SocialVoD: a Social Feature-based P2P System

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Outline

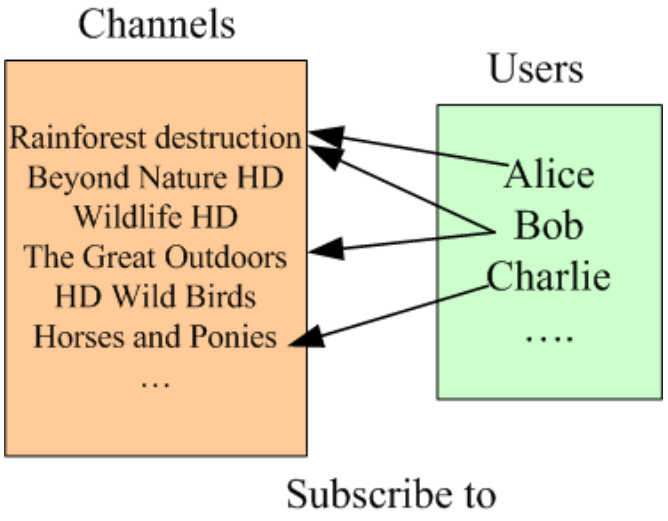
1. Introduction
2. Background and Related Work
3. Vimeo Category and User Interests
4. Overlay Design and File Searching
5. Evaluation
6. Conclusion

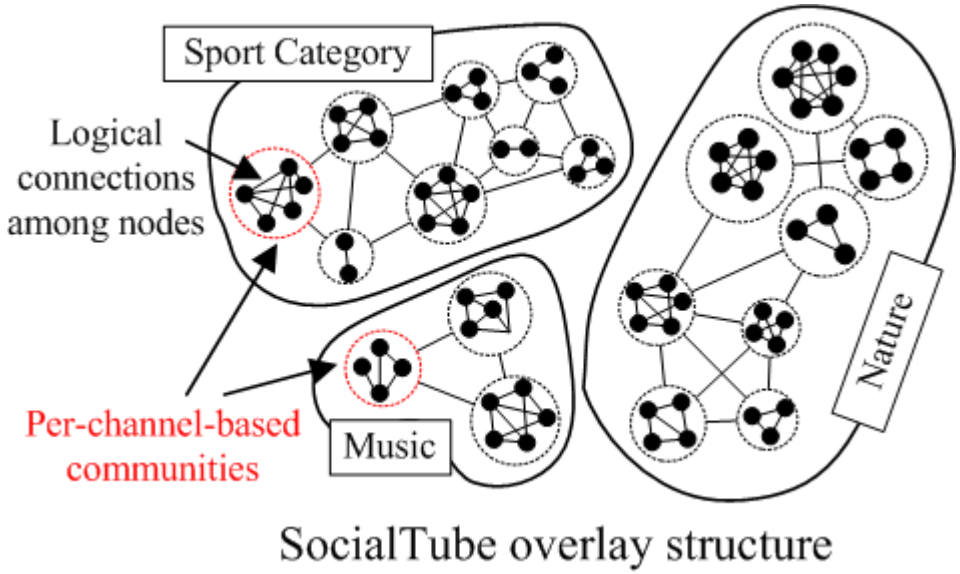
Introduction

- Video-on-demand (VoD) service has been explosively growing since its first appearance. For maintaining an acceptable buffering delay, the bandwidth costs have become a huge burden for the service providers.
- Complementing the conventional client-server architecture (CS) with a peer-to-peer system (P2P) can significantly reduce the central server's bandwidth demands.
- Previous works focus on establishing a P2P overlay for each video, which not only generates prohibitive costs for maintaining the overlay, but also create plenty of redundant links between a pair of nodes on different overlays.

Introduction (cont.)

