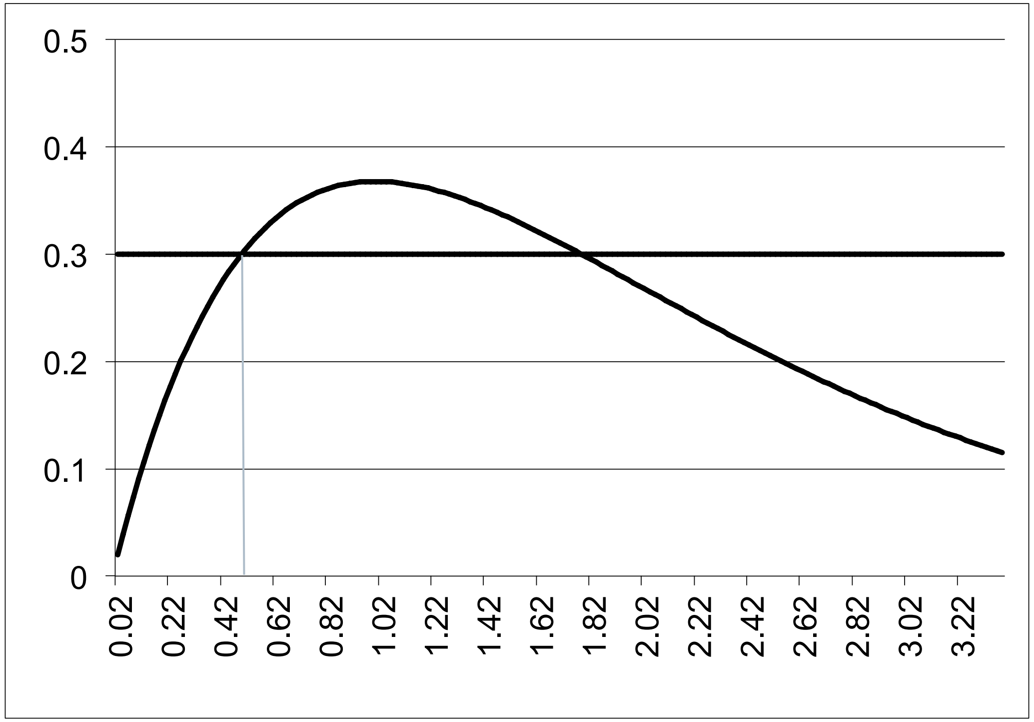


1)	1	0	0	0	1	1	1
2)	1	1	1	1	1	0	0
3)	0	0	0	0	1	1	0
4)	0	0	1	1	0	1	0
5)	0	1	0	0	0	1	1
6)	0	1	1	1	0	0	1
7)	0	1	0	1	0	1	0

Exercise 4

- a) Derive the single buffer model for Aloha protocol and comment its possible operational states.
- b) Characterize the behavior of the protocol (number and type of equilibrium states) in the case:
  - $M = \infty$
  - $M \alpha = 0,3$

Solution 4



$$s(g) = ge^{-g}$$

$$a(g) = M\alpha = 0{,}3$$

$$s(g) = a(g)$$

$$s = 0{,}3$$

$$g \cong 0.49$$

Exercise 5

- a) Derive the model for the waiting time in polling systems with round robin service.
- b) In the case of:
- Transmission time = 10 ms
- Token passing time = 1 ms
- Traffic ρ = 0.8
- Number of stations = 10
- Calculate: 1) average waiting time; 2) average cycle duration; 3) average number of packets in the local queue 4) average number of packets transmitted per cycle.

Solution 5

- Part b)

$$E[W] = \frac{\rho}{2(1-\rho\frac{h+T}{T})}T + \frac{M+\rho}{2(1-\rho\frac{h+T}{T})}h = 78.34\ ms$$

$$E[C] = \frac{Mh}{1-\rho} = 50\ ms$$

$$E[N_l] = \frac{\lambda E[W]}{M} = 0.63$$

$$Q_c = \frac{E[C]-Mh}{T} = \lambda E[C] = 4$$

Exercise 6

- In a WiFi network, statistical indicator for an access points provide the following information related to a 5 minutes period:

MCS	Usage	Protocol overhead
1 Mbps	10%	15%
2 Mbps	10%	20%
5.5 Mbps	40%	30%
11 Mbps	40%	40%

Total data traffic	83 MB

- Calculate the average time necessary for a user using the 11Mbps MCS for transferring a 33 MB file using the processor sharing model.

