MULTIMEDIA COMMUNICATIONS TECHNICAL COMMITTEE
IEEE COMMUNICATIONS SOCIETY
http://www.comsoc.org/~mmc

E-LETTER

Vol. 7, No. 5, May 2012

IEEE COMMUNICATIONS SOCIETY

CONTENTS

SPECIAL ISSUE ON "ADVANCES IN MULTIMEDIA SOCIAL NETWORKS"

Advance in Multimedia Social Networks

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With the growth of multimedia applications and reshaping of high-speed internet, large size multimedia content can be delivered smoothly to end users for their entertainment. These end users not only consume multimedia content such as online TV program, and but also produce the multimedia content such as photos and video clips to the internet servers. The social relationships among end users significantly impact the multimedia content distribution and usage. On the other hand, multimedia cloud computing and services grow fast and are providing powerful software and service platforms for many online social network applications.

However, there are still significant research challenges remained for multimedia social networks. For example, (1) network bandwidth dynamics due to heterogeneous networks make it difficult to guarantee QoS for social network applications. (2) The computational intensive media processing on lightweight mobile social clients is time and energy consuming. (3) the complex relationship between social structure and patterns of multimedia content distribution demands further investigations.

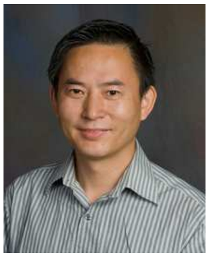
Therefore, significant research efforts are expected in the area of media processing, social networks and communications to push forward this key multimedia social network technology.

In the first paper titled as **"Content Delivery as a Service for Cloud-Centric Multimedia Social Networks,"** a novel cloud based content delivery solution is provided to address the problem on the efficient distribution of user generated content in multimedia social networks. In particular, the authors aim to realize content delivery as a service by leveraging the cloud computing technology. The schematic framework along with the design on media cloud, cloud-centric media platform and an application example, social media are presented.

An increasing amount of requests of the video sites are from online social networks (OSNs) nowadays. Their word-of-mouth based information spreading mechanisms have substantially reshaped the workload of online video services. In the second paper titled "**Video Sharing Re-shaped: An Initial Investigation on the Impact of Online Social Networks**" the authors observes the growth, and describes the technology. Particularly, they pointed out that the skewness of video popularity distribution are extremely amplified, and many attractive videos have only received limited requests in OSNs with existing imperfect video spreading mechanisms.

The third paper titled as "**Game-theoretical Approaches in Wireless Multimedia Social Networks**", which firstly provides a general introduction of the developing wireless multimedia social networks (WMSN). Then, the authors give a survey of game theoretical approaches in WMSNs with respect to important issues, including resource allocation, incentive cooperation, and copyright and digital right management. Several potential interesting issues are also pointed out for further study, e.g., energy efficiency, QoS and cross-layer consideration.

The fourth paper titled as "**Relational Data Acquisition for Animal Social Networks: Challenges and Solutions**" is a interesting research article. The authors address the major issues of animal social networks. The study of animal social networks aims at understanding the social structures and behavior of interested groups of animals, such as dolphins. However, the acquisition of animals' relational data is the first but challenging task in the study. Accordingly, this article presents an initial research effort in developing a relational data acquisition framework based upon wireless sensor networks, and solutions addressing technical challenges, e.g, long data latency, short sensor node energy life, faced in realizing the framework.



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Content Delivery as a Service for Cloud-Centric Multimedia Social Networks

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1. Introduction

Multimedia social networks, owing to the ubiquitous penetration of high-speed Internet and the rapid advances in media technology, are revolutionizing the social interactions over Internet. Nowadays, Internet users not only simply consume contents, but also publish their own generated contents (e.g., photos, videos and podcasts etc.). In 2008, 42.8% of Internet users in the U.S. (i.e., 82.5 million) contributed to user generated contents (UGC) [1], and 75% of Internet users consumed social media contents by joining social networks and reading blogs [2].

However, current content distribution solutions are inadequate to distribute UGC in multimedia social networks, due to the long-tail nature and the unique requirements (e.g., personalized QoS, micro-transaction, etc.) [3]. The leading content delivery network (CDN) service providers (e.g., Akamai, Limelight, etc.) tailor their networking architecture and the operational structure towards popular contents. As a result, they are inefficient and inflexible for UGC distribution in a profitable way.

In this article, we briefly discuss a novel content distribute solution, Content Delivery as a Service (CoDaaS) [4] [5] for this problem. Leveraging the cloud computing technology, CoDaaS is able to distribute UGCs in the most economical way, while respecting the personalized QoS metrics. Specifically, upon receiving a content delivery request from a UGC provider, CoDaaS will dynamically calculate the most cost-effective content distribution tree over an underlining media cloud, and configure a private virtual content delivery service (vCDS) overlay over the content distribution tree. The resulting vCDS then pushes the content to a list of consumers to fulfill the multimedia social interactions. When the required service time expires, this vCDS will be torn down by returning the IT resources back to the virtual resource pool.

2. Schematic Overview on CoDaaS

CoDaaS is a service model that architects over a hybrid media cloud infrastructure, as indicated in figure 1. The media cloud consists of a set of interconnected data centers, forming an un-configured content-distribution overlay. Each media data center exposes a pool of IT resources, including computing, storage and bandwidth via resource virtualization techniques [6]. A media cloud messaging bus powered by XMPP [7] is used to coordinate the resource pools and configure the virtual content delivery service for content providers. CoDaaS provides users and developers with social media software development kit (SDK) and a set of application programming interfaces (APIs). As a result, a variety of application such as social TV, social games can be integrated into a platform portal easily and efficiently.

