**University of Illinois at Urbana-Champaign**

**Department of Computer Science**

Take-Home Midterm Exam

CS 598KN – Advanced Multimedia Systems

**Exam duration: Tuesday, 10/23/2018, 4pm – Tuesday, 10/30/2018, 11:59pm**

# Instructions

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

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This is a take-home exam. You can use the lecture notes and papers that we have been reading in the class. This is an individual effort, and everybody needs to work on this exam individually.

The solutions should be written electronically (no hand-written solutions) and submitted in **pdf** format by **Tuesday, 10/30/2017 by 11:59pm to** [**klara@illinois.edu**](mailto:klara@illinois.edu)**, Subject: CS598KN Midterm Exam**.

Maximum grade on this exam is: 100

|  |  |  |
| --- | --- | --- |
| **Problem** | **Points** | **Scores** |
| Problem 1 | 5 |  |
| Problem 2 | 10 |  |
| Problem 3 | *15* |  |
| Problem 4 | 10 |  |
| Problem 5 | 5 |  |
| Problem 6 | 15 |  |
| Problem 7 | 20 |  |
| Problem 8 | 20 |  |
| Total | 100 |  |

**Problem 1: Multiple-choice (5 points – 5 questions 1 point each)**

1. **Noiseless 6KHz channel** cannot transmit a signal of two discrete levels at a rate exceeding
   1. 32 000 bits per second;
   2. 24 000 bits per second;
   3. 12 000 bits per second;
   4. 6 000 bits per second;

Answer to Q1:

1. **H.264 compression** belongs to
   1. Entropy coding schemes;
   2. Hybrid coding schemes; ;
   3. Source coding schemes;

Answer to Q2:

1. **YouTube-like applications** need
   1. Symmetric compression;
   2. Asymmetric compression;
   3. None of the above;

Answer to Q3:

1. Why does **CD audio quality** have 44.1KHz sampling rate when humans can hear only audio in the range of 20Hz -22.5KHz? The reason is because of
   1. Nyquist Theorem
   2. Weber-Fechner Law
   3. Psychoacoustic Masking Effect

Answer to Q4: a)

1. Consider the **MPEG encoded sequence** IPBBPBBPIPBPI. What is the decoding sequence?
   1. IPBBPBBPIPBPI
   2. IPPPIPPIBBBBB
   3. IPPBBPBBIPPBI
   4. IBBBBBPPPIPPI

Answer to Q5:

**Problem 2: Coding (10 Points)**

Let us consider alphabet **A={a,c,t, g}** with probabilities, p(a) = 0.05, p(c) = 0.2, p(t) = 0.05, p(g) = 0.7. Do the following tasks:

1. (3 Points) Create a **Huffman tree and Huffman table/codes** for this alphabet **A**.
2. (2 Points) Encode the words ‘**gag**’, ‘**cat**’, and ‘**tag**’ with the created Huffman codes. Which word has the shortest code?
3. (2 Point) Consider bit sequence **11000010010101111**. Decode the bit sequence with the Huffman table from the Problem 2(a).
4. (3 Points) Consider alphabet {A, B, C} with probabilities p(A) = 0.2, p(B) = 0.3, p(C) = 0.5; For this alphabet and occurrence probabilities, compare the Optimal Entropy (Shannon Theoretical Limit) code length **H** with Average Code-word length **L** (Note: the Code-word length L should be obtained via Huffman Coding, the Average Code-Word Length is *Σ P(xi)\*L(xi)),* *i=1,n, n* is number of symbols, *P(xi)* is symbol *xi* probability of occurrence, *L(xi)* is code word length of symbol *xi*).

**Problem 3: Networking (15 Points)**

Let us consider a client/server video-on-demand (VOD) service where the client and server negotiated at the beginning of the VOD service the starting frame rate of 25 frames per second (fps) for a streamed MJPEG video (**V**) with the recorded video frame rate of 25 fps. After the negotiation, the video **V** streams over best effort Internet from the VOD server to the VOD client. The receiving video frame rate of the streamed video **V** is measured at the client side, and it fluctuates over the period *K* of 10 seconds, as follows: 25fps, 23fps, 20fps, 21fps, 19fps, 20fps, 26fps, 27fps, 25fps, 24fps. Due to this fluctuation, a renegotiation of video frame rate is required between the VOD server and the VOD client.

