

Name ..... ID ..... Section ..... Seat No .....

# Sirindhorn International Institute of Technology Thammasat University

Midterm Exam Answers: Semester 2, 2011

**Course Title:** ITS413 Internet Technologies and Applications

**Instructor:** Steven Gordon

**Date/Time:** Friday 24 February 2012; 13:30–16:30

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**Instructions:**

- This examination paper has 18 pages (including this page).
- Conditions of Examination: Closed book; No dictionary; Non-programmable calculator is allowed
- Students are not allowed to be out of the exam room during examination. Going to the restroom may result in score deduction.
- Students are not allowed to have communication devices (e.g. mobile phone) in their possession.
- Write your name, student ID, section, and seat number clearly on the front page of the exam, and on any separate sheets (if they exist).

Internet Technologies and Applications, Semester 2, 2011

Prepared by Steven Gordon on 28 February 2012

ITS413Y11S2E01, Steve/Courses/2011/S2/ITS413/Assessment/Midterm-Exam.tex, r2192

## Question 1 [24 marks]

For each question fill in the blank space with an appropriate word, acronym, name or phrase. For each blank space you must give only one answer. However, there may be more than one correct answer. Each answer is worth 1.5 marks.

- (a) *OpenWRT* is firmware that can be installed on certain wireless LAN routers to replace manufacturer-supplied firmware.
- (b) In NEMO a mobile *router* manages the mobility of the hosts in a IP subnet.
- (c) A mobile telephone network is an example of an infrastructure-based network, whereas *MANETs* are considered infrastructure-less networks.
- (d) In DCF, when frames are retransmitted the *Contention Window* is approximately doubled to reduce the chance of collisions.
- (e) *IEEE* is the standards organisation that has developed protocols for wireless LAN and Ethernet.
- (f) *PDH* provides point-to-point connectivity in core networks over mainly copper cables. *SDH* was developed to improve it, by using optical fibre.
- (g) A group of networks in the Internet that are controlled by a single administrative authority is called *an autonomous system*.
- (h) *IEEE 802.15 (ZigBee) (or Bluetooth)* is designed to offer low data rate wireless networking while consuming very little power.
- (i) *ATM (or X.25 or FrameRelay)* is an example of a virtual circuit packet switching technology.
- (j) Using an IXP for multiple ISPs to connect via a shared network is a case of *public peering*.
- (k) Dial-up access was a primary form of Internet access over the PSTN in the past; now *DSL* is a popular technique for Internet access over the PSTN.
- (l) *Coaxial cable* is considered a wired access network technology that doesn't use existing telephone networks, but doesn't offer speeds as fast as FTTH.
- (m) All *Tier 1* ISPs in the Internet have peering agreements with each other.
- (n) With a *transit* agreement ISP A pays ISP B to carry A's traffic across B's networks.
- (o) *LTE* is an advancement of 3G/UMTS mobile technologies that offers higher speeds, but requires significant hardware upgrades to the network base stations.
- (p) *BGP* is used to exchange routing information between autonomous systems.

## Question 2 [13 marks]

You want to run a set of experiments to measure the performance of the SIIT WiMax link between Bangkadi and Rangsit. At each campus you have access to a computer that connects via a single Gigabit Ethernet link to the WiMax router (which is similar to the wireless router used in your assignment, but uses IEEE 802.16 WiMax instead of IEEE 802.11 Wireless LAN). You have installed `iperf` on each of the computers. The computer at Bangkadi, named *A* will be the `iperf` client and has IP address 1.1.1.1, the computer at Rangsit (*B*) has IP address 3.3.3.3 and the wireless link is on subnet 2.2.2.0 (all address use /24 subnet mask).