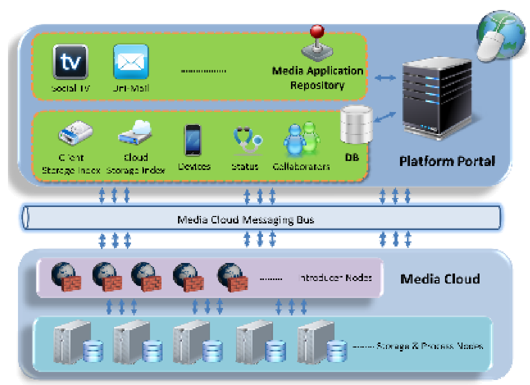


Figure 1. Schematic Overview on CoDaaS

3. Media Cloud

The media cloud serves as the infrastructure substrate of CoDaaS that is based on server virtualization, storage virtualization and network virtualization. The functional components of media cloud contain content distribution module, content process module, content storage module, and content routing module.

Content distribution module provides services to optimally distribute the content from its source to its consumers. These services are supported by content caches strategically located through the network. Our current implementation makes use of distributed hash table (DHT), one of the major Peer-to-Peer (P2P) technologies, to dynamically construct the virtual distribution tree and manage the content cache among the underlying VMs.

Content processing module provides services for content processing and rendering. It adaptively acquires contents in a context-aware manner (e.g., networking conditions, user preferences and device capability). Specifically, this module encodes published media into different formats, as soon as the content is injected into CoDaaS. Once there is a request, it will transfer the content with most suitable format to the consumers.

Content storage module provides services for storing user-generated contents in the CoDaaS platform, in a security level specified by content providers. According to different SLAs, it may place more than one copy in replicas, and do the synchronization operation among them to keep the consistency.

Content routing module provides services for navigating both clients' requests to upload their contents and consumers' requests to retrieve the contents. The selection of the most appropriate target location and routing path is typically based on the network proximity and the availability of system resources.

4. Cloud-Centric Media Platform

The cloud-centric media platform is a Platform as a Service (PaaS) layer, based on the media cloud. It provides developers with various APIs for storage management, status synchronization of contents, social group interactions and media application launcher etc. There are also a set of APIs for the admins to monitor media cloud infrastructure, configure and bookkeep virtual content delivery services, and visualize real-time system dynamics.

5. Application Example: Social Media

Figure 2 illustrates an application demo, multi-screen social TV, which is built upon CoDaaS architecture. It is a web based application powered by HTML5 and JavaScript. This demo allows users to publish their own contents to the media cloud, and consume any contents with their friends in the real-time style. The users within one social group can enjoy the same video with the same timeline at the same time. Meanwhile, they are also able to conduct a video conference to share their attitudes and feelings in a more active way. Finally, a session transfer scheme is enabled for the users to synchronize the contents what they are currently consuming among different devices (e.g., laptops, tablets and smart phones).

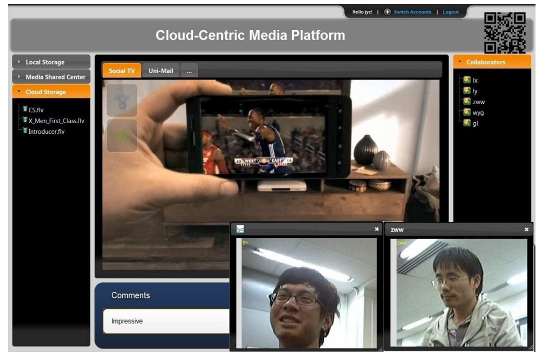


Figure 2. Screenshot of Social Media Web UI

6. Conclusion and Ongoing Works

Motivated by the dramatic growth of UGC and multimedia social networks, this E-Letter briefly presents Content-Delivery-as-a-Service (CoDaaS) in a nutshell. This cloud-centric solution is designed to meet all the unique requirements for UGC delivery in an economical and elastic way. It represents a paradigm shifting from a whole-sale content distribution market, as dominated by large CDN service providers (e.g., Akamai and Limelight), to a retail content delivery market.

At present, CoDaaS is still on its way to get improved on both technology innovation and system development. On technology innovation, we are working on exploiting optimal system parameter and operational algorithms including the distributed cache algorithm, virtual content delivery topology optimization and media stream compression. On system development, efforts are putting on enhancing the existing features by involving a larger scale resource pool, and providing applications and APIs to smart phone users.

References

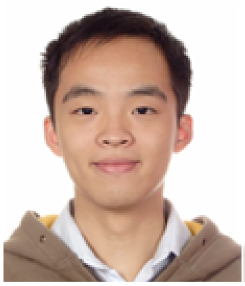
[1] P. Verna, *A Spotlight on UGC Participants*.[online] http://www.emarketer.com/Article.aspx?R=1006914.

[2] A.M. Kaplan, M. Haenlein, *Users of the world, unite! The challenges and opportunities of Social Medial.* Journal of Business Horizons vol. 53, no. 1, pp. 59–68, 2010.