Solution 6

- We ca use the processor sharing model that provides the delay as:

$$d_i(x) = \frac{x / C_i}{1 - \rho}$$

- We then need to calculate the channel traffic ρ
- Considering protocol overheads, nominal rates C_i are the following

MCS	Protocol overhead	C_i
1 Mbps	15%	0,85
2 Mbps	20%	1.6
5.5 Mbps	30%	3.85
11 Mbps	40%	6.6

- and then the averare rate is C = 4.425 Mbps

Solution 6

- The traffic on the channel is then given by

$$\rho = \frac{\lambda m_X}{C}$$

- The data traffic of 83 MB in 5 min are equivalent to a rate of

$$\lambda m_X = \frac{83 \times 8}{5 \times 60} = 2.213 \text{ Mbps}$$

- an then

$$\rho = \frac{2.213}{4.425} \cong 0.5$$

Solution 6

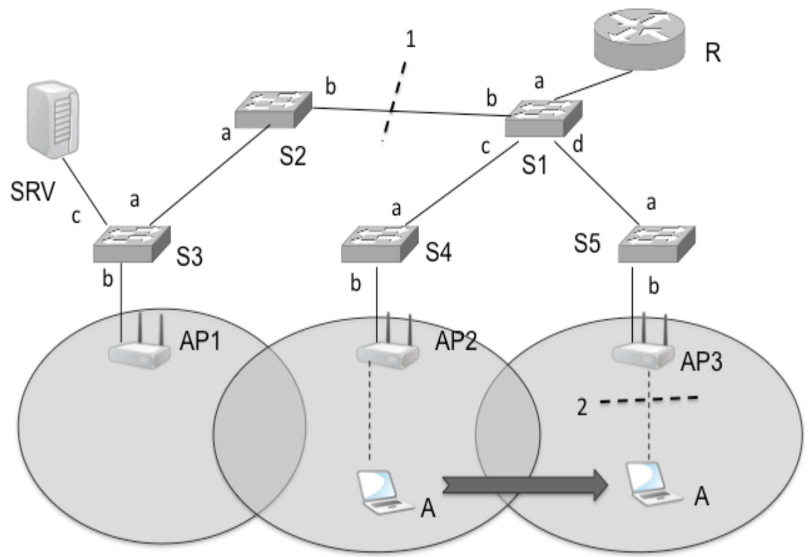
- Finally we have:

$$d_i(x) = \frac{x/C_i}{1-\rho} = \frac{33\times 8}{6.6}\times\frac{1}{0.5} = 40 \text{ s}$$

Mobility

Exercise 1

- Consider the scenario shown in the picture with a IEEE 802.11 wireless LAN and its distribution system based on Ethernet technology. R is a router, Sx are layer 2 switches, APx are 802.11 access points, A and SRV are terminals.



- Denote with MAC_x, and IP_x, with x=S,AP1,AP2,AP3, R, SRV, S1, …, S5, the MAC and IP addressed of network nodes.

Exercise 1

- a) Assuming terminal A in original position, describe step-by-step how an IP packet, which is currently in router R and with destination IP_A and source IP_B (where B is an host external to the LAN), can be delivered to destination. The terminal A then generate a reply IP packet with destination IP_B, describe how the packet reaches the router R. <u>Assume ARP table of router and terminals, as well as bridging tables of all switches are initially empty</u>. Indicate details of packets (including source and destination at IP and MAC layers) as they could be captured in points 1 and 2. Indicate the content of bridging tables of S5 and S2 after packet exchange.