- (a) Draw the network topology for your experiment. [1 mark]

**Answer.** *A—GbE—Wimax1—Ieee802.16—WiMax2—GbE—B*

- (b) How many IP subnets are in the experiment? [1 mark]

**Answer.** *3. The WiMax routers are acting as IP routers. This is known based on the IP addresses given. First subnet from computer A in Bangkadi to WiMAX router is 1.1.1.0. Second subnet between the WiMax routers is 2.2.2.0. And third subnet from WiMAX router to computer B at Rangsit is 3.3.3.0.*

- (c) Consider the data flow between devices and through the protocol stack in each device when you run an `iperf` test. For the following devices, draw the protocol stack that the data flows through (i.e. only draw the layers/protocols that are involved in the data transfer when using `iperf`; do not draw those that may be used for managing the device, like access the routers management web interface). When drawing the protocol stack, clearly label the protocols/technologies at each layer. If the question does not indicate a specific protocol, then give the layer name or typical protocol.

- i. The computer that starts the test. [2 marks]

**Answer.** *On the host there are 5 layers:*

*Application: iperf*

*Transport: TCP/UDP*

*Network: IP*

*Data Link: IEEE 802.3*

*Physical: IEEE 802.3*

- ii. The first WiMax Router (connected to the computer that starts the test). [2 marks]

**Answer.** *On the router there are 3 layers:*

*Network: IP*

*Data Link: IEEE 802.3 | IEEE 802.16*

*Physical: IEEE 802.3 | IEEE 802.16*

- (d) You want to measure the TCP throughput across the wireless link. If you run `iperf` on the computers (instead of on the WiMax routers), explain why it will give you a good indicator of throughput of the wireless link. [2 marks]

**Answer.** *The WiMax wireless link is the bottleneck in the path. The two wired links used Gigabit Ethernet, offering data rate of 1000Mb/s. WiMax has a data rate of less than 100Mb/s, and is therefore the minimum in the path. The throughput of the path will depend on the bottleneck link.*

- (e) You want to run a TCP throughput test using the default parameters. What `iperf` command (including options) do you run on the:

- i. Client [1 mark]

**Answer.** *`iperf -c 3.3.3.3`*

- ii. Server [1 mark]

**Answer.** *`iperf -s`*

- (f) You want to run a UDP throughput test for 1 minute to determine the maximum throughput of the wireless link. You know the WiMax link is configured to use a data rate of 30Mb/s. What `iperf` command (including options) do you run on the:

- i. Client [2 marks]

**Answer.** *`iperf -c 3.3.3.3 -u -b 30 -t 60`*

- ii. Server [1 mark]

**Answer.** *`iperf -s -u`*

### Question 3 [14 marks]

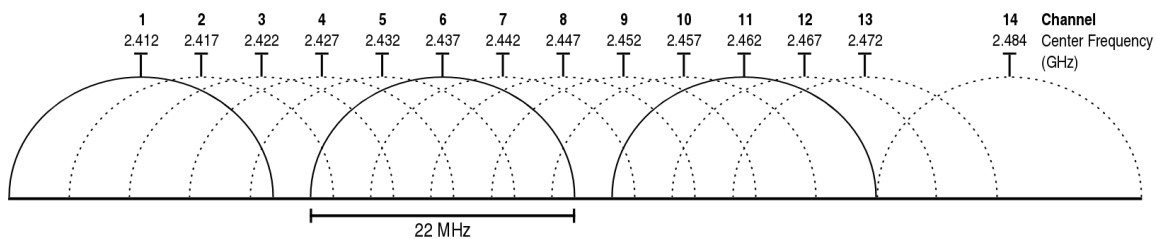
- (a) Explain an advantage of using IEEE 802.11g (compared to IEEE 802.11a). [1.5 marks]

**Answer.** *IEEE 802.11g uses the same frequency as IEEE 802.11b and therefore 11g and 11b devices can interoperate. For example, an 11g AP can support 11g clients and 11b clients. Whereas 11a uses a different frequency and a different (separate) radio would be needed in an AP to support 11a and 11b.*

- (b) Explain an advantage of using IEEE 802.11a (compared to IEEE 802.11g). [1.5 marks]

**Answer.** *As 11a uses a different frequency, there will be less interference from other WLANs (or microwaves, Bluetooth devices or cordless phones) in the area. 11g is susceptible to interference from such devices, leading to lower performance.*

The figure below shows the available channels in IEEE 802.11g. Note that although shown in the figure, channel 14 is not available for use in Thailand. Assume with a 54Mb/s data rate, the maximum throughput achievable between a pair of stations using IEEE 802.11g is 24Mb/s.



