MULTIMEDIA COMMUNICATIONS TECHNICAL COMMITTEE
IEEE COMMUNICATIONS SOCIETY
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R-LETTER

Vol. 4, No. 2, April 2013

IEEE COMMUNICATIONS SOCIETY

CONTENTS

Message from the Review Board

Introduction

In order to serve the MMTC community better, the Review Board after consulting the MMTC Chair and Vice-Chair has launched the Distinguished Category in the R-letter starting from this 2013 April issue. MMTC IGs are able to actively involve by nominating Fellow (ACM/IEEE) co-authored work in this category and the goal is to provide a broad range of high quality review articles to the readers.

The new Distinguished Category kicks off by recommending two resource management techniques for video streaming over wireless networks and for delivering improved QoE. The R-letter Regular Category in the April issue continues to feature high quality papers, including popular research topics on distributed video delivery and energy-efficiency. There are also two interesting articles discussing the statistics and semantics embedded in images.

Distinguished Category

Mobile video traffic is growing at an immense rate with the volume expected to double every year between 2012 and 2015. The availability of powerful mobile wireless devices has propelled the growth of mobile video traffic with the projected share estimated to be two-thirds of the total mobile traffic by 2015. Hence, mobile video services would likely be a significant source of revenues for network operators. Besides being bandwidth intensive, live video streaming and conversational services are highly sensitive to delay, jitter, and packet losses. In this issue, we recommend two papers studying video streaming in wireless networks.

The first paper, published in the *2012 IEEE International Conference on Multimedia and Expo*, studies QoS-driven and fair downlink scheduling for video streaming over LTE networks with deadline and hard hand-off. **The second paper**, published in *IEEE Journal on Selected Areas in Communications*, analyzes a network-level resource management to improve the QoE of video users.

Regular Category

Distributed video delivery and energy-efficiency is becoming more and more important. Hence, this issue of the regular category is partially devoted to these topics.

The first paper, published in the *IEEE Transactions on Multimedia*, introduces distributed video delivery by exploiting the network path diversity via a randomized network coding. The **second paper**, also coming from *IEEE Transactions on Multimedia*, deals with distributed video scheduling and authors investigate the impact of imperfect neighbor information. The **third paper** is published in *IEEE Transactions on Mobile Computing* and investigates energy-efficient video multicasting in 4G wireless systems. The **forth paper**, in *IEEE Transactions on Wireless Communications*, also about energy efficieny and propose a general framework for link-level optimizations with informed transmitter. The **fifth paper** is published in *IEEE Transactions on Image Processing* and proposes a novel algorithm for sparse image representation based graph-regularized sparse coding (GraphSC). Finally, the **sixth paper**, in *IEEE Transactions on Multimedia*, provides a novel approach how computers can recognize parent-child relationships in photos.

Finally, we would like to thank all the authors, reviewers, nominators, editors and others who contribute to the release of this issue.

IEEE ComSoc MMTC R-Letter

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LTE Network Downlink Scheduler for Video Streaming with QoS and Hard Hand-off considerations

A short review for "QoS-driven and Fair Downlink Scheduling for Video Streaming over LTE Networks with Deadline and Hard Hand-off"

Edited by Weiyi Zhang

Qian Liu, Z. Zou, and C. W. Chen, "QoS-driven and Fair Downlink Scheduling for Video Streaming over LTE Networks with Deadline and Hard Hand-off", *Proc. of IEEE International Conference on Multimedia and Expo (ICME) 2012*, Melbourne, Australia, pp. 188-193, 2012.

As multimedia services are becoming increasingly popular for mobile users, Long-term evolution (LTE) has been developed by the Third-Generation Partnership Project (3GPP) for the next-generation broadband wireless communications through enhancement on both downlink and uplink data rates as well as quality-of-service (QoS) provisioning. At present, more than 20 service providers worldwide confirmed their commitments to LTE, and the number of LTE subscribers is predicted to reach 32 million by 2013 [1].

