University of Illinois at Urbana-Champaign
Department of Computer Science

Midterm Exam
CS 414 – Multimedia Systems Design
March 8, 2010, 11-11:50am, 1302 SC

Exam duration: 50 minutes

Instructions
Print your name and NetID in the space provided below;
print your NetID in the upper right hand corner of every page.

Name: ____________________________________________
NetID: __________________________________________

This is a closed book, closed notes examination. You may use calculators and one page of cheat sheet.

Do all parts of all five problems in this booklet. This booklet should include this title page, plus 7 additional pages. Do your work inside this booklet, using the backs of pages if needed. The problems are of varying degrees of difficulty so please pace yourself carefully and answer the questions in the order which best suits you. The maximum grade on this midterm is 100 points.

Number of pages of the exam: 8 (including cover page)
Number of questions on the exam: 5
Maximum grade on this exam is: 100

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Problem 1: Multiple-choice (20 points – 10 questions 2 points each)

1. Noiseless 6 KHz channel cannot transmit a signal of four discrete levels at a rate exceeding
   a. 24 000 bits per second
   b. 12 000 bits per second
   c. 6 000 bits per second

Answer: ‘a’ because max data rate = 2 H*log2V; where H is bandwidth, V is discrete levels (2x 6000 x 2)

2. Color coding uses during the transmission
   a. Two luminance signals and one chrominance signal
   b. Read, green blue signals
   c. One luminance and two chrominance signals

Answer: ‘c’

3. To avoid Flicker effect, we need to
   a. Increase the pixel resolution
   b. Increase the refresh cycles per second
   c. Increase the memory in the display refresh buffer

Answer: ‘b’

4. MPEG-2 compression belongs to
   a. Entropy coding schemes
   b. Hybrid coding schemes
   c. Source coding schemes

Answer: ‘b’

5. Applying Run-length coding technique, consider the encoded sequence a!3bbc!5g!4. What is the original string?
   a. aaabbccccccggggg
   b. aaabccccccggggg
   c. a333bbc55555g4444
   d. a!3bbc!5g!4

Answer: ‘b’

6. HDTV system differs from NTSC system in
   a. Resolution, aspect ratio, viewing distance
   b. Coding, flicker effect handling
   c. Deployment, robustness

Answer: ‘a’
7. Differential Pulse Code Modulation represents
   a. Each PCM-encoded sample as a whole
   b. First PCM-coded sample as a whole and the following samples as
c      differences from previous PCM-coded samples
   c. First PCM-coded sample as a whole and following samples as least error
      square differences.

Answer: ‘b’

8. Zig-zag ordering in JPEG compression was introduced because
   a. It allows better inclusion of the psycho-acoustic effect
   b. It is better for the image preparation to enter the DCT transformation on
      8x8 blocks.
   c. It is computationally more efficient to work with vectors rather than
      matrices

Answer: ‘c’

9. Nyquist theorem says
   a. For lossless digitization, the sampling rate must be in the range of human
      hearing frequency
   b. For lossless digitization, the sampling rate must be 44100 Hz
   c. For lossless digitization, the sampling rate must be at least twice the
      maximum frequency responses.

Answer: ‘c’

10. Quantization of an audio sample means
    a. Allocation of number of bits to the height of the sampled waveform
    b. Rate at which a continuous waveform is sampled
    c. Frequency of a sound

Answer: ‘a’

**Problem 2: Audio (20 Points)**

1. Consider that the threshold of hearing is at $10^{-12}$ W/m$^2$ and the threshold of pain
   for hearing is at 1 W/m$^2$. (assume dB = $10\log(I/I_0)$, where $I_0$ is the reference
   level, equal to the threshold of hearing)

   a. (5 Point) Show that the threshold of hearing is 0 dB.

   **Answer:**
   
   
   $\text{dB} = 10\log \left( \frac{I}{I_0} \right)$, where $I_0 = 10^{-12}$. Then
   
   $10\log (10^{-12}/10^{-12}) = 10\log 1 = 10\times 0 = 0\text{ dB};$

   b. (5 Point) Show that the threshold of pain is 120 dB.

   **Answer:** $10\log (1/10^{-12}) = 10\log(10^{12}) = 10\times 12 = 120 \text{ dB};$
c. (10 Points) Suppose an electric fan produces an intensity of 10 dB. How many times more intense is the sound of a conversation if it produces an intensity of 60 dB?

Answer: 10 dB is 10 times more intensive than TOH; 60 dB is $10^3$ times more intensive than TOH. Then Conversation is $10^6/10$ times $= 10^5$ more intense than the sound of electric fan.

Problem 3: Huffman and Arithmetic Coding (20 Points)

Consider the alphabet $A=\{a, b, g\}$. Let $p(a) = 0.5$, $p(b) = 0.3$, $p(g) = 0.2$. 