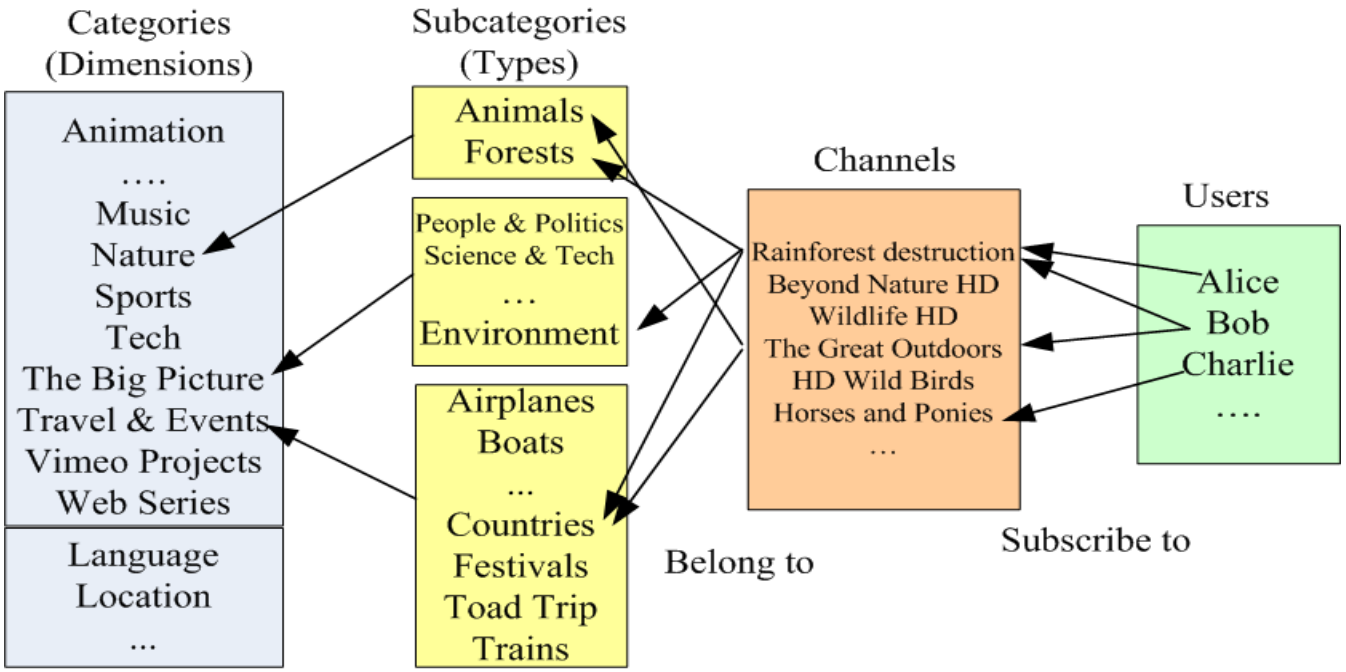
- Many VoD sites provide channel subscription functions to users.
- Considering that the subscribers of a channel are likely to watch the same videos from the channel, SocialTube proposes an interest-based per-channel hierarchical overlay.





Introduction (cont.)

- SocialTube has two problems.
  - It is not efficient for subscribers to explore (unsubscribed channels') videos belonging to other categories.
  - It is not applicable for the VoD sites, such as Vimeo, who are rich in category information.



Introduction (cont.)

- In this paper, we propose a new hierarchical P2P overlay structure, called SocialVoD, by exploring both the subscription relationships and channels' similarities on Vimeo.
- The key design of SocialVoD is the utilization of channel subscribers' social closeness: the closer the watching preferences of users are, the better the overlay connectivity should be between them.
- We not only build interest-based per-channel overlays, but also, in a high-level, we organize these overlays according to channels' existing category information: by neighboring the channel overlays, whose category information differs in one dimension, the resulting graph contains enough routing "hints" for seeking other unsubscribed channels' videos.