The LTE network architecture is highly simplified with two types of nodes: evolved Node-B (eNodeB) and mobility management entity/gateway (MME/GW). The eNodeBs are interconnected via X2 interface and are also connected to MME/GW entity via S1 interface [2]. Since eNodeB is the only node between users and the core network, the downlink scheduling algorithms in the eNodeB play an important role in the realization of radio resource management functions [3] as well as QoS provisioning. One crucial problem of downlink scheduling in LTE is how to balance QoS and fairness. This problem becomes even more challenging when we consider multimedia consumers together with regular data (e.g. FTP, http) users. Another issue that should be considered is the delay constraints of individual multimedia flows. Video packets have deadlines, as time determines whether or not a video packet is still valid. A time-out video packet is equivalent to a loss packet, as it is not available for video reconstruction when needed. Therefore, a deadline-aware scheduling is necessary to guarantee QoS. Furthermore, the deadline violation problem becomes even more severe during LTE hard hand-off (HO) procedure. As is known, LTE only adopts hard HO, which is a "break before make" transition, causing service interruption for the end user. The interruption time and data forwarding delay introduced by the HO procedure may be intolerable for delay-sensitive applications, such as video streaming. Therefore, the downlink scheduling scheme should be designed to overcome this problem in order to guarantee the users' service quality.

Most of the previous related works have not considered the problems associated with QoS metrics of video deadlines, fairness, and the service degradation induced by hard HO procedure. To address these problems, the authors aim to design a QoS-driven downlink scheduling scheme. The major contribution of the proposed scheme is the innovative design of the scheduler through two QoS driven operational control modules, the transmission deadline control module and the HO control module. In this paper, the authors have developed a novel integrated approach to jointly resolve intertwined challenges in QoS provisioning, fairness, and hand-off (HO)-induced service degradation for the LTE networks. This scheme has been proved to enable guaranteed quality-of-experience (QoE) through the design of two operational control modules: transmission deadline control module and hand-off control module. These modules strategically map the requested flows into radio resources to provide optimal scheduling with assured fairness for both multimedia consumers and regular data users even during the hand-off (HO) procedure. In particular, the video consumers shall enjoy guaranteed QoE with not only optimal video quality with minimum loss due to deadline violation but also continuous reception of video streams even when the user is undergoing hard hand-off moving from one eNodeB to another.

Extensive simulations have been carried out to verify the performance of the proposed integrated

scheme with two novel and effective control modules. LTE-Sim [1], an open source simulator for LTE networks, is used to evaluate the efficiency of the proposed downlink scheduler. The proposed scheme is compared with two existing schemes, PF and EXP-PF, and has shown that it is able to substantially outperform the existing schemes with guaranteed QoE and desired fairness. In particular, several QoS and QoE related measures have been considered in these simulations. Such performance measures include (1) Percentage of expired video packets; the study showed that the proposed scheduling algorithm outperforms PF and EXP-PF algorithms under all the simulation scenarios. (2) Peak signal-to-noise ratio (PSNR); performances of PF and EXP-PF algorithms decrease as the number of active multimedia consumers and users' moving speed increase. In contrast, the proposed algorithm has the best performance which almost unchanged in different simulation scenario. (3) Average goodput and fairness; proposed scheduler uses 55.09% service time for regular flows, which is only 3.28% lower than the PF algorithm. (4) Service interruption caused by HO. The simulation finds out that PF and EXP-PF algorithms suffer from service interruption aroused by the hard HO procedure. Due to the design of the alert zone, the proposed algorithm transmits more video data to UE before HO such that the user can buffer enough data before HO procedure resulting continuous video streaming service. The combination of all these measures enables the QoE guarantee and fairness for video streaming over LTE networks.

Acknowledgement:

This paper is nominated by the MMTC QoEIG.

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A Resource Management Algorithm for Real-Time Video Streaming in the Next-Generation Broadband Wireless Communications

A short review for "Interference Shaping for Improved Quality of Experience for Real-Time Video Streaming"

Edited by Irene Cheng

S. Singh, J.G. Andrews and G. de Veciana, "Interference Shaping for Improved Quality of Experience for Real-Time Video Streaming," IEEE Journal on Selected Areas in Communications, vol. 30, no. 7, pp. 1259-1269, Aug. 2012.

Video data delivery is a major consumer of communication bandwidth. Real-time video applications are commonplace not only through wired connections which are more stable, but also over heterogeneous wireless networks. The latter often suffers from bursty interference, packets disruption and other physical impairments and network congestion. These conditions in wireless networks makes real-time video streaming on displays ranging from traditional desktops to modern smart handheld devices more challenging. In order to provide session continuity and user expected Quality of Experience (QoE), this paper proposes an "interference shaping" resource management algorithm at a network-level, to smooth out the channel throughput variations and thus improve the QoE for real-time video streaming.