Exercise 1

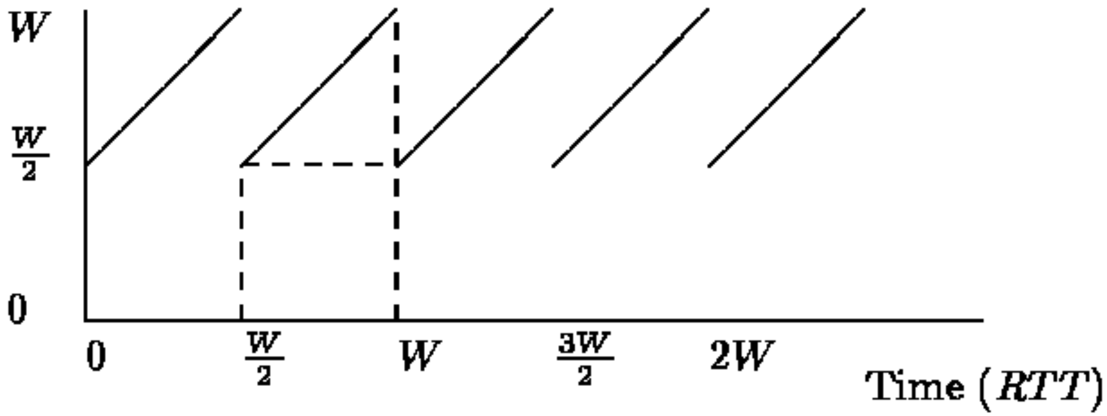
- b) Assume terminal A moves as indicated in the figure while it is exchanging IP packets with the server SRV. Please indicate how mobility is managed and packets delivered in both directions. Indicate the content of bridging tables of S1 and S5 before and after A moves from AP1 to AP2.

TCP

Exercise 1

- a) Derive the model for the computation of the average throughput of long-lived TCP connections (clearly specifies assumptions) with random losses.
- b) Calculate the average time for transferring a 10MB file assuming:
  - Segment losses are all recovered with fast retransmit
  - Losses are only due to congestion
  - The capacity of the bottleneck link is 10 Mb/s
  - RTT is 200 ms
  - MSS is 1000B

Solution 1

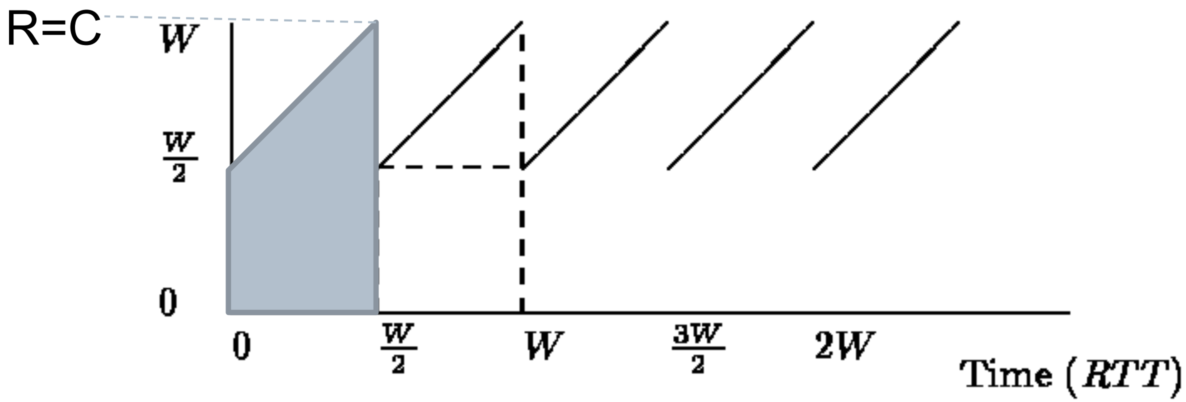


- Part b)
- We don’t have a loss probability here like in the model
- Due to congestion we loose segments when rate is equal to the capacity:

$$C = \frac{W \cdot MSS}{RTT}$$

Solution 1

- Average rate can be obtained replacing W from previous expression in the model formula
- Alternatively we can simply observe that:



$$R = \frac{3}{4} C = 7{,}5 \text{ Mb/s}$$

Solution 1

- And therefore

$$t = \frac{80\ Mb}{7{,}5\ Mb/s} = 10{,}67\ s$$

Exercise 2

- a) Derive the model for the computation of the average transfer delay of short-lived TCP connections .
- b) estimate the average time for transferring a 30KB file assuming:
  - Loss probability 2×10^{-2}
  - RTT 200 ms
  - Initial timeout 2s
  - MSS 1000B