1. (10 Points) Compute the Huffman code for this alphabet and encode the word “gab”.

   Answer: 
   
   \[
   \begin{array}{c|c|c}
   \text{Symbol} & \text{Code} & \text{Probability} \\
   \hline
   a & 1 & 0.5 \\
   b & 01 & 0.3 \\
   g & 00 & 0.2 \\
   \end{array}
   \]

   Huffman table: $a == 1; b == 01; g == 00; the word gab == 00101$

2. (10 Points) Consider the above alphabet $A=\{a, b, g\}$ and their occurrence probabilities. Consider Arithmetic Coding and consider a word that has the encoded value 0.625 (binary presentation of the encoded word is 0.101), and the length of the word is 3. What is the original word? Show your work as you decode the encoded value.

   Answer: The original word is “bag”, when decoding the value 0.625 with word length 3.

   - b symbol is between 0.5 and 0.8, since 0.625 falls into this interval;
   - a symbol is between 0.5 and 0.65, since 0.625 falls into this interval;
   - g symbol is between 0.620 and 0.65, since 0.625 falls into this interval;

Problem 4: Translation of QoS (10 Points)

Consider uncompressed video stream with video characteristics 640x480 pixels video frames, 16 bits per pixel resolution, 30 fps (frames per second). Assume that the video application puts message header of 32 bytes in front of each video frame at the application layer with header information such as media-type, time-stamp, rate, and...
sequence number. (Note: At the application layer, a single video message in the video stream consists of one video message header and one video frame). Consider that the video stream is going to be sent over the transport protocol, where the payload of the transport packet is 64 Kbytes.

1. (5 Points) **Translate** the video stream characteristics from the application layer into the transport stream characteristics, i.e., compute the transport packet rate (in packets/second) at which the uncompressed video will be sent into the network via this transport protocol.

   Answer: \[ RN = \left\lfloor \frac{MA}{MN} \right\rfloor / RA; \]
   \[ MA = \text{header plus frame} = 32 \text{ bytes} + (640 \times 480 \times 16 / 8) = 32 + 614400 = 614432 \text{ Bytes} \]
   \[ MN = \text{packet payload} = 64 \times 1024 \text{ Bytes} = 65536 \text{ Bytes} \]
   \[ \left\lfloor \frac{MA}{MN} \right\rfloor = \left\lfloor \frac{614432}{65536} \right\rfloor = 10 \text{ (need 10 transport packets to transmit 1 video frame)}; \]
   \[ RN = 10 \times 30 \text{fps} = 300 \text{ packets per second}; \]

2. (5 Points) What is the bandwidth requirement (bps) of this uncompressed video stream at the application layer?

   Answer: \((32 \times 8 + 640 \times 480 \times 16) \times 30 = 147463680 \text{ bps};\)

**Problem 5: Multimedia Establishment Phase (30 Points)**

Consider a multimedia system with three system components along the end-to-end path, the server/sender (S), the network/router (N) and the client/receiver (C):

- Assume that the server S has the initial bandwidth availability at 100 Mbps (Megabits per second), the network provider N has the initial bandwidth availability of 50 Mbps and the client C has the initial bandwidth availability of 30 Mbps.
- Assume that server S wants to send to client C over the network N three MPEG-2 streams with bandwidth requirements \((B_{\text{min}}, B_{\text{target}})\) as follows:
  - stream s1 with \(B_1 = (5 \text{ Mbps, 25 Mbps})\),
  - stream s2 with \(B_2 = (10 \text{ Mbps, 30 Mbps})\),
  - stream s3 with \(B_3 = (8 \text{ Mbps, 25 Mbps})\).

Solve the following problems:

1. (3 Points) Can all three streams be **accepted (admitted)** at the minimal bandwidth requirement level at all three components S, N, C? If yes, explain why. If no, explain why. Show your work.

   **Answer:** yes for all three streams: S: \((5+10+8) \text{ Mbps} = 23 \text{ Mbps} < 100 \text{ Mbps}\)
   N: \(23 \text{ Mbps} < 50 \text{ Mbps}\)
C: 23 Mbps < 30 Mbps
So for all three streams Bmin requirements passed through the available bandwidth bounds, so connection can be established at the level of Bmin.

2. (3 Points) Can all three streams be accepted at the target bandwidth level at all three components S, N, C? If yes, explain why. If no, explain why. Show your work.

Answer: S: (25+30+25) Mbps = 80 Mbps <100 Mbps (yes for server)
N: 80 Mbps > 50 Mbps (no for network)
C: 80 Mbps > 30 Mbps (no for client)
All three streams cannot be accepted along the path, since only S can accept all three. The other two components could accept only 1 or 2 at their target bandwidth requirements.