QoE is defined as the overall acceptability of an application or service, as perceived subjectively by the end-user [1]. Based on this definition, the authors argue that traditional network metrics, which focus on network assessment using Mean Opinion Score (MOS) or Differential MOS (DMOS), cannot reliably predict QoE. In contrast, their work prioritizes real-time video delivery over best effort traffic allocating resource across base stations (BSs). While most other interference avoidance techniques try to reduce only the impact from mean interference power (first moment), the authors also address the burstiness of interference (second moment). Their Interference Shaping algorithm is designed to complement existing interference mitigation algorithms and would work best when the connection is not capacity-constrained or the interference power is less than the average signal power.

Instead of evaluating based on average quality, their Interference Shaping algorithm applies temporal pooling objective quality scores [2], the objective full reference multiscale structural similarity (MS-SSIM) index [3] and coefficient of quality variation (CoVQ) metric. The current experimental video-specific cellular model, with randomly located interfering BSs transmitting bursty best-effort data, shows that the QoE of real-time video users in the network can be increased by 2-3 times with insignificant decrease in QoE for best effort users. The authors tested their algorithm for unicast streaming, which can be optimized for a point-to-point link. They also tested for multicast streaming, where multiple users can enjoy a live video event concurrently.

It is observed that although interference shaping can improve the QoE of real-time video users, it may degrade QoE for bursty non video traffic users. The authors quantify this tradeoff by using an objective full reference quality metric MS-SSIM [4] for quality assessment on the rendered video, together with a pooling strategy at the frame level to account for drops in video quality. Different from temporal averaging, this pooling strategy estimates objectively the quality at the current frame based on the bad quality experienced in the recent past.

The algorithm can be implemented in current standards like LTE easily. The key components include:

- QoE monitoring and feedback
- QoE information sharing
- QoE aware power scaling

These implementation features are also applicable in situations where a Base Station transmits a mix of real-time video and bursty data.

The authors believe that the integration of hysteresis subjective effects of video and quality variation into the performance analysis is new. Their proposed resource management algorithm is an effective solution to resolve a major issue in the next-generation broadband wireless communications, and to enhance QoE over wireless networks.

Acknowledgement:

This paper is nominated by the MMTC QoEIG.

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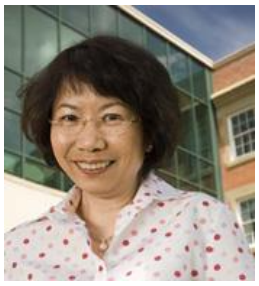

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Distributed Video Delivery with Priority Considerations based on Randomized Network Coding

A short review for "Prioritized Distributed Video Delivery With Randomized Network Coding"

Edited by Xiaoli Chu

N. Thomos, J. Chakareski and P. Frossard, "Prioritized Distributed Video Delivery With Randomized Network Coding," IEEE Transactions on Multimedia, vol. 13, no. 4, pp. 776-787, Aug. 2011.

Driving by the continuing advances in broadband technologies and video compression techniques, peer-to-peer systems have emerged as one of the most popular paradigms for online media delivery [1]. In peer-to-peer media streaming systems, the networks are usually organized into overlay structures, which improve the control of the delivery process. This is because overlay networks offer the possibility of employing basic processing operations at intermediate network nodes, in addition to providing increased path and/or source diversity. For example, the nodes can perform network coding to enable efficient distributed multimedia delivery in lossy overlay networks [2].

In the meanwhile, multimedia data is typically characterized by a variable importance of the data units in terms of their contributions to the overall reconstructed media quality. Moreover, networks are usually characterized by a large diversity in terms of client capabilities and access speeds and, hence, the video streaming scheme should allow for multiple levels of Quality of Service (QoS) in order to accommodate for the network heterogeneity. Therefore, the problem of prioritized video streaming over lossy overlay networks needs to be addressed.