[3] M. Cha, H. Kwak, et al., *Analyzing the Video Popularity Characteristics of Large-Scale User Generated Content Systems*, IEEE/ACM Transactions on Networking, vol. 17, no.5, pp.1357-1370, 2009.

[4] Y. Wen, G. Shi, et. al., *Designing an inter-cloud messaging protocol for content distribution as a service (CoDaaS) over future internet*, 6th Int'l Conference on Future Internet Technologies, pp. 91-93, 2011.

[5] Y. Jin, Y. Wen, et al., *CoDaaS: An Experimental Cloud-Centric Content Delivery Platform for User-Generated Contents*, Int'l Conference on Computing, Networking and Communication, pp. 934-938, 2012.
[6] P. Barham, B. Dragovic, et al., *Xen and the Art of Virtualization*, Operating Systems Review, Vol. 37, pp. 165-177, 2003.
[7] P. Saint-Andre, *Extensible Messaging and Presence Protocol (XMPP): Core*, RFC 6120, 2011.



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Video Sharing Re-shaped: An Initial Investigation on the Impact of Online Social Networks

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1. Introduction

Recently, online social networks (OSNs) have become popular destinations for connecting friends as well as sharing contents [1, 2]. Starting from 2007, users can post YouTube videos in Facebook, and then these videos can be shared among friends. The interaction between video sharing sites (VSSes) and OSNs through video link sharing provides new implications in business opportunities. The VSSes can boost their daily video views by a large margin through OSN shares; on the other hand, the OSNs readily offer a video service with no extra cost. As a result, this convenient service has been widely acclaimed, and Facebook then quickly become one of the major portals for users to share and view YouTube videos, albeit the real video data remains to be downloaded from YouTube. It is reported that as of January 2011 over 150 years worth of its video is watched on Facebook every day [3]. Besides Facebook/YouTube, we have seen similar trends in other OSNs/VSSes, for example, between RenRen [4], the largest Facebook-like OSN in China, and Youku [5], one of the most popular VSS in China. Our measurement shows that, as of July 2011, more than 54 million unique RenRen users have participated in video viewing and 20 million participated in sharing, generating 12.4 million views and 1.64 million shares every day. Among these shared videos, 80% are hosted by Youku.

However, such characteristics have not yet been explored in real online social networks at large scales due to a number of challenges. First, privacy protection generally prevents crawling video viewing information as easily in OSNs as in VSSes; Second, unlike dedicated video sites, OSNs rarely provide rich statistics about shared videos; Finally, given the wide distribution of OSN users, tracing traffic from a small subset of network routers/switches can hardly reveal the geographic evolution of video sharing, not to mention the sheer volume of the mixed network traffic to be analyzed.

To understand video sharing in OSNs, we closely collaborate with RenRen to analyze its server access logs. Starting from March 24^{th}, 2011, we recorded the detailed user viewing and sharing behaviors over three months: when a user started to view a video shared by her/his friend or further shares the video, a separate record was sent to the log server. The trace data records such information as the time, viewer, sharer, and video URL, which enables us to extract rich statistics. Our measurement unveils many distinctive features of video sharing through OSNs as compared to VSSes [6, 7]. In this paper, we focus on the video popularity distribution in RenRen and try to find their potential limitations in spreading videos. Note that most current OSNs take similar information spreading method (word-of-mouth) as RenRen, and thus our conclusions can be still applicable to these OSNs, such as Facebook and Twitter.

2. The RenRen Online Social Network

Launched in 2005, RenRen is the earliest and so far the largest OSN in China. RenRen can be best characterized as Facebook's Chinese twin, implementing Facebook's features, layout, and a similar user interface. Like Facebook, RenRen's users can post video links from VSSes. Unlike Facebook, RenRen has two unique features that make it an attractive platform for our study. First, while RenRen users have full privacy control over their private profiles, their shared videos are public and thus can be crawled. For example, each individual user has a page that lists all shared videos with their statistics, including the number of views and shares. Second and perhaps more importantly, RenRen provides us certain proprietary traces of user viewing behaviors.

Video sharing in RenRen is based on the friend relationships. Initially, some users (as *initiators*) share a video link from a VSS to RenRen. This link immediately appears in their friends' main page as a ``News Feed`` in chronological order. Then the friends of these initiators will probably click the shared video appeared in their ``News Feed``. A video can be further propagated only if some viewers re-share the link. Such spreading method is also adopted in other systems, such as Facebook and Twitter [1].

3. Distribution of user requests across videos

shared in RenRen

The analysis of YouTube shows that 10% of the most popular videos account for 80% of user requests [6]. It is interesting to see whether the OSN-based sharing can amplify or smooth this skewness. As shown in Figure 1, we can see a dramatically skewed result that top-0.5% videos account for more than 80% of the total requests (the x-axis of this figure represents the videos sorted from the most popular videos to the least popular ones, with video ranks being normalized between 0 and 1); and top-2% videos account for 90% of the total requests. This suggests that OSNs amplify the skewness of video popularity. For attractive videos, more friends would view them if some users share them; and again with higher probability these viewers will further share them. For unattractive videos, fewer users want to view them and are also not likely to share them after the viewing. Such difference in videos' attractiveness can be further amplified over the cascade process along friend links. Thus, attractive videos receive more requests and unattractive videos fade out quickly after very few cascade steps. An immediate implication of this skewed distribution is that caching can be made very efficient since storing only a small set of objects can produce high hit ratios.