3. (24 Points) Write a pseudo-code of the triangular negotiation protocol for bounded value where as an input pair you enter \([s, (B_{min}, B_{target})]\) for one stream.
   - Consider the sender-initiated triangular negotiation.
   - As part of the negotiation protocol, do not forget to put pseudo-code with respect to admission control of bandwidth at each component S, N, C
   - As part of the negotiation protocol, do not forget to put pseudo-code with respect to bandwidth reservation and allocation at each component S, N, C.

   a. (7 Points) Write the pseudo-code of the functionality at the caller (sender/server S) side during the triangular negotiation.

   Answer:

   Get_input(s, Bmin, Btarget); /* s being any stream out of the three and Bmin/Btarget the corresponding bandwidth requirements */
   If Btarget < Bavail then /* Bavail is the available BW at the Server S */
      { Bavail = Bavail – Btarget;
        Btarget_resv = Btarget;
        Reserve (s, Btarget_resv); }
   Else
   If Bmin ≤ Bavail < Btarget then
      { Btarget = Bavail;
        Bavail = Bavail = Btarget;
        Btarget_resv = Btarget;
        Reserve (s, Btarget_resv); }
   Else
   If Bavail < Bmin then
      { reject connection; exit; }
   Send_request_to_network(s, Bmin, Btarget);
Wait_for_response_from_network(s, answer, Btarget);

If (answer == reject) then
  {reject connection;
   Bavail = Bavail + Btarget_resv;
   exit;}
If (answer == accept) then
  { Btarget_alloc = Btarget;
    change reservation (s, Btarget_resv) to (s, Btarget_alloc);
    adjust Bavail accordingly of Btarget_resv ≠ Btarget_alloc; }

b. (7 Points) Write the pseudo-code of the functionality at the callee (receiver C) side during the triangular negotiation.

Answer:

Get_msg_from_network (s, Bmin, Btarget);
If Btarget < Bavail then /* Bavail is the available BW at the client C */
  {Bavail = Bavail – Btarget;
   Btarget_alloc = Btarget;
   Allocate (s, Btarget);
   answer = accept;}
If Bmin ≤ Bavail < Btarget then
  {Btarget = Bavail;
   Bavail = Bavail – Btarget;
   Btarget_alloc = Btarget;
   Allocate (s, Btarget);
   answer = accept;}
if Bavail < Bmin then
  {Btarget = 0;
   answer = reject; }

Send_response_to_network(s, answer, Btarget);

c. (10 Points) Write the pseudo-code of the functionality at the network (router N) during the triangular negotiation.

Answer:

Get_msg_from_caller(s, Bmin, Btarget);
If Btarget < Bavail then /* Bavail means the available BW at the network router */
  {Bavail = Bavail – Btarget;
   Btarget_resv = Btarget;
   Reserve (s, Btarget_resv);
   Send_request_tocallee(s, Bmin, Btarget); }

7
If $B_{\text{min}} \leq B_{\text{avail}} < B_{\text{target}}$ then
   \{ $B_{\text{target}} = B_{\text{avail}}; \$
   \qquad B_{\text{avail}} = B_{\text{avail}} - B_{\text{target}};
   \qquad B_{\text{target}}_{\text{resv}} = B_{\text{target}};
   \qquad \text{Reserve}(s, B_{\text{target}}_{\text{resv}});
   \text{Send}_\text{request}_\text{to}_\text{callee}(s, B_{\text{min}}, B_{\text{target}}); \}$

If $B_{\text{avail}} < B_{\text{min}}$ then
   \{ answer = reject;
   \qquad B_{\text{target}} = 0;
   \text{Send}_\text{response}_\text{to}_\text{caller}(s, \text{answer}, B_{\text{target}}); \}$

Wait_for_response_from_callee(s, answer, B_{\text{target}});

If (answer == reject) then
   \{ release reservation (s, B_{\text{target}}_{\text{resv}});
   \qquad B_{\text{avail}} = B_{\text{avail}} + B_{\text{target}}_{\text{resv}}; /* released reserved resource must go back to
the general pool */
   \text{Send}_\text{response}_\text{to}_\text{caller}(s, \text{answer}, B_{\text{target}}); \}$

If (answer == accept) then
   \{ B_{\text{target}}_{\text{alloc}} = B_{\text{target}};
   \text{change reservation } (s, B_{\text{target}}_{\text{resv}}) \text{ to } (s, B_{\text{target}}_{\text{alloc}}) \text{ and take into account}
   \qquad \text{if } B_{\text{target}}_{\text{resv}} > B_{\text{target}}_{\text{alloc}} /* adjust BW allocation accordingly; */
   \text{Send}_\text{response}_\text{to}_\text{caller}(s, \text{answer}, B_{\text{target}}); \}$