In this paper, the authors propose to exploit the network path diversity via a randomized network coding approach, which provides unequal error protection to the packets that convey the video contents. A distributed receiver-driven streaming solution is developed, where a receiving peer requests packets of different priority classes from its neighbors in the overlay, and then based on the received requests, a node chooses a network coding strategy to forward combinations of the selected packets to the requesting peers, so that the resulting rate allocation between the different packet classes minimizes the average distortion at the requesting peers. Subsequently, the receiving peer requests packets from its parent nodes according to the resulting rate allocation.

Choosing the appropriate network coding strategy at each node is then cast as an optimization problem as a function of the available bandwidth. The formulated optimization problem is shown to have log-concavity properties and is solved by an iterative algorithm at low complexity.

The results of randomized network coding in [3] are used to construct the new distributed delivery algorithm, where the network coding decisions are adapted to prioritized video delivery for receivers of different capabilities, without the need for centralized control. Packet classes are constructed by using the unequal contribution of the various video packets to the overall quality of the presentation [4], or from the arrangement of data in scalable video streams [5]. Prioritized transmission is then achieved by varying the number of packets from each different class to be used in embedded network coding operations that are performed at the overlay nodes.

Various performance aspects, such as decoding performance and performance under timing constraints, of the proposed randomized network coding based distributed video streaming scheme are evaluated through extensive simulation experiments. The presented simulation results show that the proposed scheme outperforms reference schemes such as baseline network coding algorithms and approaches employing rateless codes with built-in unequal error protection properties. The simulation results also demonstrate that the proposed scheme respects the relative priorities of the different packet classes, achieves a good quality adaptation to network resource constraints (e.g., decreased effective bandwidth), and is robust in a variety of transmission scenarios.

In summary, the proposed receiver-driven video streaming technique considers the unequal importance of the various packet classes and implements different randomized network coding protection levels. The randomized network coding strategy permits to keep a simple code design and avoids the use of expensive policies at the intermediate network nodes. The unequal error protection properties are obtained by selecting the proper rate allocation between the different video classes. A client node periodically requests different shares of network-coded packets from each importance class. The requests are computed independently at each node in a way that the average distortion is minimized. The authors then propose a simple iterative search algorithm to find the optimal rate allocation at each network node. By properly handling the various video classes and offering adaptivity to local network statistics, the proposed technique can achieve efficient distributed video delivery over heterogeneous overlay networks, especially for the peer-to-peer delivery of scalable video contents.

Furthermore, the authors also review the general characteristics of network coding as they pertain to networked multimedia in this paper. While initially network coding research has mainly focused on throughput enhancement, nowadays, network coding has also attracted a lot of attention from the research community for error resilient multimedia communications, which is driven by similarities between network coding and channel coding techniques. Related recent work is reviewed and discussed.

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On Distributed Multimedia Scheduling with Constrained Control Channels

A short review for "On Distributed Multimedia Scheduling With Constrained Control Channels"

Edited by Koichi Adachi

L. Zhou and H.-H. Chen, "On Distributed Multimedia Scheduling With Constrained Control Channels," IEEE Transactions on Multimedia, vol. 13, no. 5, pp. 1040-1051, Oct.

The current wireless network technologies offer higher data throughput and, hence, it makes it feasible to support high-speed multimedia applications with the help of various network-oriented multimedia scheduling schemes [1-12]. Traditional multimedia scheduling approaches assume perfect control channels where each node has perfect access to the knowledge of its neighbors which can be used for scheduling. However, in the practical system, the information exchange among the network nodes are performed through constrained control channels. Therefore, it is important to understand how the constrained control channels influence the performance properties, preferably in a quantitative manner. In this paper, the authors investigate the impact of imperfect neighbor information on distributed multimedia scheduling. Therefore, the authors introduce a constrained factor to formulate the optimal multimedia scheduling problem when a limited information is available due to the constraint control channels.

Networked multimedia scheduling algorithms can be divided into two categories, i.e., centralized and distributed approaches, according to their control methods employed. The scheduling algorithm can be viewed as a queue length update policy for each network node. The scheduling at each node can be written as a function of *queue length*, *control input* – which is known for a specific communication protocol –, and *control gain* (*CG*). Therefore, the core task of designing a multimedia scheduling policy is how to design the *CG* under various network conditions and multimedia types [10,13,14,15].