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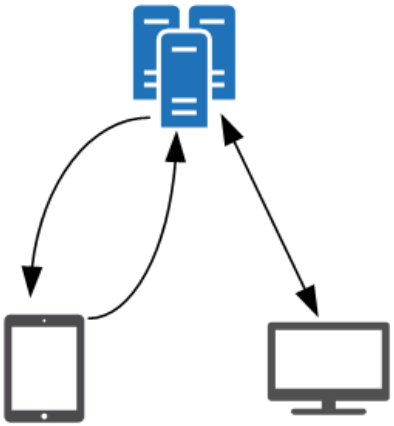
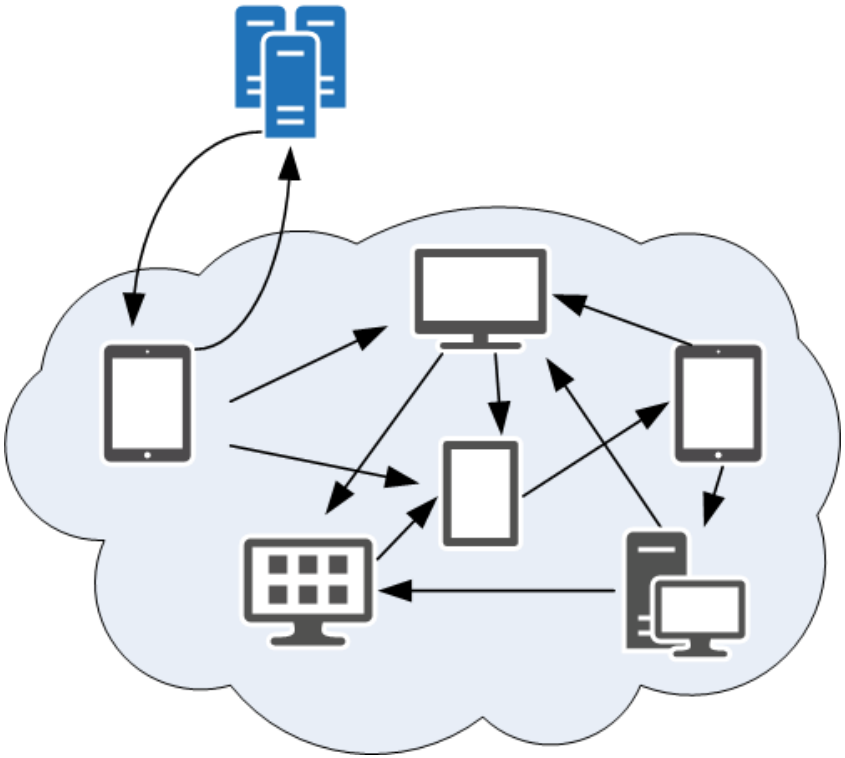
Background and Related Work





P2P overlay design:

- Without social information
  - Hypercup and et al.
- With social information
  - NetTube: same watching history
  - SocialTube: same channel subscription
  - SocialVoD: neighboring nodes with similar watching preferences

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Vimeo Category and User Interests

- It has been shown that most videos on VoD systems are short, and there are strong clustering behaviors among users.
- We further investigate the category features on Vimeo, and the change of users' interests over years.
- There are 58.06% popular channels (>300 subscribers) associated with more than one category feature.
- Users' watching preferences do change over the years.

TABLE I. THE DISTRIBUTION OF VIMEO CHANNELS' ASSOCIATED CATEGORY NUMBERS.

Number of Categories	1	2	3	4	5	...
Percentage (%)	41.94	38.11	8.44	7.54	3.96	0

TABLE II. THE CHANGE OF CATEGORY INTERESTS OVER 5 YEARS (%)

Year	Narrative	Arts	Music	Video School	Personal	Big Picture	Sports	Animation	Travel	Tech	Experimental	Comedy	Nature
2011	21.7	16.6	41.7	0	3.3	0	10.0	3.3	0	0	0	3.4	0
2010	41.2	4.8	4.1	4.5	11.4	4.6	0	9.4	13.6	0	1.8	4.6	0
2009	35.7	1.8	12.5	0	0	7.1	14.3	5.4	0	14.3	8.9	0	0
2008	13.0	6.2	22.5	24.5	4.1	4.1	4.1	6.2	0	2.9	4.2	8.2	0
2007	8.8	9.3	8.1	16.8	7.0	0	0	12.5	0	7.6	17.9	6.0	6.0

Watching Pattern of Users

- We summarize users' watching pattern of as follows:
  - Users frequently look for the videos from their subscribed channels;
  - Users are likely to seek other unsubscribed channels' videos, which satisfy their watching habits;
  - The watching habits may change. Users may access certain videos to explore new preferences.
- Based on these features, we design the new P2P overlay structure, SocialVoD.