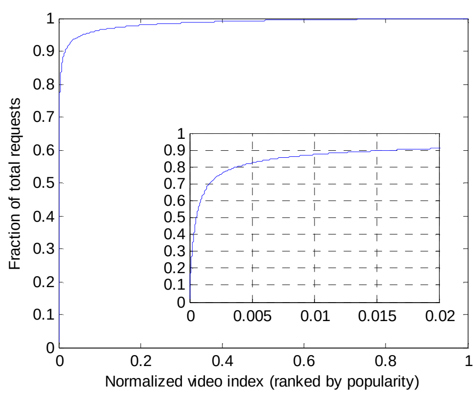

Figure 1. One-day-period requests across all videos ever viewed on that day

To further analyze user requests distribution, we also take a closer look at the videos that are initially shared on the same day (March 24th). Since mostly users are more interested in newly updated videos, this analysis will avoid the possible bias due to different video ages. We count the cumulative requests of those videos within one day, two days, one week, and one month respectively since March 24th, and plot the results in Figure 2. Similarly, the popularity of those videos also exhibits such a high skewness that the top-2% popular videos account for 90% of the total requests. We also notice that the skewness increases as the time-window increases, and almost converges after one week.

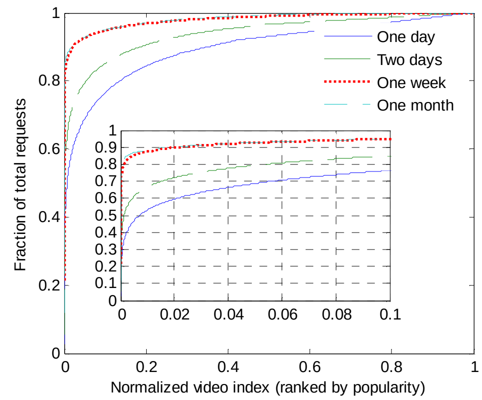

Figure 2. Requests across videos initially shared in the same day

4. Are the rarely-requested videos in RenRen really unattractive?

We have shown that top-2% popular videos account for 90% of total requests, and thus the remaining 98% videos only contribute 10% of total requests. However, are those rarely-requests videos in RenRen really so unpopular or just due to some design bottlenecks? If the huge number of rarely-requested videos were due to some removable bottlenecks, then in the system without such bottlenecks, these videos would gain deserved views, offering the better chances to discover rare niche videos to users and potential business opportunities to the company.

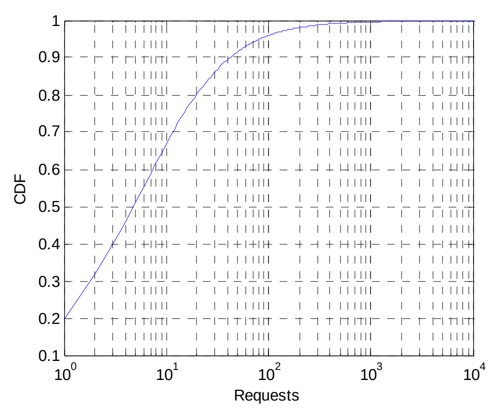

Figure 3. Distribution of requests per video

To investigate the unpopular videos in a clearer way, we further plot cumulative distribution of views per video in one month-period. As shown in Figure 3, we can observe that after one month, 80% of videos only have less than 4 requests and 90% of videos only have less than 10 requests.

To explore whether the rarely-requested videos in RenRen are also unpopular in VSSes, we further crawled the statistics of these videos in Youku. We used Youku as the representative VSS in our study, first because almost 80% of shared videos in RenRen are from this site, and also because it enables access to certain valuable detailed information, such as the views, likes, dislikes, and comments. We compare the video views in RenRen and Youku in Figure 4. At the first glance, the numbers exhibit roughly positive correlation. Yet a closer examination shows that many rarely-requested videos (e.g., less than 100) still have for a large number of requests in Youku. The fact that all videos shared in RenRen are popular videos in Youku can be explained by the following user behavior: users share limited videos sampled from the video pool that they have watched in VSSes, and intuitively the sampling is biased toward interesting ones.

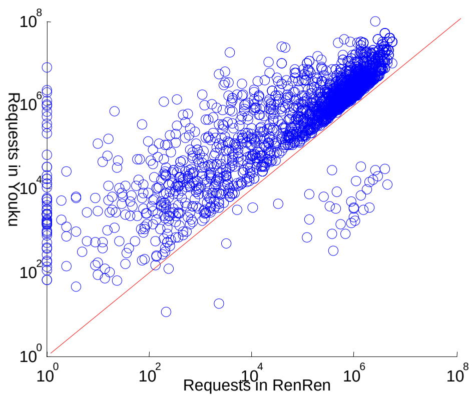

Figure 4. Video requests in RenRen vs in Youku

To find the reason why so many popular videos are rarely requested in OSNs, we trace the spreading process of all videos initially shared on the same day over one month. First, we show the distribution of the number of initiators for individual videos in Figure 5. It shows that 90% videos have less than three initiators. Second, we find that there are less than 2 direct viewers for 80% shares, and among them, only 10% will re-share the video after viewing. Therefore, many videos can only propagate in limited range with high probability and thus do not have the opportunity to be exposed to many other users who have potential interesting in them. To this end, richer spreading strategies are suggested to current OSNs, such as searching, personal-interests-based recommendation, and public pages that list commonly popular videos.