1. (**3 Points**) Calculate the **predictive QoS (frames per second)** at the client side over the above discussed fluctuation period K= 10 seconds. You can select any of the predictive functions (average, maximum, minimum) and argue what your predictive function-choice means when the predictive value is used for a renegotiation request.
2. **(5 Points**) Design the **peer-to-peer renegotiation protocol** for the QoS parameter ‘*frames per second’* that occurs after the period of 10 seconds as discussed in our example above. It means, clearly explain
   1. Who triggers the renegotiation,
   2. What functions are executed on the client and server side during the renegotiation, and
   3. What message(s) and values are exchanged between the VOD client and server.
3. (**7 Points**) Let us assume that you have a proxy node between the VOD server and the VOD client. The proxy node receives the frames with fluctuating frame rates due to the Internet over the 10 second interval as follows: 25fps, 23fps, 20fps, 21fps, 19fps, 20fps, 26fps, 27fps, 25fps, 24fps. **Design a token bucket traffic shaper at the proxy node**, i.e.,
   1. Calculate the peak frame rate (in frames per second ***λpeak*)** ;
   2. Calculate the average frame rate (***λavg***);
   3. Calculate the token rate **ρ**, i.e., specify what the range of the token rate **ρ** is, at which the tokens are placed into the bucket;
   4. If you assume a bucket size **β** of 20 tokens, will you see token bucket always full, or always empty, or partially full?

**Problem 4: Video-on-Demand (10 Points)**

With the increased bandwidth availability, Video-on-Demand (VOD) services emerge. Clients explicitly request videos from a video server, causing large bandwidth demands on video servers when serving thousands of clients.

1. (**2 Points)** What are the requirements on near video-on-demand and true video-on-demand systems?
2. (**6 Points**) Compare the Stream Tapping Method with Hierarchical Patching Method, i.e., (1) describe protocols between VOD server and client for Stream Tapping Method and Hierarchical Patching; (2) specify disadvantages of Stream Tapping Method when compared with Hierarchical Patching.
3. (**2 Points**) Compare and explain the needed server playout bandwidth (in average number of channels at the server) for VOD when using unicast and hierarchical patching VOD video distribution. (Note: Assume a video of length ‘L’ seconds and arrival of λ clients per second).

**Problem 5: Multimedia Protocols (5 Points)**

Consider three protocols, broadly used in Multimedia Systems: DASH (Dynamic Adaptive Streaming HTTP), SIP (Session Initiation Protocol) and RTSP (Real-Time Session Protocol). Specify

(a) (**3 Points**) how do these protocols work,

(b) (**1 Points**) what are the similarities (at least one similarity), and

(c) (**1 Points**) what are the differences (at least one difference).

**Problem 6: HTTP Adaptive Streaming (HAS) over Mobile Networks (15 Points)**

Let us consider video flows over mobile networks, operated by Mobile Network Operators (MNO).

1. (**3 Points**) Describe the steps of video flow traffic shaping at the application layer for mobile networks.
2. (**2 Points**) How do MNOs extract video application-layer information to allow scheduling and traffic shaping of video streams and what are the problems of current methods to extract accurate application-layer information?
3. (**8 Points**) Develop an algorithm to profile HAS video traffic at the layers 2 and 3.
4. (**2 Points**) Describe a “k-fold cross-validation approach” to train and validate datasets, used in video flow profiling.

**Problem 7: Adaptive Bitrate Algorithms in DASH (20 Points)**

Modern video streaming systems use Adaptive Bitrate Algorithms (ABR) inside of video players and constantly adjust the quality of video segments that are downloaded and rendered to the user.

1. (**2 Points**) Describe what does it mean that a video freezes, and how (why) does video freezing happen.
2. (**4 Points**) Develop and present in detail an algorithm and protocol that would avoid video freezing at the client side when video is streamed from the server side.
3. (**2 Points**) Why is maximizing re-buffering and bitrate oscillation not desirable in Adaptive Video Streaming?
4. (**2 Points**) What are the requirements for an effective Adaptive Bitrate algorithm?
5. (**4 Points**) Explain BOLA (Buffer Occupancy based Lyapunov Algorithm) ABR algorithm and argue why it is not sufficient for dynamic adaptive streaming and BOLA-E is needed?
6. (**3 Points**) Why and when do we need the placeholder algorithm in BOLA-E?
7. (**3 Points**) What is the difference between BOLA and DYNAMIC algorithms? Provide at least two advantages and disadvantages for each algorithm.

**Problem 8: Content Distribution Networks (20 Points)**

Let us consider live content broadcasting platforms which are facing great challenges to accommodate large scale of dynamic viewers.

1. (**10 Points**) Compare Live Broadcast Schemes such as (1) Periodic Broadcast, (2) live content broadcast over IP-multicast, (3) P2P Live streaming, (4) AngelCast and (5) LiveJack live streaming. Provide few sentences of explanation how each scheme works and what are the advantages and disadvantages of each scheme (2 advantages and disadvantages).
2. (**2 Points**) What are Virtual Media Functions (VMFs), where are they placed within LiveJack system, and what are the advantages and disadvantages of VMF?
3. (**2 Points**) What are Network Virtual Functions (NVFs) and what is the difference between VMF and NVF?
4. (**6 Points**) Compare LiveJack and PPLive systems: (1) describe the session control protocol for each system, (2) describe the content distribution protocol for each system, (3) present two similarities and two dissimilarities of the two systems.