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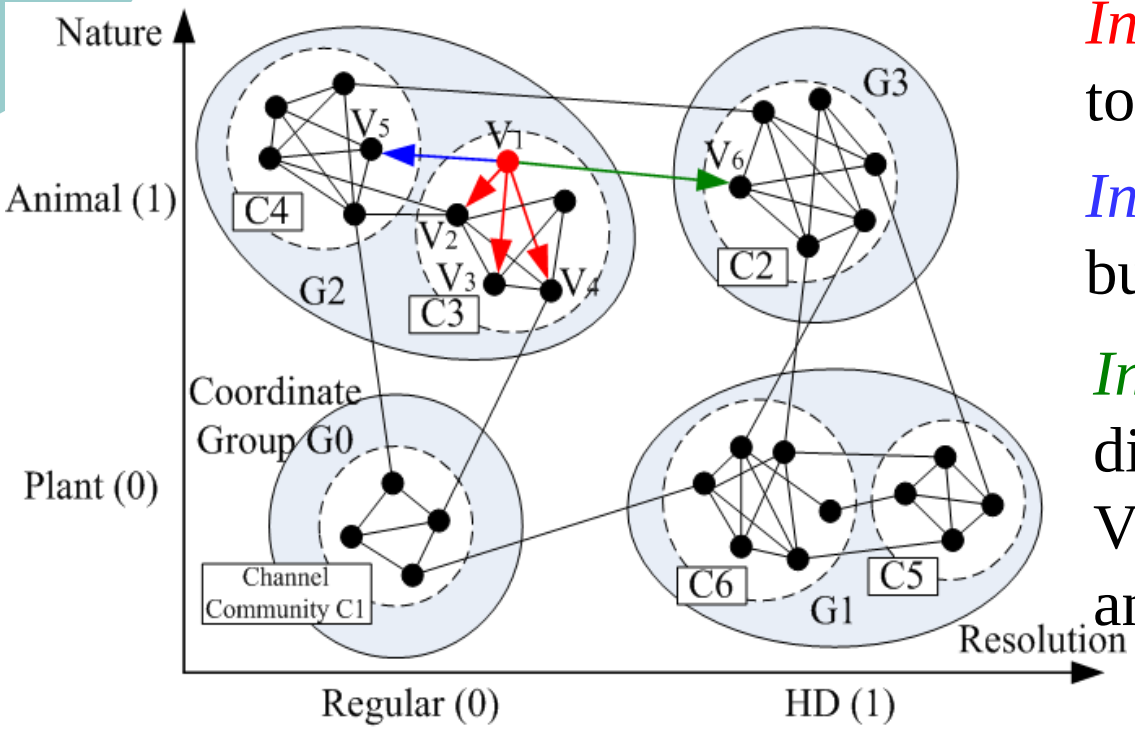
Overlay Design: basic model

- Feature coordinate of a video: $(f_1, f_2, \ldots, f_m), 1 \leq f_i \leq r_i$
- e.x. , in "Language" category dimension, $f_i = 0, 1, 2, \ldots$ may indicate English, Chinese, Spanish, and et al.
- Based on the feature coordinates, the category-feature space is partitioned into $\Pi_{i=1}^{m} r_i$ groups, and each channel belongs to one and only one group.
- Mapping: real-world users → nodes on P2P
- Establishing a logical connection in P2P: storing the IP address of another user.

Overlay Design: overlay construction

- There are three types of connections in SocialVoD, and the number of connections for each type following: $p : (1-p)q : (1-p)(1-q)$, $p, q \in (0.5, 1)$



