Rate adaptation with Bayesian attractor model for MPEG-DASH

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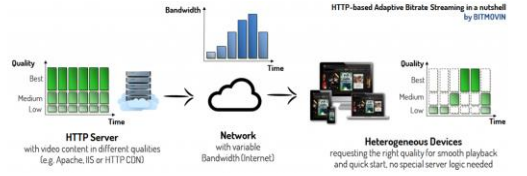
Background – Video streaming service

- **MPEG-DASH (Dynamic Adaptive Streaming over HTTP)** is widely used for video streaming service
  - Using DASH, the video player can dynamically switch video quality



cited from https://bitmovin.com/dynamic-adaptive-streaming-http-mpeg-dash/

- Bitrate selection is based on an **Adaptive bitrate (ABR) algorithms**
  - Estimate the instantaneous network quality
  - Select a video bitrate of the next segment to be downloaded

Background – Quality of Experience (QoE)

- **The QoE is attracting attention as an important factor in video streaming service**
  - A measure of the degree of user satisfaction with a service
  - Improving QoE is the general goal of ABR algorithms
- **The QoE is strongly correlated with video player events**
  - Start-up delay, played bitrate, frequency of bitrate switch, rebuffering (video freezing), etc

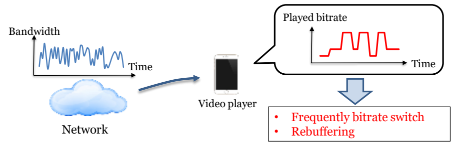
- High bitrate
- Smooth moving picture
- Not video freezing

- Low bitrate
- Frequent bitrate switch
- Video freezing

High QoE user **Low QoE user**

Problem

- **Bitrate selection degrading the user QoE due to a fluctuation of network quality**
  - Difficulty in estimating of network quality in mobile network
    - Increase in mobile traffic intensifies the degree of fluctuation
    - Signal strength, interference, noise, and user mobility
  - Inaccurate estimation can lead to inappropriate bitrate selections
  - This results in degrading the user QoE



- **The factors that improve the QoE differ person by person**

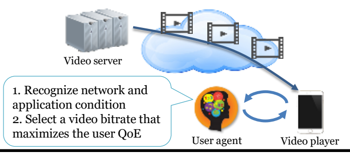
Research purpose and approach

Purpose

To maximize the QoE of individual users

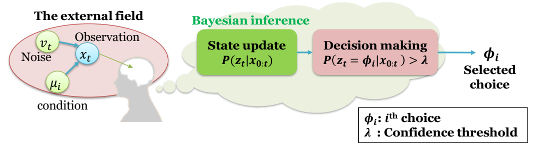
Approach

- Apply a process of the brain to bitrate selection in video streaming application
  - The brain can judge even when only incomplete and uncertain information can be obtained
  - User agent using a brain model selects a video bitrate
- Provide an ABR algorithm according to a user's preference



Bayesian attractor model (BAM) [7]

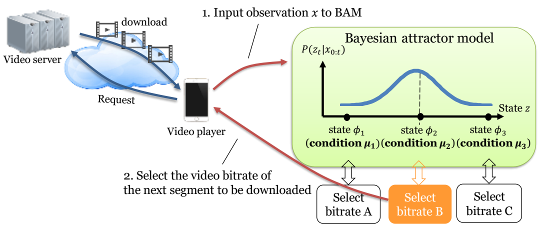
- The BAM models a human's brain
  - Update **a internal state** z based on **observation** x using the Bayesian inference framework
  - Typical conditions $\boldsymbol{\mu}_1, \dots, \boldsymbol{\mu}_K$ are defined in advance
    - μ_i is associated with a fixed point ϕ_i in state space of $\boldsymbol{z}$ $(i = 1, \dots, K)$
    - ϕ_i is one of choices in the BAM's decision making
  - Make a decision according to the posterior density which is called "*confidence*"
    - When ϕ_i is selected, the current condition is estimated to be μ_i



[7] S. Bitzer, J. Bruineberg, and S. J. Kiebel, "A bayesian attractor model for perceptual decision making," PLoS Computational Biology, 2015.