Solution 2

- Part b)
- We have:

30 segments

$$l = 30\frac{0{,}02}{1\text{-}0{,}02} = 0{,}6 \text{ loss segments}$$

$$\mathrm{Q(p)} = \min\left(1; \frac{3}{\sqrt{\dfrac{3}{8\mathrm{pb}}}}\right) = 0{,}7$$

$$u = l \cdot Q(p) \cdot (1-p) = 0{,}6 \cdot 0{,}7 \cdot 0{,}98 = 0{,}41$$

Solution 2

- continues:

$$t_{RTO} = u \cdot t_u = 0,41 \cdot 2 = 0,82 \text{ s} \quad \text{with } t_u \cong t_0$$

$$e = \frac{30 + 0,6}{u+1} = 21,7$$

$$t_{xfer} = \log_2\left(\frac{e}{w_0} + 1\right)(u+1)RTT = 1,27 \text{ s}$$

$$\mathrm{t}_{\mathrm{tot}} = 1,27 + 0,82 + 0,2 = 2,29 \text{ s}$$

Exercise 3

- a) Derive the model for the computation of the average throughput of long-lived TCP connections (clearly specifies assumptions) with random losses.
- b) Estimate the transfer time for a D=5MB file assuming:
  - All losses are recovered with fast retransmit
  - Loss probability 8 x 10^{-3}
  - RTT 300 ms
  - MSS 1000B
  - Channel capacity 2 Mb/s
  - Delayed ack policy
- c) What does change if there are two TCP connections on the channel? What in the case of 10 connections?

Solution 3

- Part b):

$$R = \frac{MSS}{RTT}\frac{C}{\sqrt{p}} = 258Kb/s$$

$$C = \sqrt{3/4}$$

$$t_{xfer} = \frac{D}{R} \cong 155{,}04\ s$$

- Part c) With 2 connection the throughput estimation is still correct since 2R << Capacity; with 10 connections the estimate is no longer valid since there may be congestion on the channel

Exercise 4

- a) Derive the model for the computation of the average throughput of short-lived TCP connections .
- Calculate the maximum file size for which the connection can still be considered short-lived assuming:
  - RTT 250 ms
  - MSS 512B
  - Channel capacity is 4194,304 Kb/s
- Estimate the average time for transferring a 100 KB file assuming:
  - Loss probability 5 x 10^{-2}
  - Initial timeout 300 ms

Solution 4

- b) The connection remains in slow start (short lived) until the rate is below available capacity:

$$\frac{cwd}{RTT} = B$$

- Where

$$B = \frac{C}{MSS}$$

Solution 4

- We have:

$$cwd = B \cdot RTT$$

$$2^{i-1} = B \cdot RTT$$

$$i = \log_2\left(B \cdot RTT\right) + 1 = 9$$

- Total amount of data sent is:

$$data = \left(2^i - 1\right) MSS = 261{,}632 KB$$

Solution 4

- c)

data = 200 segments

$$l = \frac{data \cdot p}{1-p} = 10.53 \text{ loss segments}$$

$$Q(p) = \min\left(1, \frac{3}{\sqrt{\frac{8}{3bp}}}\right) = 0.41$$

prob. che una perdita porti a RTO

Solution 4

$$l = lQ(p) = 4.32$$ Num of RTO

$$u = lQ(p)(1-p) = 4.11$$ Num RTO groups

$$t_u = \frac{1 + p + 2p^2 + 4p^3 + 8p^4 + 16p^5 + 32p^6}{1-p} T_0 = 333.3\,\text{ms}$$

$$t_{RTO} = uT_u = 1369.3\,\text{ms}$$

Solution 4

$$\nu = u + 1 = 5.11$$ num. slow start phases

$$e = \frac{data + l}{\nu} = 41.2$$ Segments per phase

$$t_{tot} = t_{RTO} + t_{xfer} + RTT = 2960 \text{ ms}$$

Example questions

Question

- Describe into detail the multiple access scheme used in the DCF function of IEEE 802.11 presenting in particular:
  - a) What the *RTSThreshold* is and why it is introduced;
  - b) How broadcast frames are transmitted;
  - c) How the hidden terminal problem is avoided;
  - d) What the exposed terminal problem is;
  - e) given an direct graph *G(N,V)* representing network topology and a transmission *(i,j),* indicate which transmissions are blocked by the virtual carrier sense and which could be possible without collisions;
  - f) why physical carrier sense is used in addition to the virtual carrier sense.