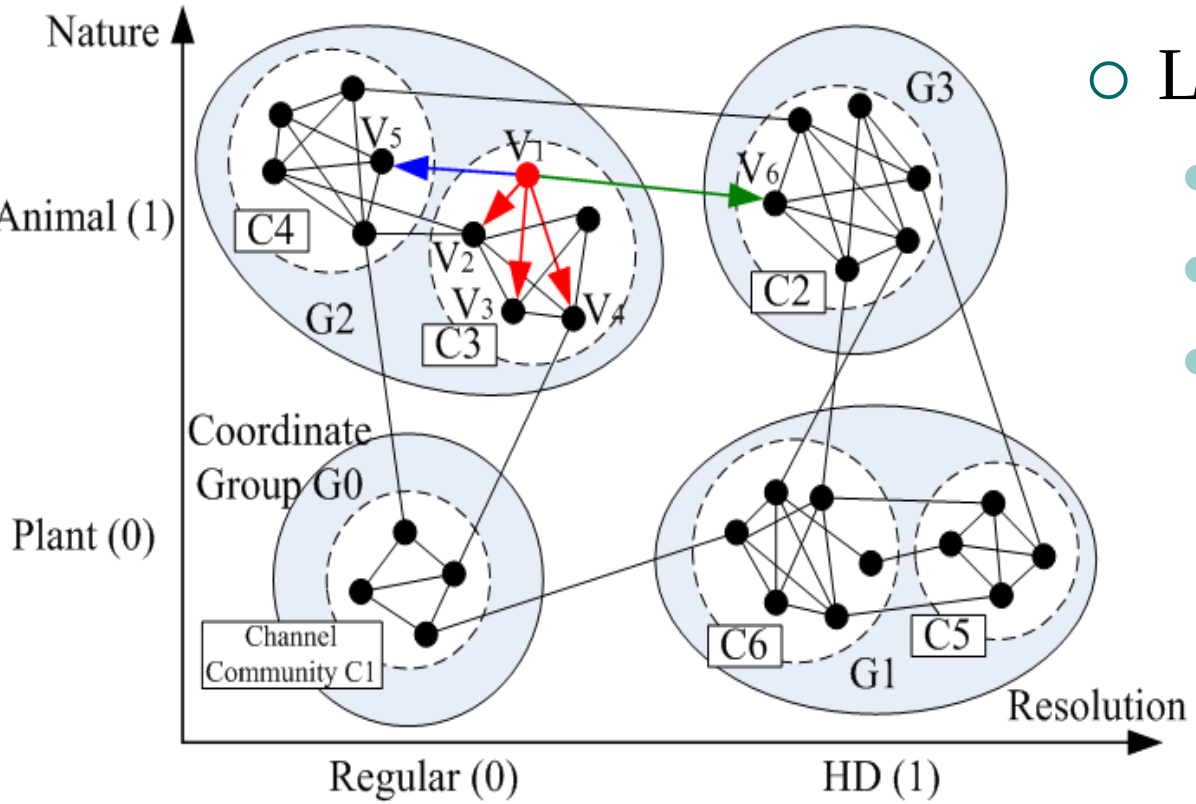
Intra-channel: V_i,V_j subscribes to the same channel, i.e. V_1V_2.

Intra-group: different channel but same coordinate, i.e. V_1V_5.

Inter-group: feature coordinates differ in one dimension, i.e. V_1V_6, where coordinates of V_1 and V_6 are (0,1) and (1,1).

Overlay Construction (cont.)

- SocialVoD creates a two-tier community structure and three levels of overlays. Different types of queries are conducted by different overlays.



- Link management
  - New node joining
  - Link updating
  - SocialVoD gives more emphasis on how to reach a destination, instead of where the destination is.

Routing in SocialVoD

- A query is conducted by two steps in SocialVoD:
  - Feature-spaced inter-group routing: use the highest-level overlay to locate the group with the specific feature coordinate.
  - Intra-group/channel searching: apply the conventional random walk-based approach to search the target file within the specific group or channel.
- In order to control the network traffic, each query has a limited number of query copies, assuming h. During inter-group routing, one should avoid the situations where several query messages search the same space.