The related constraints in the control channels can be categorized into following four types:

1) Quantization errors of the node state transmitted over unreliable control channels.
2) Multimedia distortions caused by finite capacity of the control channels.
3) Communication constraints resulting from sharing network resources by multiple nodes
4) Scheduling deviations due to the heterogeneous multimedia playout deadlines and packet importance levels.

It is well known that the presence of these constraints can sensitively influence the performance of multimedia scheduling [1,4]. Unfortunately, much of the existing literature considered only some of the aforementioned constraints, while ignoring the rest. Thus, the contribution of the authors in this paper is to address the issues on how to dynamically schedule multimedia applications by considering the following constrains jointly. The two classes of the *constrained factor distribution (CFD)* are considered. One is a class with finite mean and variance, and the other is a general class that does not have a parametric representation.

In the first part of the paper, a class of *CFD* with finite mean and variance is considered. The lower bound of the CG for achieving the optimal multimedia scheduling is derived in *Theorem 1*. The lower bound is expressed as a function of the number of nodes equipped with a uniform level quantizer within the network and the parameters of CFD. The authors also derive the *upper bound* of the *asymptotical convergence rate* (*ACR*) in *Theorem 2*, when CG is given so that the optimal multimedia scheduling is ensured. Theorem 1 states that if a network is connected, CG can be properly chosen so that the optimal multimedia scheduling is achieved for any finite-level uniform quantizer with known CFD. A fundamental convergence rate limit of various scheduling schemes is established by Theorem 2, which implies that the larger CG provides faster ACR.

In the second part of this paper, the authors relax the restriction of CFD, and assume that it belongs to a broad class of functions that need not admit any parametric representation. The goal is to see whether the optimal multimedia

scheduling is achievable with this relaxation. Under this relaxation, the *lower bound* of CG for achieving the optimal multimedia scheduling is derived in *Theorem 3* and it is shown that the *upper bound* of the ACR is the same as the one given in *Theorem 2*. Theorem 3 can be viewed as a design rule for the general networked multimedia scheduling from the viewpoint of the system.

The authors provide simulation results based on their previous work [3] with slight modifications based on the results obtained in this paper (*Theorem 1* and *Theorem 3*). It is confirmed that the simulated performances are consistent with the derived analytical results. The authors make several observations for peak signal-to-noise ratio (PSNR) results for both the CFD with finite mean and variance and the general class of CF: 1) Once the minimum CG is satisfied, a stable network state can be achieved and the performance remains invariable, 2) the CG can affect the ACR. Furthermore, from the results, the authors find that: 1) no matter what value of network connection is, there always exists optimal multimedia scheduling; 2) the lower the network connection value, the larger the needed control gain. These obtained results consistent with the derived theorems in the paper.

The derived results in this paper are quite useful to properly choose the *control gain* (*CG*) so that the optimal multimedia scheduling can be achieved with an exponential convergence rate.

Acknowledgement:

This paper is nominated by Dr. Liang Zhou, Key Lab of Broadband Wireless Communication and Sensor Network Technology, Nanjing University of Posts and Telecommunications.

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Towards Efficient Multimedia Resource Allocation for Mobile Devices

A short review for "Energy-efficient Video Multicast in 4G Wireless Systems"

Edited by Jun Zhou

Y. Yu, P. Hsiu, and A. Pang, "Energy-efficient Video Multicast in 4G Wireless Systems," IEEE Transactions on Mobile Computing, vol. 19, vo. 10, pages 1508-1522, October, 2012.

With the development of wireless communication and multimedia technology, video data has been widely accessed and shared by consumers. A common problem that mobile users face is the high power consumption of mobile devices. For example, when multimedia functions are intensively used, the battery of a smart phone may only last for a few hours. Therefore, building energy-efficient system has become an important research topic in the related communities. Although this power consumption problem can be tackled from different perspectives [1,2], in the multimedia research area, improving resource allocation for mobile users has become one of the most promising solutions. This is typically achieved by optimizing the data delivery in video multicast.

Two layer-based coding methods have been widely used for this purpose: scalable video coding (SVC [3]) and multiple description coding (MDC [4]). Both methods allow different levels of video quality be provided to users, which is controlled by dividing a video into several layers and then determining how users receive these layers. Furthermore, adaptive modulation and coding is often used with the layer-based coding so that video content can be changed based on the users' channel conditions.