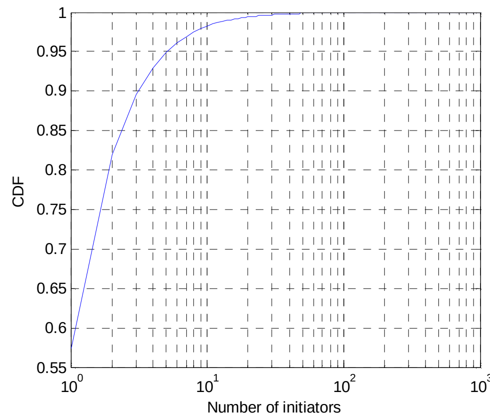

Figure 5. Distribution of the number of initiators

5. Conclusion

In this paper, we presented a measurement study on the popularity distribution of videos shared in RenRen, the largest Facebook-like OSN in China. We found that word-of-mouth based spreading method extremely amplifies the skewness of user requests across videos: the top-2% videos contribute 90% of the total requests, while more than 90% videos receive less than 11 requests in a one-month period. We further found that most of these rarely-requested videos are not really unattractive to users, but due to the limitation of current spreading method. Thus, richer methods should be provided to increase the user requests, especially for the rarely-requested videos.

References

[1] T. Rodrigues, F. Benvenuto, M. Cha, K. P. Gummadi, and V. Almeida, "On Word-of-Mouth Based Discovery of the Web," In *Proc. of IMC*, 2011.

[2] H. Wang, F. Wang, and J. Liu, "Accelerating Peer-to-Peer File Sharing with Social Relations: Potentials and Challenges," In *Proc. of INFOCOM, 2012*

[3] http://www.youtube.com/t/press_statistics/

[4 http://www.renren.com/

[5] http://www.youku.com/

[6] M. Cha, H. Kwak, P. Rodriguez, Y. Ahn, and S. B. Moon, "I Tube, You Tube, Everybody Tubes: Analyzing the World's Largest User Generated Content Video System," In *Proc. of IMC, 2007.*

[7] X. Cheng, C. Dale, J. Liu, "Statistics and Social Networking of YouTube Videos," In *Proc. of IWQoS, 2008.*

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Game-theoretical Approaches in Wireless Multimedia Social Networks

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1. Introduction

Multimedia content sharing over social networks becomes increasingly popular. In addition, with the advance of mobile technologies and the explosive growth of handheld devices, people can consume, create, and share multimedia files or watch live programs right via their handheld device such as smart phones, PDA, or iPad. This naturally creates a new communication paradigm *wireless multimedia social network (WMSN)*, where multimedia content is shared among mobile terminals based on social contexts.

Meanwhile, technical issues may arise in WMSN and the solutions may be challenging. In this paper, we focus on three important problems in WMSN: cooperation stimulation, resources allocation, and security by using game-theoretical approaches. For this, this article first provides a general introduction of the developing wireless multimedia social networks. Then, we give a survey of game theoretical approaches in WMSNs. Finally, we point out several potential interesting issues that worth further study.

2. Wireless Multimedia Social Networks

Wireless multimedia social networks, which combines mobile multimedia and social-networking services, has been introduced as a new technology to enrich people's lives through enhanced multimedia distributions. The explosive advance of mobile multimedia signal processing and wireless communication technologies makes mobile phones more sophisticated and far beyond the traditional roles as communication devices, the newly designed functions like multimedia processing and social networking become attractive. Users that share, exchange, and watch multimedia content with some purpose (e.g., location, profession, interest, education, hobby and so on) over their mobile devices comprise a wireless multimedia social network.

WMSNs are characterized by high flexibility, mobility, self-organization, content diversity and social connection. With WMSNs, people are no longer limited to sit in front of their PCs of large size when interacting with friends or enjoying live programs. More importantly, information about surroundings of users, such as a video clip of emergency and a picture of scenery, can be timely and vividly shared to their friends or the public, and this may be the key point that WMSNs appeal to people.

However, to establish robust systems and provide good quality of service to users, several significant issues including platform design, cooperation stimulation, resources allocation and security should be addressed. In next section, we will focus on some of these issues.

3. Game-theoretic Approaches in WMSNS

Game theory is a branch of applied mathematics that describes and analyzes interactive decision situations. It is composed of a set of analytical tools that predict the outcome of complex interactions among rational players. In wireless multimedia social networks, users compete for precious resources such as multimedia data and bandwidth, and have to rationally make decisions in order to achieve better performance. This provides a natural framework for the employment of the powerful tool game theory, which can help understand how users interact with and respond to each other.

The use of game theory in WMSNs has recently attracted much attention and there are several studies on different research issues.

Resource Allocation

Bandwidth and multimedia data are two major and scarce resources in WMSNs, which poses a main challenge in designing WMSNs, that is, using these network resources as efficiently as possible while providing the QoS requirements by the users. The study in [1] presented a strategy-proof Vickrey-Clarke-Groves (VCG) mechanism in the design of resource management scheme for wireless multimedia applications, where wireless stations are rational and selfish players competing for limited wireless multimedia resources. To obtain an efficient and fair resource allocation for multiple classes of traffic, a two-person game for call admission control in CDMA mobile multimedia systems was studied, where fairness and efficiency are of great importance [2], [3]. Chen *et al.* [4] proposed a delivery scheme for multimedia streaming content and formulated the spectrum allocation problem as an auction game. In addition, based on the conclusion drawn from the analysis of the famous Prisoners' Dilemma, a novel approach for resource allocation and creation of distribution trees was developed for P2P video streaming under an evolutionary game framework [5].