Coordinate Routing Sequence

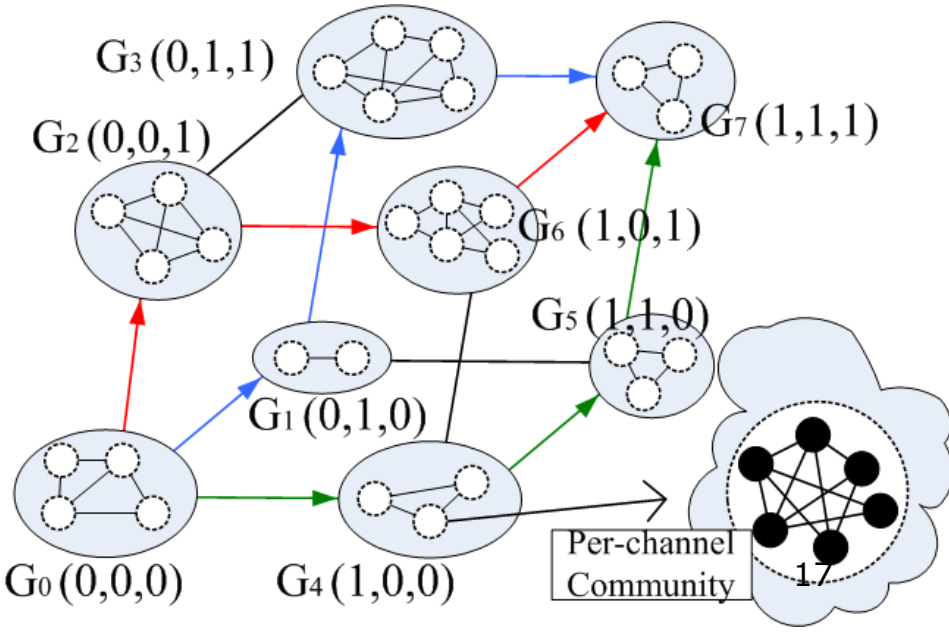
- Feature difference set $H(S, D)$: a set of different dimensions between source S and destination D.
- Coordinate routing sequences: suppose S differs D in k dimensions, $H(S, D) = \{1, 2, ..., k\}$; there are k coordinate sequences forming k node-disjoint paths.

$$R_1 = \langle 1, 2, ..., k-1, k \rangle$$
$$R_2 = \langle 2, 3, ..., k, 1 \rangle$$
$$\cdots\cdots$$
$$R_k = \langle k, 1, ..., k-2, k-1 \rangle$$

- For example:

$R_2 = \langle 2, 3, 1 \rangle$: blue path

$R_3 = \langle 3, 1, 2 \rangle$: red path



The Selection of Coordinate Routing Sequences

- When h<k, the source S needs to determine which path (or coordinate routing sequence) has more of a chance to reach the destination group.
- We approximate a coordinate routing sequence's success rate by subcategories' popularity:

$$T_i' = (|H|-1)! \prod_{j \in H \setminus \{i\}} T_j, \text{ where } \quad T_i = \frac{|\{v_j | F_i(v_j) = d_i, v_j \in V\}|}{|\{v_j | F_i(v_j) \neq s_i, v_j \in V\}|}$$

- Source node always selects the top-h sequences with the highest success rate. This method essentially explores the rare intergroup links first.

Feature Space Routing

Algorithm 2 Inter-group Routing from Source S

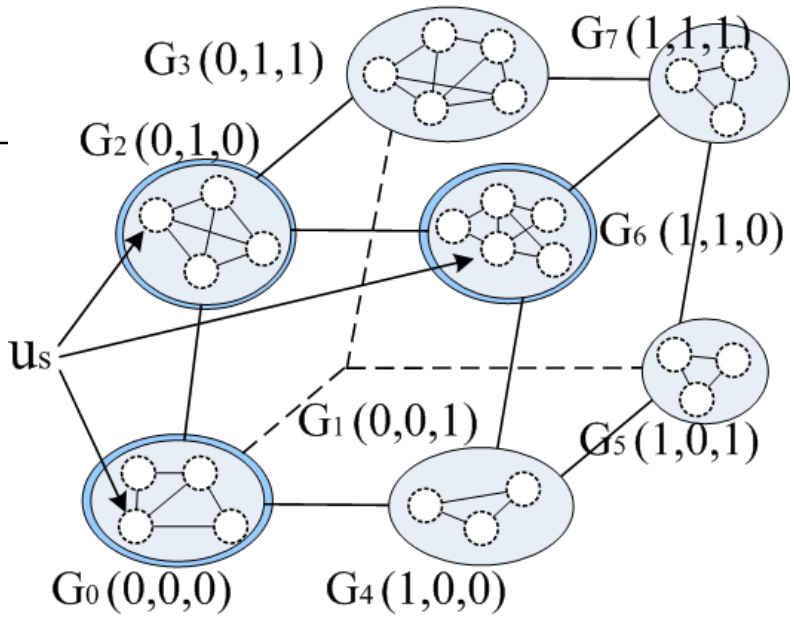
while $h > 0$ **do**
  if $R \neq \phi$ **then**
    /*shortest path routing*/
    Pick up a sequence R_i from R.
    Find $G_j \in N(G_s)$ s.t. $F_i(G_j) \neq s_i, F_i(G_j) = d_i$.
    $R \leftarrow R \backslash \{R_i\}$, $mode \leftarrow 0$, send $(R_i, mode)$ to G_j.
  else
    /*non-shortest path routing*/
    Find $G_j \in N(G_s)$ s.t. $F_i(G_j) \neq s_i, i \in \overline{H}$.
    $\overline{H} \leftarrow \overline{H} \backslash \{i\}$, $mode \leftarrow 1$, send $(H \bigcup \{i\}, mode)$ to G_j
  $h \leftarrow h - 1$