- (c) What is the bandwidth occupied by a single wireless LAN channel? [1 mark]

**Answer.** *22MHz*

- (d) You build a network using a single AP to provide network access for your laptop and three of your friends in your home (i.e. 4 clients). All clients are fixed and are within several metres of the AP. The AP is connected to your full-duplex 100Mb/s FTTH internet connection. If all clients attempt to upload data at the same time, what is the (approximate) maximum throughput that your laptop can achieve? Explain your answer. [2 marks]

**Answer.** *If all 4 clients have data to transmit, then the throughput of a single link (24Mb/s) must be shared amongst the four users, i.e. 6Mb/s per user.*

- (e) Now consider the same scenario but with 30 clients (i.e. you plus 29 others). Your friends bring some extra APs, so you now have five APs setup near each other, and all clients within several metres of all APs. Explain how you would configure the APs to achieve the maximum possible throughput per user (when all are attempting to upload). Explain why you think this will achieve maximum throughput. [3 marks]

**Answer.** *Since there are 3 non-overlapping channels, configure 3 of the APs to use those non-overlapping channels: 1, 6 and 11. The other two APs are not needed. Then, on average, 1/3 of the clients associate to one AP, 1/3 to the second and 1/3 to the third AP. The transmissions from the first set of clients to the other 2/3 do not interfere. So for AP1 the 24Mb/s is shared amongst 10 users, giving 2.4Mb/s per user. And for AP2 the 24Mb/s is shared amongst 10 users, giving 2.4Mb/s per user. And same for AP3.*

- (f) In part (e), what is the (approximate) maximum throughput that your laptop can achieve? [1 mark]

**Answer.** *As above, your laptop achieves a throughput of 2.4Mb/s.*

- (g) Now consider the scenario as in part (e), except the clients are spread out across a square area of approximately  $14m \times 14m$ . The range of APs (and clients) is approximately 10 metres when transmitting at 54Mb/s (and they are all configured to only use 54Mb/s, not less). All APs are in the centre of the square area. What problem may arise in this scenario that will limit the throughput even further? Explain how the problem arises and why it may reduce throughput. [3 marks]

**Answer.** *The hidden terminal problem may arise. Some of the clients will be on either side of the AP, within its range, but outside of range of each other. That is, the clients are hidden from each other. In this case when client A transmits to the AP, client B does not know the transmission is occurring and so may also start transmitting (even with the DCF mechanisms), causing a collision at the AP. Collisions lead to retransmissions which leads to lower throughput.*

- (h) What parameter(s) would you change on the devices to fix the problem in part (g)? What value would set the parameter to? [1 mark]

**Answer.** *Change the RTS Threshold, setting it to a lower value. That means more packets will use the RTS/CTS mechanism which alleviates the hidden terminal problem.*

## Question 4 [11 marks]

The process of a wireless LAN client changing from one AP to another is called a *handover*. The time it takes to perform the change is called the *handover time*. That is, from the moment when the client can no longer send data to the old AP until the moment when the client can send data to the new AP.

Consider a scenario where a client (C) is moving between AP1 and AP2. The APs have partially overlapping coverage areas. Assume the client has just reached the edge of the coverage area of AP1 (i.e. it just lost connectivity with AP1) and is already in the coverage area of AP2. The APs use different channels.