In this paper, authors have followed the above scheme in 4G wireless systems so as to minimize the total energy consumed by a number of mobile devices while guaranteeing the quality of the user requested videos. This is formulated as an optimization problem such that the number of symbols received by all the users is minimized, subject to several constraints on number of resources, modulation setting, and video quality that user can receive. The authors pointed out that when solving this optimization problem using both SVC and MDC, the complexities of the solutions are *NP*-hard. Formal proof has been given to show that this can be derived from the partition problem [5]. Then they proposed two efficient approximation algorithms for both SVC and MDC, respectively.

The algorithm for SVC consists of two stages. The first stage is used to determine the assignment of video layers to each group of users and their modulation option. In the second stage, appropriate tiles, i.e., symbol and sub-channel combinations, are allocated to the video layers determined in stage one. Proof is given to show that this solution is a 2-approximation algorithm, and that the first stage derives the minimum number of tiles required by all users in order to meet the energy efficient requirement.

When MDC is applied to the problem, the optimization algorithm is also two-stage. In stage one, a dynamic programming method is used to determine the allocation of video layers with modulation options. This is followed by the same stage two of the algorithm for the SVC solution. Proof shows that this is a pseudo-polynomial time 2-approximation algorithm that meets the energy-efficient goal. Several examples are given while describing the algorithms, which has greatly facilitated the understanding of the approach.

Simulations on five popular test video sequences validated these two algorithms. The results show that the proposed algorithms have outperformed the conventional method in [6] and are very close to the optimal solution generated by brute-force search. The energy saving effect is more apparent when a large number of user groups are in the networks and when the symbols available for multicast services contain more sub-channels.

In addition to energy efficiency, the proposed method also has several other advantages: 1) it is fully compatible with frame-based 4G wireless networks; 2) it allows flexibility of video layer

encoding parameter setting; 3) it is easy to implement with low computational cost at base station; and 4) it can be easily adapted to heterogeneous devices whose energy consumption mode are different.

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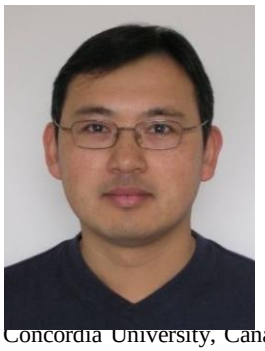

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Link-Level Energy-Efficiency Maximization

A short review for „Framework for Link-Level Energy Efficiency Optimization with Informed Transmitter“

Edited by Christian Timmerer

C. Isheden, Z. Chong, E. Jorswieck, and G. Fettweis, "Framework for Link-Level Energy Efficiency Optimization with Informed Transmitter," IEEE Transactions on Wireless Communications, vol.11, no.8, pp. 2946-2957, August 2012.

Energy efficiency is becoming an important design objective for wireless networks. The increasing demand for high data rates, for ubiquitous access, and for cheap and light mobile devices requires to consider the efficient usage of energy resources in the link-layer design. A comprehensive survey of joint physical and medium access control layer techniques for green wireless can be found in [1]. From the system design perspective, adding energy efficiency as an additional utility metric introduces new tradeoffs among transmission rates, outage probabilities, bit error rates, delays, and Quality of Service (QoS). Such an optimization problem can be formulated as a multi-objective programming problem (MOP) [2]. For multi-media networks, QoS and Quality of Experience (QoE) are important design objectives. Several service classes need to be supported by the physical (PHY) and medium access control (MAC) layers within heterogeneous network environments [3].

One way to approach MOPs is to include several design dimensions into a single objective function. Typical energy efficiency functions belong to the general class, i.e., the ratio of amount of data transmitted to energy consumed [4]. Special cases include the achievable weighted sum transmission rate over the total power consumed, or good-put, defined as number of successfully transmitted bits over the transmit power [5]. This type of optimization is known as fractional programming. The objective functions are typically non-linear and non-convex where standard methods from convex optimization cannot be applied.

In this paper, the authors derive a framework for solving fractional programming problems [6] that exploit the specific properties of energy efficiency objective functions. In contrast to convex programming, fractional programming theory is not well known to the wireless communications community. Therefore, a self-contained view with various approaches is derived: the parametric convex program, the parameter-free convex program, the dual program formulation, and the convex fractional program. All models result in a simple yet efficient algorithm for finding the global optimum solution, which is due to Dinkelbach [7].