Question

- Describe into detail the multiple access scheme used in the HCF function of IEEE 802.11e presenting in particular:
  - a) the scheme used for the EDCA access;
  - b) the scheme used for the HCCA access;
  - c) how the HCF solve the issues that prevent PCF to provide quality of service guarantees;
  - d) why EDCA traffic classes are considered statistical priorities and how it could be possible to obtain deterministic priorities;
  - e) how packets in different traffic queues of the same device are selected for transmission;
  - f) what the goal of the Direct Link Protocol (DLP) is.

Question

- Describe into detail the piconet formation mechanism of Bluetooth and the multiple access mechanism used after network formations. Describe also:
  - a) why the page procedure requires a high energy consumption for the devise in page and a very low consumption of the device in scan;
  - b) How long the procedure can last in the worst case;
  - c) Why the reply to a *inquiry* message is FHS packet;
  - d) If the *inquiry* procedure is followed immediately by a page procedure, how long can page last;
  - e) How is the frequency hopping managed in case of multi-slot packets transmission.

Question

- Describe the concept of scatternet defined in Bluetooh. Why a device can be master in only one piconet? Describe possible low energy states for a Bluetooth device and their possible use in scatternets.

Question

- Describe the ZigBee technology and protocols, considering in particular:
  - a) possible network topologies;
  - b) the difference between FFD and RFD also in relation with network topologies;
  - c) the beacon-enabled medium access;
  - d) the non beacon enabled medium access;
  - e) routing based on cluster tree;
  - f) the reactive routing and its relation wit cluster tree routing.

Question

- Considering wireless IEEE 802.16 technology, describe:
  - a) Possible network architectures;
  - b) The multiple access mechanism used by MAC layer;
  - c) The signaling mechanism for bandwidth requests;
  - d) The use of uplink map,
  - e) The use of down link map,
  - f) The scheduling classes;
  - g) The difference between OFDM and OFDMA versions.

Question

- Describe the MAC layer of WiMax for OFDM version with point-to-multipoint topologies.
- Present the resource reservation mechanism for the centralized and distributed mesh mode.

Question

- a) Describe into detail the stabilization mechanism of Aloha base on the channel access probability (β) considering the algorithm executed by each station for the estimation of the access probability.
- b) Present alternative stabilization methods.

Question

- Present possible approaches to centralized fair scheduling in wireless access network considering in particular:
  - a) differences with traditional schemes of fixed point-to-point links;
  - b) fair queuing scheme based on channel state (good-bad channel model);
  - c) fair queuing schemes in case of adaptive rate.

Question

- Describe main characteristics of ad hoc routing protocols of reactive type DSR and AODV and their differences in route management and route caching.

Question

- Present the main differences between ad hoc routing protocols of type proactive, reactive, and geographical.

Question

- Describe Mobile IP mechanism, its application scenarios, and possible alternative approaches to mobility management in IP networks.

Question

- a) Present the main characteristics of geographical routing protocols for ad hoc networks and compare them with those of proactive and reactive protocols.
- b) Describe the based greedy forwarding of GPSR and the procedure for escaping local minima.

Question

- Describe in detail the analytical model for the computation of the throughput in 802.11 systems, considering the case of:
  - a) broadcast transmission;
  - b) point-to-point transmission with RTS-CTS-DATA-ACK. Assume the channel is fully broadcast (no hidden terminals).

Question

- a) Describe the model for the computation of the queuing time in polling systems with round-robin service policy (present the formula derivation step by step).
- b) Show how it is possible to modify the model for taking into account the specific characteristics of Bluetooth in the case (1) of 1-slot packets only and in the case (2) of packets of 1, 3 and 5-slots.