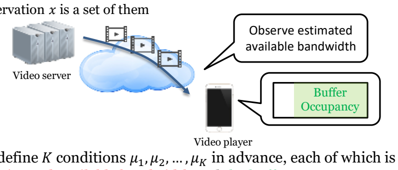
Overview of our method

- **The estimation of the network and application condition**
- **Bitrate selection based on the decision result**



The estimation of the network and application condition

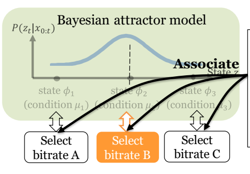
- The client device observes **estimated available bandwidth** and **buffer occupancy**
  - Observation x is a set of them



- We predefine K conditions $\mu_1, \mu_2, \ldots, \mu_K$ in advance, each of which is also a set of estimated available bandwidth and the buffer occupancy
  - The condition expresses that
    - Which bitrates the available bandwidth can accommodate
    - Whether the current buffer is abundant or depleted
- With the BAM, our method estimates which of the predefined condition μ_i the current condition is closest to

Bitrate selection based on the decision result

- This selection is independent of the BAM's cognitive model
- It is possible to realize bitrate selection according to a user's preference
- As a example, we propose it with considering the preference of the user who prefer **less rebuffering** and **fewer changes in the bitrate**



Bitrate selection policy for the user

- In case the buffer occupancy is low, select a bitrate lower than estimated available bandwidth to avoid rebuffering
- In case the buffer occupancy is abundant, keep the current bitrate or not change bitrate largely to suppress bitrate changes
- and so on

Performance evaluation

- **The content of evaluation**
  - We simulate our proposed method assuming a 5 minute movie in a situation where the available bandwidth changes dynamically
  - We evaluate our method in terms of factors influencing user QoE
    - **The average bitrate**: How much the video quality is good
    - **The average bitrate change**: How frequent and largely the bitrate switches
- **Comparison method**
  - TCP-Like AIMD [8]: throughput-based ABR algorithm
  - BOLA-O [4]: an algorithm used in dash.js which is a client-side reference implementation of MPEG-DASH

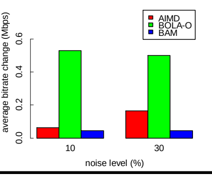
[4] K. Spiteri, R. Urgaonkar, and R. K. Sitaraman, "BOLA: Near-optimal bitrate adaptation for online videos," in Proceedings of IEEE INFOCOM 2016, vol. 2016-July, 2016.
[8] C. Liu, "Rate Adaptation for Adaptive HTTP Streaming," Dl.Acm.Org, pp. 169–174, 2011. [Online]. Available: https://dl.acm.org/citation.cfm?id=1943575

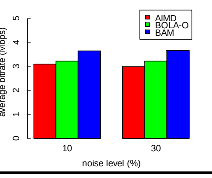
Simulation scenario

- **Video content for simulation**
  - The 5 minute video was encoded at 5 bitrates
    - $0.5Mbps, 1.0Mpbs, 1.5Mbps, 3.0Mbps, 5.0Mbps$
  - It is partitioned into 1 second segments
    - ABR algorithms can switch a bitrate every time the download is completed
- **Network environment for simulation**
  - The average value of available bandwidth is changed every $30s$
    - The value is switched to $9.0, 4.0, 2.0, 1.0, 2.0, 4.0,$ *and* 9.0 $Mbps$ in order
  - Additionally, we add a different noise to each average value
    - The noise follows a normal distribution having an average of zero and standard deviation of $\boldsymbol{l_{noise}}$ (%) of each average value
    - l_{noise} is set to 10% and 30%.

Simulation result

- **For the average bitrate change (left figure)**
  - The changes of the BOLA was larger than that of the other methods
    - The BOLA's bitrate selection depends on recent estimated bandwidth strongly
  - In both AIMD and the BAM, the average bitrate change is low
    - The BAM achieves better performance at noise level of 30
- **For the average bitrate (right figure)**
  - The BAM had the highest results at both noise level of 10, 30





Summary and future work

- **Summary**
  - We focused on the cognitive model of a human's brain, the Bayesian attractor model (BAM)
  - With the BAM, we proposed a method that recognizes the video player's condition and selects an appropriate video bitrate
  - Our computer simulation shows that our proposed method can perform appropriate bitrate control
    - Even in the situation where network available bandwidth greatly fluctuates
- **Future work**
  - Implement our proposed method in an actual video streaming application
  - Reflect a user's preference for video quality in bitrate selection
    - Using feedback signal from EEG (Electroencephalogram), our method realizes bitrate selection according to a user's preference