· INCENTIVE COOPERATION

Cooperation among users in WMSNs, such as relaying multimedia data for each other, can make the network more scalable and robust, and thereby users can achieve higher performance. However, each user would like to enjoy multimedia content with high quality while paying as little as possible to help others. Under the assumption that full cooperation between users in peer-to-peer multimedia social networks cannot be guaranteed and some users may even behave dishonestly or maliciously, a repeated game was formulated to analyze user's behavior and some cheat-proof and attack-resistant strategies were proposed based on incentive to motivate user cooperation [6]. The study in [7] modeled the cooperation among peers in peer-to-peer video streaming systems as an evolutionary game and figured out the evolutionary stable strategy (ESS) which enables cooperation among group peers.

· COPYRIGHT AND DIGITAL RIGHTS MANAGEMENT

Given that various and a large amount of multimedia data floods in WMSNs, the protection and copyright of multimedia data become even severe. How to discourage illegal usage and unauthorized redistribution of multimedia data attracts more attention of researchers. Zhang and Lou [8] firstly formulated a digital rights management game for P2P streaming, under different game constructions such that some misbehavior of peers can be avoided. Multi-user collusion attack in multimedia fingerprinting system was investigated in [9]. The authors modeled the colluders' behavior of maximizing profit while minimizing risk from redistributing the multimedia content as a non-cooperative game. The dynamics of the interaction among colluders were clearly revealed by studying the solution under different fairness criteria: Absolute, Max-Min, Max-Sum and Nash-Bargaining.

4. Future research directions

So far, the proposed game theoretic approaches addressing different problems for WMSNs have been demonstrated promising, and there still exist a number of interesting issues that can be possibly analyzed and addressed using game theory.

· ENERGY EFFICIENCY

Energy efficiency of mobile devices/terminals/stations is a critical issue that needs to be studied in WMSNs. Mobile devices are typically battery-powered, and require frequent battery-charging which causes substantial inconvenience for their users, especially when it is out of power. Since wireless communication accounts for a large proportion of energy consumption and multimedia data are often of large size, one needs to make a good balance between multimedia content sharing performance and energy consumption.

· QOE CONSIDERATIONS

Users in WMSNs can freely share multimedia content that they would like to and enjoy multimedia content that they are interested in. This indicates that WMSNs is a user-centric system. Besides, from user's perspective, the quality of network service can be substituted by his/ser subjective experience of multimedia content. Thus, network design should takes user's subjective measure of the network service into consideration. This measure can be represented by quality of experience (QoE) [10]. Using game theoretic approach to analyze QoE provision, specifically introducing the concept of QoE in the definition of user's utility can be a challenge.

· CROSS-LAYER DESIGN

Another possible future research is cross-layer design. Multimedia signal processing in physical layer and multihop networking in network layer are two special functions of mobile devices that can perform multimedia social network services, and therefore cross-layer optimization among these two layers might be of significant interest.

Acknowledgements

This research is partially supported by research grants from the National Science Foundation of China under Grant No.70701025 and 71071105, the Program for New Century Excellent Talents in Universities of China under Grant No.NCET-08-0396.

References

[1] F. Fu, M. van der Schaar, "Noncollaborative Resource Management for Wireless Multimedia Applications Using Mechanism Design," *IEEE Transactions on Multimedia*, vol. 9, no. 4, pp.851-868, June 2007.

[2] J. Virapanicharoen and W. Benjapolakul, "A Game Theoretic Framework for Call Admission Control in CDMA Mobile Multimedia Systems with
Traffic Asymmetry between Uplink and Downlink," *TENCON 2005 2005 IEEE Region 10* , vol., no., pp.1-6, 21-24 Nov. 2005.

[3] J. Virapanicharoen and W. Benjapolakul, "Fair Efficient Threshold Parameters Selection in Call Admission Control for CDMA Mobile Multimedia Communications Using Game Theoretic Framework," *Proc. IEEE Consumer Comm. and Networking Conf. (CCNC 05)*, pp. 439-444, Jan. 2005.

[4] Y. Chen, Y. Wu, B. Wang and K.J.R. Liu, "Spectrum Auction Games for Multimedia Streaming Over Cognitive Radio Networks," *IEEE Transactions on Communications*, vol. 58, no. 8, pp.2381-2390, August 2010.

[5] L. Chisci, F. Papi, T. Pecorella, R. Fantacci, "An Evolutionary Game Approach to P2P Video Streaming," *IEEE Global Telecommunications Conference (GLOBECOM)*, 2009, pp.1-5, Nov. 30 2009-Dec. 4 2009.

[6] W. S. Lin, H. V. Zhao, and K. J. R. Liu, "Incentive cooperation strategies for peer-to-peer live multimedia streaming social networks," *IEEE Trans. Multimedia*, vol. 11, no. 3, pp. 396-412, Apr. 2009.

[7] Y. Chen, B. Wang, W.S. Lin, Y. Wu and K.J.R. Liu, "Cooperative peer-to-peer streaming: An evolutionary game-theoretic approach," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 20, no. 10, pp.1346-1357, Oct. 2010.