- (a) Draw a diagram that shows the exchange of frames for the client to actively discover AP2 and join AP2's network. Label each frame with its name. [3 marks]

**Answer.** *Probe Request from Client to AP2 Probe Response from AP2 to Client Authentication Request from Client to AP2 Authentication Response from AP2 to Client Association Request from Client to AP2 Association Response from AP2 to Client*

Assume the transmission of a single frame in part (a) takes  $200\mu\text{s}$ . All frames take the same time. Ignore the delays incurred by DCF (e.g. backoff). Propagation, processing and queuing delay is 0.

- (b) Calculate the handover time for part (a). [2 marks]

**Answer.**  *$1200\mu\text{s}$ , since there are six messages to be exchanged all taking  $200\mu\text{s}$  each.*

- (c) If only passive discovery of APs is used, and beacons are sent at a rate of 20 per second, calculate the:

- i. Minimum handover time [2 marks]

**Answer.** *The minimum handover time occurs if the client receives a beacon immediately after leaving coverage of the old AP. That is, it switches to the new frequency of AP2 and receives the beacon transmission. Therefore, discovery takes  $200\mu\text{s}$ . The authentication/association takes  $800\mu\text{s}$ . Therefore the minimum handover time is  $1000\mu\text{s}$ .*

- ii. Maximum handover time [2 marks]

**Answer.** *The maximum handover time occurs if the client enters the new network immediately after a beacon was received by, therefore having to wait for the next beacon. A beacon is sent every  $50,000\mu\text{s}$ , and therefore the handover time is  $51,000\mu\text{s}$ .*

- (d) Explain a way to reduce the handover time for wireless LANs when only passive discovery is used. [2 marks]

**Answer.** *Increase the rate that beacons are sent, so that the discovery time reduces.*



## Question 5 [12 marks]

- (a) If Mobile IP is not used, explain the two problems that arise for a mobile host in the Internet (i.e. the problems that motivate the use of Mobile IP). [2 marks]

**Answer.** *If a mobile host moves to a new subnet and keeps its original IP address, the a correspondent node will not be able to send packets to the mobile host. If the mobile host changes its IP address, the transport/application connection will be disrupted.*

- (b) Explain two methods that a Mobile IP host can use to discover a FA. Refer to the specific types of packets. [2 marks]

**Answer.** *Passive Discovery: the FA periodically broadcasts Router Advertisements; when the client receives an Router Advertisement it has discovered the FA. Active discovery: the client broadcasts a Router Solicitation; if a FA receives the packet it responds with a Router Advertisement.*

- (c) Draw a diagram showing the exchange of packets for the Mobile IP registration procedure. Indicate the types of packets, the ordering of packets (e.g. which one is sent 1st) and the nodes involved. [2 marks]

**Answer.** *Registration Request from Client to FA Registration Request from FA to HA Registration Reply from HA to FA Registration Reply from FA to Client*

- (d) Assume a Correspondent Node (CN) is corresponding with a Mobile Node (MN) in a foreign subnet, and the Mobile IP registration has been completed. For the following, indicate the address in the outer most IP datagram. Refer to the node names (CN, MN, ...) or other common identifiers for the address. [4 marks]

- i. For packets from CN to MN, destination address of datagram sent by CN:

*MN*

- ii. For packets from CN to MN, destination address of datagram received by FA:

*CoA*

- iii. For packets from CN to MN, source address of datagram received by FA:

*HA*

- iv. For packets from MN to CN, destination address of datagram received by FA:

*CN*

- (e) Explain two advantages of using NEMO to support network mobility (as opposed to using Mobile IP). [2 marks]

**Answer.** *With NEMO, the hosts within the mobile network do not need to support Mobile IP; they are unaware of their mobility. The signalling overhead is reduced in NEMO: only the Mobile Router performs signalling during handover, whereas with an all Mobile IP solution, all hosts contribute to signalling overhead.*

## Question 6 [13 marks]

Consider a wireless LAN with one AP and two clients (A and B) under the following conditions:

- Both clients are within range of the AP, however the clients are outside of range of each other (e.g. A cannot hear B).
- Fragmentation is not used.
- When choosing random numbers, the stations choose the following values in order:
  - Client A: 6, 19, 7
  - Client B: 20, 5, 23
  - AP: 1, 12, 3
- Stations have data with payload 875 Bytes ready to transmit at the following times:
  - Client A: time  $0\mu s$  to AP
  - AP: time  $10\mu s$  to B
  - Client B: time  $150\mu s$  to AP

Parameter	Value
Data Rate	48 Mb/s
DATA Header	25 Bytes
ACK transmission time	$20\ \mu s$
RTS transmission time	$20\ \mu s$
CTS transmission time	$20\ \mu s$
DIFS	$30\ \mu s$
SIFS	$10\ \mu s$
Slot Time	$10\ \mu s$
CW <sub>min</sub>	31
CW <sub>max</sub>	1023
ACKTimeout	$30\ \mu s$

On the following pages, draw a diagram that illustrates the DCF operation. You must clearly label all events/frames in the operation. Start at time 0, and finish when the last DATA frame is acknowledged. Your diagrams do not have to be to scale, however showing the timing of events will help with answering subsequent parts of this question.

- (a) Basic access is used [5 marks]
- (b) RTS/CTS is used [5 marks]

B



AP



A



B



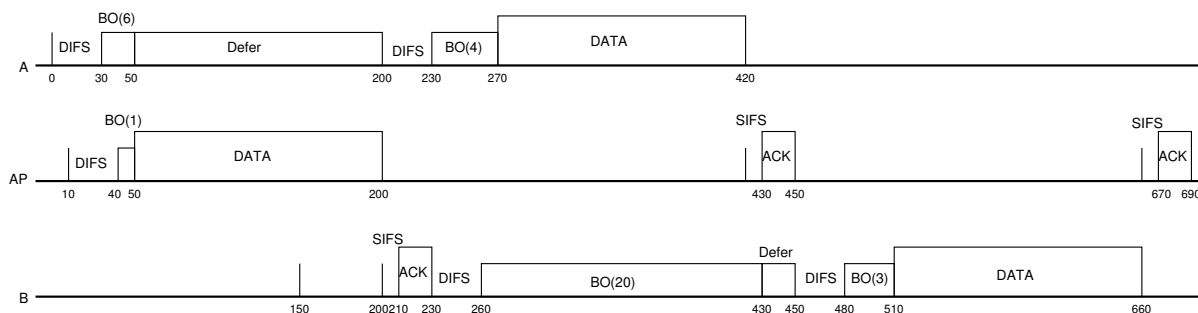
AP



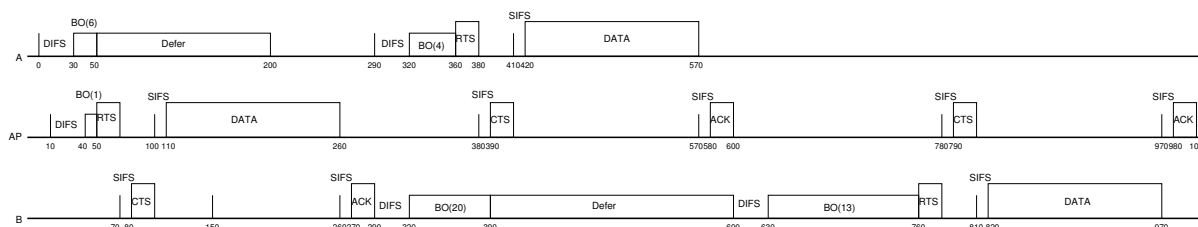
A



**Answer.** *Basic access:*



*RTS/CTS:*



(c) For the following cases, at what time does each station know the data has been successfully delivered to the destination? [3 marks]

- i. Basic Access, Client A:  $450 \mu s$
- ii. Basic Access, Client B:  $690 \mu s$
- iii. Basic Access, AP:  $230 \mu s$
- iv. RTS/CTS, Client A:  $600 \mu s$
- v. RTS/CTS, Client B:  $1000 \mu s$
- vi. RTS/CTS, AP:  $290 \mu s$

