1 Modeling of the P2P service migration problem

We suppose there are M videos, and N ISPs. There are one on-premise server and one cloud node in each ISP.

1.1 Optimization of the problem with Lyapunov optimization

This is a combination of optimization for one time deployment and time-average variables. The placement of content is one time deployment while the schedule is for time-average.

Notation definition:

B_s: storage capacity of the on-premise server

B_u: upload bandwidth capacity of the on-premise server

h_j: charging rate for storage on the cloud at the $j-th$ ISP

k_j: charging rate for upload bandwidth on the cloud at the $j-th$ ISP

s_m: storage of $m-th$ video

$x_m^j = \{0,1\}, m = 1, ..., M$: $x_m^j = 1$ if the placement of the $m-th$ video is on the on-premise server at the $j-th$ ISP; $x_m^j = 0$ otherwise;

$y_m^j = \{0,1\}, m = 1, ..., M$: $y_m^j = 1$ if the placement of the $m-th$ video is on the cloud at the $j-th$ ISP; $y_m^j = 0$ otherwise;

D_s^{ji} is the delay from source j to on premise server i, and D_c^{ji} is the delay from source j to on cloud node i.

$A_m^j(t)$: at time slot t, number of requests of the $m-th$ video generated from the $j-th$ ISP.

$r_m^j(t)$: at time slot t, number of requests of the $m-th$ video that are admitted into the system. $r_m^j(t) \leq A_m^j(t)$

$S_m^j(t)$: at time slot t, number of requests for video m that are routed from region j to on-premise server i

$C_m^{ji}(t)$: at time slot t, number of requests for video m that are routed from region j to cloud node i

$Q_m^j(t)$: at time slot t, queues of requests from video m from ISP j.

Note: The queue update is: $Q_m^j(t+1) = \max[Q_m^j(t) + r_m^j(t) - S_m^j(t) - \sum_{i=1}^N C_m^{ji}(t), 0]$

Different from the previous sub section, $S_m^j(t)$ and $C_m^{ji}(t)$ is not a schedule of fraction of arrival rates for all time slots. Now they are schedule of number of requests (integers) for each time slot.

Note: minimize sum of:

- time average spending cost of upload bandwidth at cloud node
- spending cost of time average upload bandwidth at on premise server
- cost of storage at cloud
- cost of storage at on premise server
- time average weighted delay

maximize $g(\sum_{m=1}^{N}\sum_{j=1}^{N}\overline{r_m^j})-\alpha_1\overline{\sum_{m=1}^{M}\sum_{j=1}^{N}\sum_{i=1}^{N}(s_m C_m^{ji}(t)k_i)}-\alpha_2\sum_{m=1}^{M}\sum_{j=1}^{N}\sum_{i=1}^{N}\overline{s_m S_m^j(t)}-\alpha_3\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m y_m^j h_j)-\alpha_4\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m x_m^j)-\alpha_5\sum_{j=1}^{N}\sum_{i=1}^{N}\overline{\sum_{m=1}^{M}s_m(C_m^{ji}(t)D_c^{ji}+S_m^{ji}(t)D_s^{ji})}$
subject to:
$y_m^j=\{0,1\},\forall j=1,...,N,\forall m=1,...M$
$x_m^j=\{0,1\},\forall j=1,...,N,\forall m=1,...M$
$0\le S_m^j(t)\le S_m^j(t)x_m^j,\forall j=1,..,N,\forall i=1,...,N,\forall m=1,...,N,\forall t$
(instead, we can assume that on premise server keeps all videos)
$0\le C_m^{ji}(t)\le C_m^{ji}(t)y_m^t,\forall j=1,..,N,\forall i=1,...,N,\forall m=1,...,N,\forall t$
$\sum_{m=1}^{M}s_m x_m^j\le B_s,\forall j$ (on-premise server's storage constraint)
$\sum_{m=1}^{M}\sum_{j=1}^{N}s_m S_m^j(t)\le B_u,\forall i=1,...,N,\forall t$ (on-premise server's upload bandwidth constraint)
Queues $Q_m^j(t)$ is stable, $\forall m,j$, i.e., $\overline{r_m^j(t)}\le\overline{\sum_{i=1}^{N}S_m^j+\sum_{i=1}^{N}C_m^{ji}}$
$Q_m^j(0)=0,\forall m,j$
Note:
known values: B_s, B_u, h_j, k_j, s_m, $r_m^j(t)$, D_c^{ji}, D_s^{ji}
optimization variables: x_m^j, y_m^j, $S_m^j(t)$, $C_m^{ji}(t)$

$\overline{\sum_{m=1}^{M}\sum_{j=1}^{N}\sum_{i=1}^{N}(s_m C_m^{ji}(t)k_i)}+\alpha\sum_{m=1}^{M}\sum_{j=1}^{N}\overline{s_m S_m^j(t)}+\beta\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m y_m^j h_j)+\gamma\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m x_m^j)-\rho\sum_{j=1}^{N}\sum_{i=1}^{N}\overline{\sum_{m=1}^{M}s_m(C_m^{ji}(t)D_c^{ji}+S_m^{ji}(t)D_s^{ji})}$
$=\sum_{m,j,i}s_m\overline{C_m^{ji}}k_i+\sum_{m,j}\alpha s_m\overline{S_m^j}-\sum_{m,j,i}\rho s_m\overline{C_m^{ji}}D_c^{ji}-\sum_{m,j}\rho s_m\overline{S_m^j}D_s^{ji}+\beta h\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m y_m^j)+\gamma\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m x_m^j)=\sum_{m,j,i}s_m\overline{C_m^{ji}}k_i+\sum_{m,j}\alpha s_m\overline{S_m^j}-\sum_{m,j,i}\rho s_m\overline{C_m^{ji}}D_c^{ji}-\sum_{m,j}\rho s_m\overline{S_m^j}D_s^{ji}+\beta h\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m y_m^j)+\gamma\sum_{m=1}^{M}\sum_{j=1}^{N}(s_m x_m^j)$
$\Delta(Q(t))-Vutility$
$\le B+\sum_{m,j}Q_m^j(t)(r_m^j(t)-S_m^j(t)-\sum_{i=1}^{N}C_m^{ji}(t))-Vg(\sum_{m,j}r_m^j(t))+V(\sum_{m,j,i}s_m C_m^{ji}(t)k_i+\sum_{m,j}\alpha s_m S_m^j(t)+\sum_{m,j,i}\rho s_m C_m^{ji}(t)D_c^{ji}+\sum_{m,j}\rho s_m S_m^j(t)D_s^j)$
$=B-\sum_{m,j,i}C_m^{ji}(t)(Q_m^j(t)-Vs_m k_i-V\rho s_m D_c^{ji})-\sum_{m,j}S_m^j(t)(Q_m^j(t)-V\alpha s_m-V\rho s_m D_s^j)-(Vg(\sum_{m,j}r_m^j(t))-\sum_{m,j}r_m^j(t)Q_m^j(t))$

2 Extension

1. Add time average budget constraint 2. Add queueing delay