[8] J. Zhang, W. Lou, "The digital rights management game in peer-to-peer streaming systems," *2011 Proceedings IEEE INFOCOM*, pp.416-420, 10-15 April 2011.

[9] W. Lin, H. Zhao and K. Liu, "Game-Theoretic Strategies and Equilibriums in Multimedia Fingerprinting Social Networks," *IEEE Trans. Multimedia*, vol. 13, no. 2, pp. 191-205, Apr. 2011.

[10] Special Issue on "Quality of Experience Communications" IEEE COMSOC MMTC E-Letter, Vol.7, No.3, March 2012.

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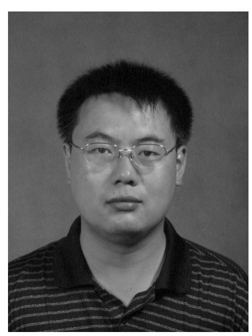

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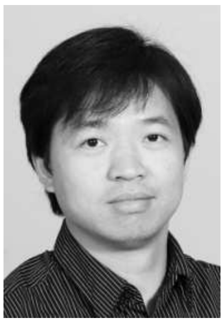

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Relational Data Acquisition for Animal Social Networks: Challenges and Solutions

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1. Introduction

The study of animal social networks aims at understanding the social behavior, interactions and organizations of interested groups of animals e.g., dolphins [1], which exhibit social activities very similar to human beings. By animal social network analysis, facilitated by software tools, e.g., SOCPROG [2], UCINET [3], etc., biologists, ecologists and environment scientists can determine information and parasite transfer patterns, epidemiological model, and community structures within studied animal populations [4].

Nevertheless, effective and efficient collection of animals' relational data, which describes the existence, strength and types of associations between animals in a population [4], remains a very challenging task. The challenges are raised because relational data can only be gathered through observations (since animals cannot

provide interviews or fill in questionnaire as humans) and
only sampled observations are practically feasible. While observation sampling rates and sample sizes, which depend on many factors such as animal types, animal population sizes, environment constraints, etc., are not trivially set, inevitable sampling errors and data uncertainty considerably affect the quality of animal's social network analysis [6].

Despite to a certain degree, data cleaning and correction techniques can help improve the data quality during social network analysis [6], it is crucial to improve data collection processes so as to achieve high animal social network analysis accuracy. Motivated by this, we are initiating a research project on animals' relational data acquisition. In the following, we describe challenges in relational data acquisition, present a relational data acquisition, and state our research agenda.

2. Design Goals and Challenges

The effectiveness and efficiency are two major design criteria of relational data acquisition, but they cannot be achieved by conventional means.

Effectiveness refers to the completeness and accuracy of collected animals' relational data. As a common practice, activities and interactions between animals are tracked via photographing, sound recording or video shooting [7]. Scientists then examine individual recorded photos, sound tracks or video clips to infer the types and strength of associations existed between animals, which imply competitive, cooperative, predatory, sexual, hostile, or aggressive behavior between the animals [5]. Very often the types and strength of association are very abstract and human judgment is needed to quantify them in relational data. Apparently, not all animals' activities and interactions can be captured; and interpretations of collected photos, video clips and sound tracks based on subjective judgment inevitably introduce human errors in relational data [6].

Efficiency, on the other hand, concerns time and costs consumed in relational data collection plus the amount of properly collected data for a given amount of resources. As aforementioned, many cameras and microphones needed to be deployed in habitats to capture animals' activities. Yet, this means is infeasible to high mobility animals, e.g., seasonal birds. Besides, costly human effect is required to process, examine and interpret a large quantity of recorded photos and video clips. For example, dolphins' research project [1] took over 7 years (from 1994 to 2001) to construct a social network of 62 bottlenose dolphins.

3. Relational Data Acquisition Framework

Next, we propose a relational data acquisition framework as the first solution in the literature for effective and efficient animals' relational data collection. The main core of the framework is a wireless sensor network, which can be built using off-the-shelf products such as MICAz [8], TinyOS [9], etc. Different from existing research works in the literature that mainly used wireless sensor networks to examine animal conditions [10] and to monitor animals' habitats [11], our framework is designed for collecting animals' relational data.

3.1 Framework Design

Depending on the types and population sizes of animals to be studied and habitat environments the animals reside, our framework can be customized for different settings; and basically, it is composed of (i) stationary sensor nodes, and (ii) mobile sensor nodes.

The stationary sensor nodes are deployed in habitats where target animals reside to measure environment conditions, such as light intensity, temperature, humidity, air/water pressure, etc. that may affect the monitored animals' social activities. The sensor nodes can also be equipped with cameras and microphones to take pictures and videos and to record sound, respectively. In addition to environment sensing, these sensor nodes are wirelessly connected to form a data routing network to forward collected data to a dedicated node (i.e., the sink). Further, each sensor node is computationally powerful to perform in-network data filtering and processing.

The mobile sensor nodes are those lightweight sensor nodes carried by some (if not all) target animals. Their functions are to detect and record some measurements, which are useful to infer the interactions of carrier animals to one another. For most (if not all) situations, associations between animals including their types and strength can be roughly deduced by the animal locations and distances [4]. The distances, on the other hand, can be estimated via measuring wireless signal strength received by the mobile sensor nodes. Likewise, the amount of time the animals are collocated/comoving together with the identities of their carried sensor nodes can be recorded. If there is a need and some additional weights do not affect the carrier animal motions, cameras and voice recorders can be added to mobile sensor nodes to collect multimedia data.