## Question 7 [13 marks]

The following algorithms/events change the value of the Congestion Window ( $cwnd$ ) in TCP congestion control:

- Additive Increase
  - Slow Start
  - Loss detected by Timeout
  - Loss detected by Duplicated ACKs
- (a) The following equations describe how the new Congestion Window is calculated. Match the correct algorithm/event above to the equation below by writing the name of the algorithm/event: [4 marks]

i.  $cwnd_{new} = MSS$  Loss detected by timeout

ii.  $cwnd_{new} = cwnd_{old} + MSS$  Slow Start

iii.  $cwnd_{new} = cwnd_{old} + \frac{MSS * MSS}{cwnd_{old}}$  Additive Increase

iv.  $cwnd_{new} = \text{minimum}(ssthresh, cwnd_{old})$  Loss detected by Duplicate ACKs

- (b) In addition to the congestion window, TCP also has an advertised window. Explain the purpose of the two windows. [1 mark]

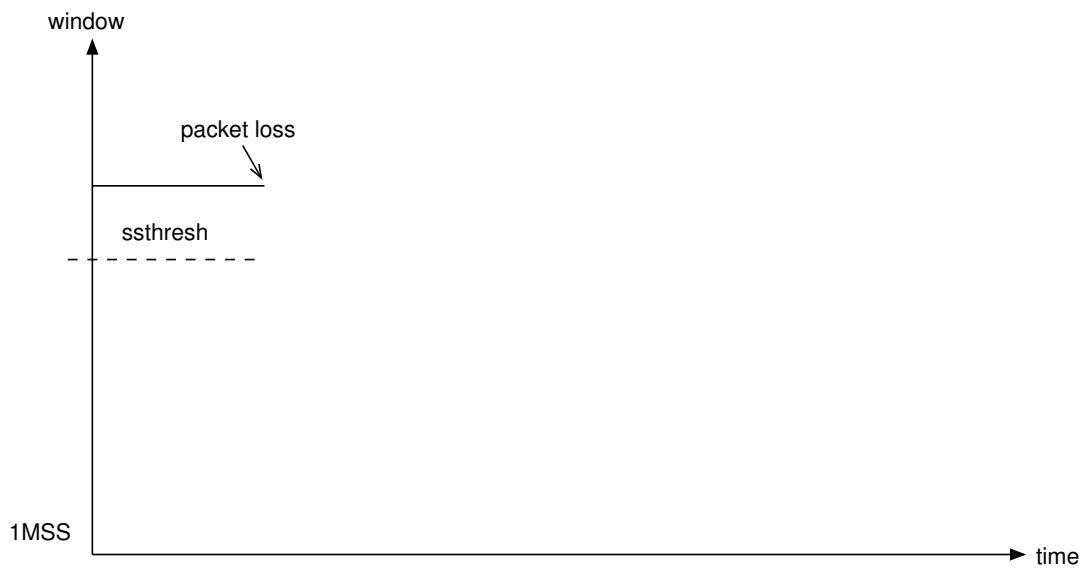
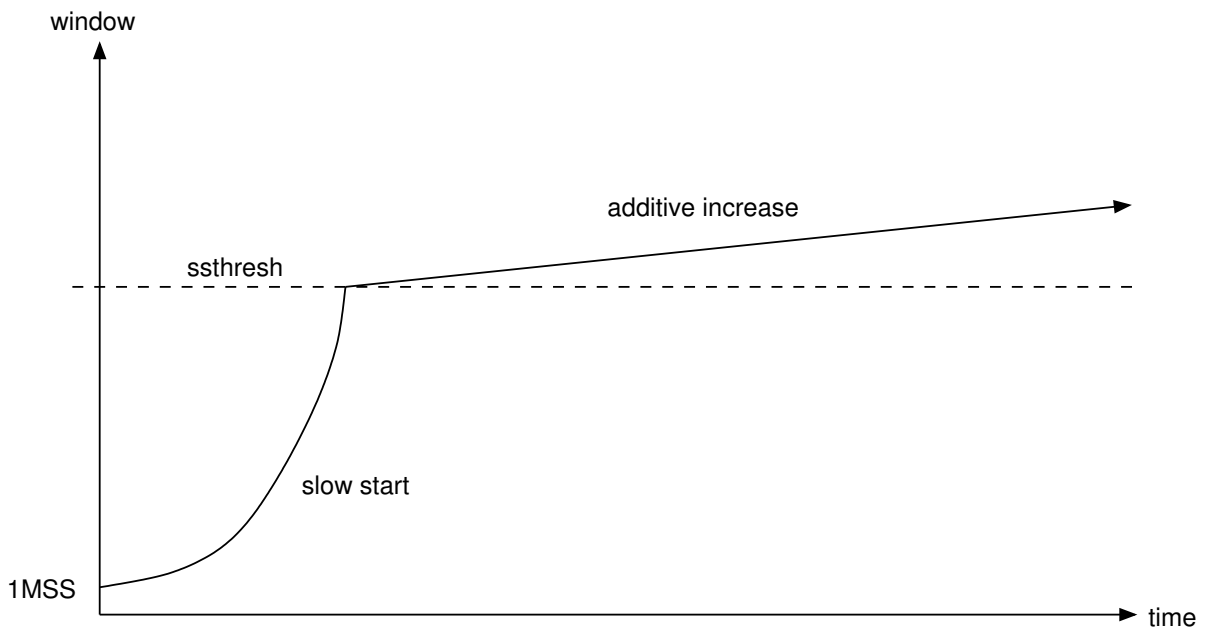
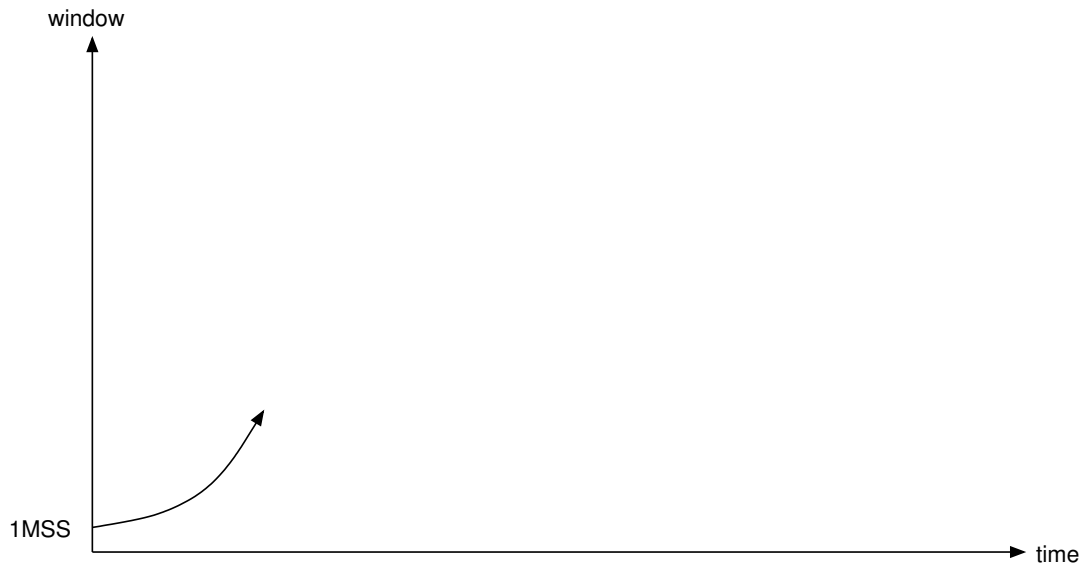
**Answer.** *Advertised Window is used by the receiver to limit the rate at which the sender sends so that the buffer at the receiver does not overflow (flow control). Congestion Window is used by the sender to determine how much can be sent so that congestion doesn't occur in the network.*