Algorithm 3 Inter-group Routing for a Relay Node in G_i

if $F(G_i) = F(D)$ **then**
  Use intra-group routing within G_i.
else
  if $mode = 0$ **then**
    $R \leftarrow R \backslash R[1]$, the next resolving dimension $k \leftarrow R[1]$.
    Find $G'_i \in N(G_i)$ s.t. $F_k(G_i) \neq d_k, F_k(G'_i) = d_k$.
    Send $(R, mode)$ to G'_i.
  if $mode = 1$ **then**
    $H \leftarrow H \backslash \{j\}$.
    Find $G'_i \in N(G_i)$ s.t. $\exists k \in H, F_k(G_i) \neq d_k, F_k(G'_i) = d_k$. Send $(H, mode)$ to G'_i.

- Source node:
  - Are there redundant searching paths?
  - If not, which coordinate sequences should be used?
- Relay node:
  - Am I in the destination feature group?
  - For a query message, does it use shortest-path mode or non-shortest path mode?
  - Who should I forward the message to?

Extension



- Multi-channel subscription
  - Initial node selection
  - Feature matching shortcut
- Pre-fetch for new videos
  - Random walk-based propagation
- Routing for non-subscribers
  - Most frequently searched subcategory features
  - Local overlay keeps updating while developing his own watching preference