3.2 Relational Data Acquisition

In our framework, a data acquisition task is initiated by a sink, which is a stationary sensor node, broadcasting an initiation message to all other nodes. Then, all stationary sensor nodes start to sense their surrounding and to route the sensed to the sink. Intermediate sensor nodes would aggregate forwarded data from different nodes during propagation.

Meanwhile, mobile sensor nodes periodically broadcast beacon messages and they listen to those delivered by others. Based on the signal strength of received beacons and broadcast sensor node information, mobile sensor node estimate the distance of opponent sensor nodes and record them. Mobile sensor nodes may not directly connected to stationary sensor nodes. It can either forward collected data through multi-hop communications towards the sink or wait until any stationary sensor nodes are within its communication range. In addition, cameras and microphones (which are off by default) can be switched on to collect more details when some animals are closely located.

3.3 Discussion

Thus far, we have briefly outlined the framework design and its data acquisition operations. Some additional challenges need to be tackled before the framework can be implemented and deployed. We discuss three of them in the following.

First, it may not be feasible to have all target animals to carry mobile sensor nodes, especially for large animal populations. Some animals would be tracked as samples instead of entire populations. It raises an issue of selecting representative (subsets of) animals as carriers. Other than expert judgments, we believe that relational data deduced from some preliminarily assigned carrier animals can help deciding better additional/alternative sample animals to improve relational data collection processes.

Second, potential long data collection latency due to disconnections of mobile sensor nodes carried by some animals from stationary sensor nodes is another issue. As mentioned, multi-hop communication can be a remedy to improve the timeliness of collected data. However, animals' movement can make network topologies highly dynamic. The problem about data forwarding in uncertain network connectivity is known as delay-tolerant network [12]. To address this issue, we are going to investigate to use deduced relational data, which implies the likelihood and time windows that animals are closely located, to estimate efficient routes for collected data.

Third, energy issue is especially important, since animals' relational data acquisition is typically a long process lasting for weeks, months or even years. It is undesirable to install bulky and heavy batteries to mobile sensor nodes that impacts on the animal mobility. Use of renewable energy, such as solar power and animals' kinetic energy, appears to be a possible solution to the issue; and it is worth detailed investigations, in addition to some other suitable energy-efficient techniques for computation and communication.

4. Summary and Research Agenda

This paper has discussed the motivation of animal social network analysis and challenges encountered in collecting animals' relational data. To collect animals' relational data effectively and efficiently, we have proposed a new data acquisition framework that is built on top of a wireless sensor network. We have also presented its general system design and operations as well as some additional technical challenges.

As the future work, we are going to tackle the above discussed challenges, and to undergo theoretical performance study. In the mean time, we shall prototype the framework and apply the prototype in practical situations.

References

[1] D. Lusseau and M. Newman, *Identifying the Role that Animal Play in Their Social Networks*, Proceedings of the Royal Society B: Biological Sciences, p477-481, 2004

[2] H. Whitehead, *Programs for the Analysis of Animal Social Structure (SOCPROG)*, [web] http://myweb.dal.ca/hwhitehe/social.htm

[3] UCINET Software, *UCINET for Windows: Software for Social Network Analysis*, [web] https://sites.google.com/site/ucinetsoftware/home

[4] D. Croft, R. James and J. Krause, *Exploring Animal Social Networks*, Princeton University Press, 2008

[5] J. Krause, D. Croft and R. James, *Social Network Theory in the Behavior Sciences: Potential Applications*, Behavioral Ecology and Sociobiology, p15-27, 2007

[6] D. Lusseau, H. Whitehead and S. Gero, *Incorporating Uncertainty into the Study of Animal Social Network*, Animal Behaviour, p1809-1815, 2008

[7] R. Kays, B. Kranstauber, P. Jansen, C. Carbone, M. Rowcliffe, T. Fountain and S. Tilak, *Camera Traps As Sensor Networks for Monitoring Animal Communities*, Proceedings of IEEE Conference on Local Computer Networks, p811-818, 2009

[8] Moog Crossbow, MICAz mote, [web] http://www.xbow.com/

[9] TinyOS, [web] http://www.xbow.com/

[10] J. Thiele, J. Link, O. Osechas, H. Mallot and K. Wehrle, *Dynamic Wireless Sensor Network for Animal Behavior Research*, New Developments in Biomedical Engineering, p629-644, InTech, 2010.

[11] R. Szewcyk, E. Osterweil, J. Polastre, M. Hamilton, A. Mainwaring and D. Estrin, *Habitat Monitoring with Sensor Networks*, Communication of the ACM, 47(6), p34-40, 2004.

[12] K. Fall, *A Delay-Tolerant Network Architecture for Challenged Internets*, Proceedings of ACM SIGCOMM, 2003.

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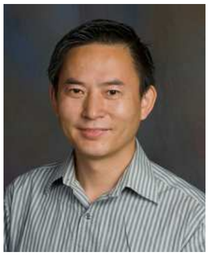

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Submission Procedure

Topics of interest

- QoE relation and mapping to QoS
- KPI and KQI for the QoE definition
- QoE models, their applications and use cases
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- QoE evaluation methodologies and metrics (subjective, objective, online versus offline)
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- QoE-based routing and resource management
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