- (c) How does the TCP source calculate the window from the congestion and advertised windows? [1mark]

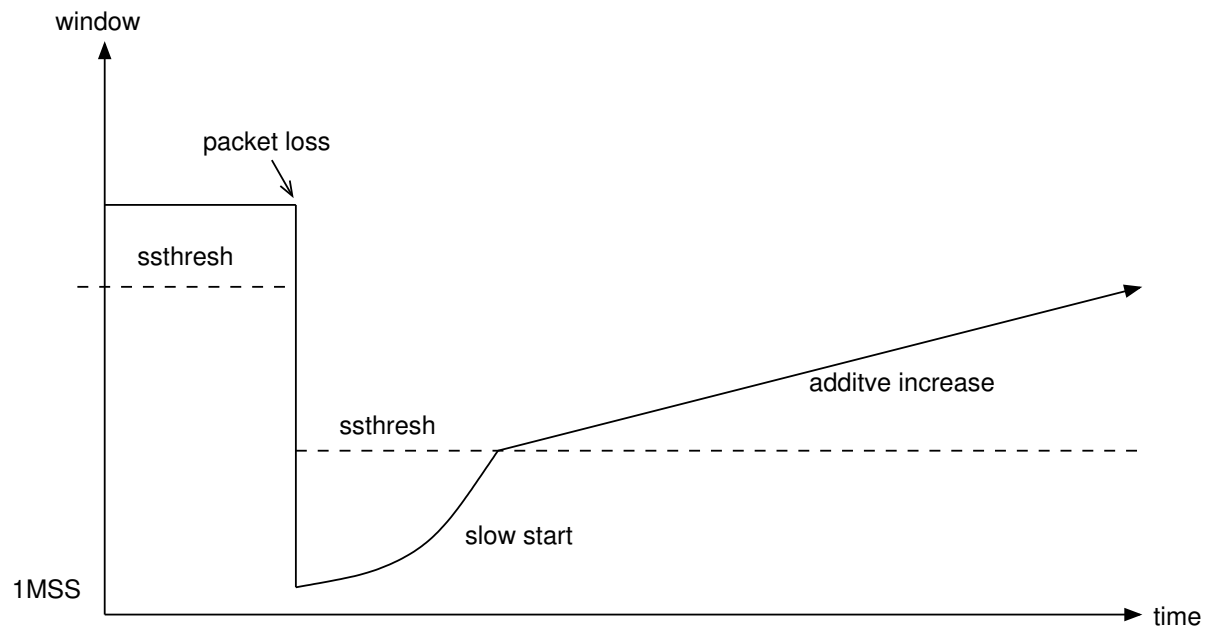
**Answer.** *Minimum of the congestion and advertised window.*

The following cases require you to draw a plot of the value of TCP source window over time. The plot does not have to be exact or to scale, but should clearly show the different phases (additive increase, slow start, responses to loss, etc.) and how they differ. That is, the shape of the plot should be clear. You should also show the slow start threshold on your plot. As a guide, the initial values of the window are given. You should assume the time on the horizontal axis is a long period, meaning the slow start threshold should be reached within that time.

- (d) Buffer space at receiver is infinite. No packet loss. [3 marks]
- (e) Buffer space at receiver is finite and greater than slow start threshold. Loss due to timeout occurs. Note that the diagram below shows the current value of the window when the loss occurs as a solid line. [3 marks]







- (f) Explain why TCP source responds differently when there is a loss due to a timeout compared to when there is a loss due to a 3rd duplicate ACK. [1 mark]

**Answer.** *If a single packet is lost, then the loss due to 3rd duplicate ACK should be detected before a timeout occurs. However if many packets are lost or packets are significantly delayed, then the 3rd duplicate ACK may not be received before the timeout. In other words, loss due to 3rd duplicate ACK normally means there is less congestion than if a loss due to timeout occurs. Therefore, in the event of a loss due to timeout (ie. large congestion), TCP decreases its congestion window significantly in order to avoid further congestion.*