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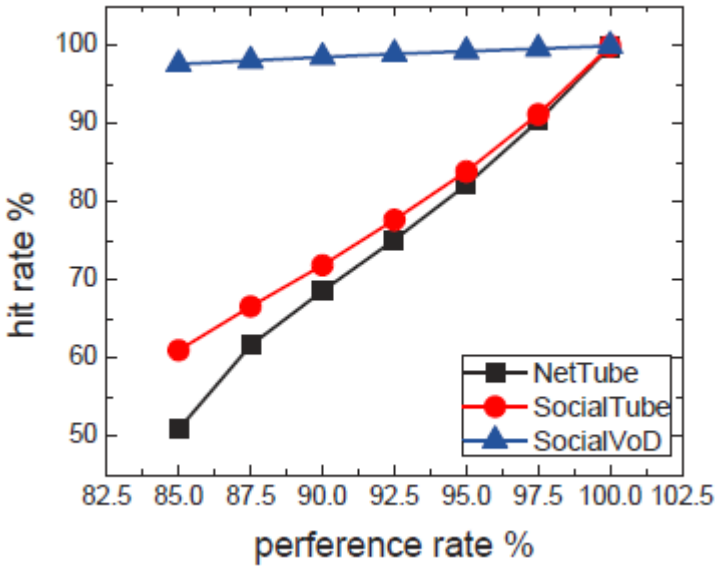
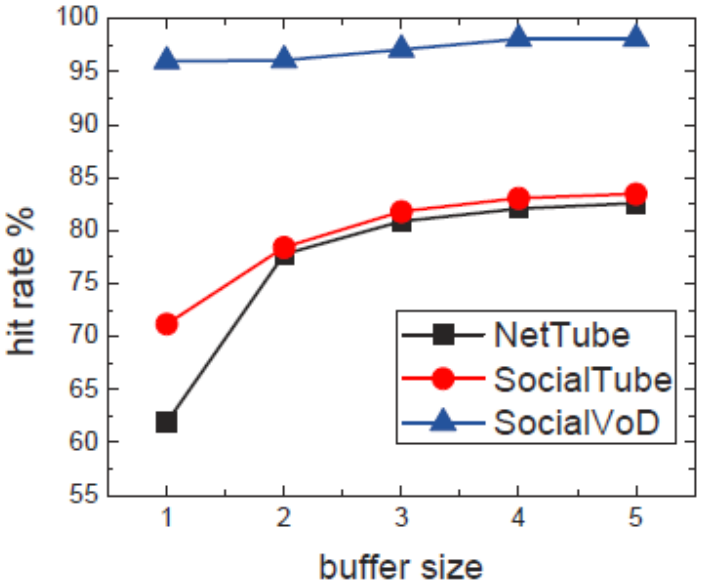
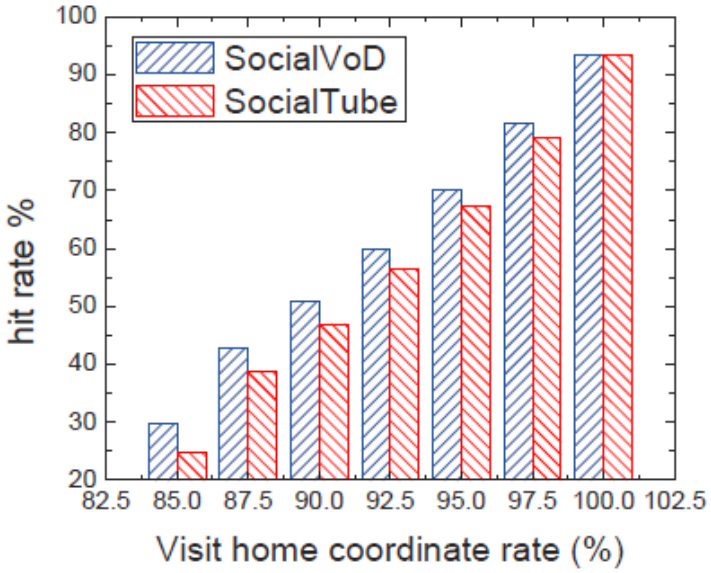
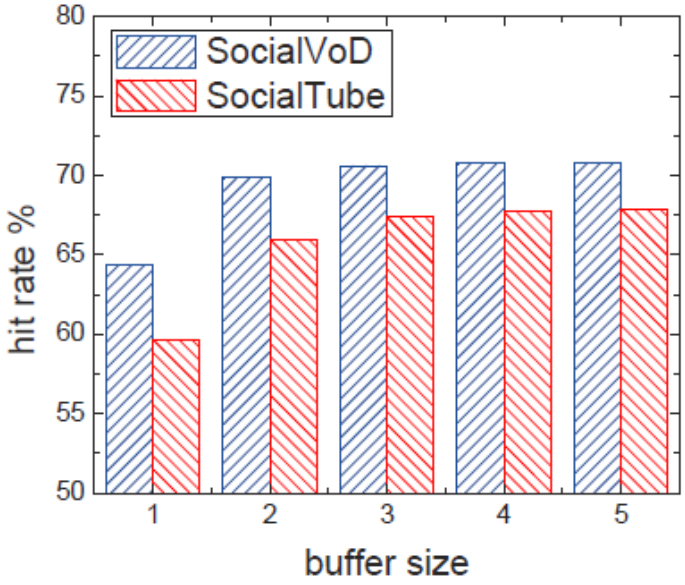
Evaluation


hit rate %
perference rate %
NetTube
SocialTube
SocialVoD


hit rate %
buffer size
NetTube
SocialTube
SocialVoD


hit rate %
Visit home coordinate rate (%)
SocialVoD
SocialTube


hit rate %
buffer size
SocialVoD
SocialTube

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Conclusion

- We find that the existing P2P systems do not fully utilize the social properties behind the users' watching patterns.
- Based on the existing channel subscription knowledge and category structure on the Vimeo platform, we introduce a new hierarchical P2P overlay structure.
- Our new system explores the existing category information as an overlay's construction "guide" and routing "hints", which significantly reduces the searching space of videos.
- We provide extensive simulations to show that our new system can efficiently locate the files and is applicable in a large scale.

Thank you!