In order to apply the framework for energy efficient system design, a suitable model of the power dissipation needs to be modeled suitably, the system model parameters should be identified, and the constraints correctly modeled and then the framework can be applied directly. In order to simplify the power dissipation model, two main parts are identified: the variable part, which depends on the chosen transmission strategy, and the constant part, which is independent of the transmission strategy. A model for macro and micro base stations is applied [8].

In the paper, four example applications illustrate the derived algorithm framework. All address the PHY and MAC layer and assume full buffers. The first example studies time-invariant parallel sub-channels which occur in quasi-static block frequency-selective fading channels or in multiple-input multiple-output (MIMO) fading channels. A water-filling type of solution is obtained. The second example studies time-varying flat-fading channels. Depending on the fading distribution, closed form expressions for the optimal energy efficient power allocation are obtained. A final example shows how finite modulation and coding schemes can be treated using the framework.

Numerical simulations illustrate the usefulness of the framework. Results regarding the optimal number of active antennas in MIMO links show that additional transmit antennas should be carefully deployed. For different modulation formats (QPSK, 16-QAM, 64-QAM), the operating point (power allocation) should be carefully chosen depending on signal-to-noise ratio (SNR), channels, and power models.

The paper provides a unified view of various separate results for energy efficiency maximization in wireless networks. Currently, the framework considers only the link and medium access control layers. However, the approach is general enough to introduce also higher layer requirements mapped either into the objective function or into the constraints. Objectives like QoS or delay requirements should be

incorporated for an energy-efficient cross-layer design.

Another future work item is to extend the notion of energy efficiency to multiuser networks in which nodes have conflicting interests. For example, game theoretic approaches have turned out to find suitable energy-efficient solutions and operating points for the multi-agent scenarios [9].

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Graph-based Sparse Image Coding

A short review for "Graph Regularized Sparse Coding for Image Representation"

Edited by Vladan Velisavljević

M. Zheng, J. Bu, C. Chen, C. Wang, L. Zhang, G. Qiu, and D. Cai, "Graph Regularized Sparse Coding for Image Representation," IEEE Transactions on Image Processing, vol. 20, no. 5, pp. 1327-1336, May 2011.

Sparse image representation is an important part of image processing and has been used in several areas, such as image compression, retrieval and analysis or machine learning. The target is to provide an efficient representation of original image using only a few nonzero coefficients [1]. In a typical use of sparse representation in image compression, the most important goal is to reduce the distortion of the reconstructed image subject to a limited number of nonzero coefficients (or bit rate) [2]. This is commonly implemented by searching for a small subset of basis functions within an adopted dictionary that captures best high-level semantics of the image. This approach has been also studied in biological vision because of some evidences that it is used in biological early visual areas [3].

In this paper, the authors propose a novel algorithm for sparse image representation based on a manifold learning algorithm called graph-regularized sparse coding (GraphSC). In manifold learning [4], the aim is to extract a sub-manifold of the entire vector space that approximates well the support of the sampled probability distribution functions. The extraction algorithms are commonly based on the idea of local invariance [5] and their efficiency can be improved by exploiting local geometrical structures in manifolds. For that reason, the proposed algorithm GraphSC captures the geometrical information in image by building k-nearest neighbor graphs smoothed by a graph Laplacian operator to preserve the local manifold structure. Such a smoothed graph is called regularized and, hence, the image representation is ensured to vary smoothly along the geodesics of the manifold.

In the underlying optimization problem, the best subset of basis vectors from a dictionary is chosen such that the loss of representation, which is measured as L2-norm of the difference between the original and reconstructed images (equivalent to the mean-square error), is minimized jointly with a sparseness metric of the representation. The minimization is constrained by imposing an upper bound on the basis vector norms. The simplest sparseness metric counts the number of nonzero components of the representation vectors (L0-norm). However, such a metric leads to a NP-hard global optimization problem, which can be substituted with greedy approaches, such as Matching Pursuit or Basis Pursuit. Similar to the method based on Basis Pursuit [6], the authors choose the L1-norm instead, which makes the optimization problem convex in either the set of basis vectors (dictionary) or the set of representation vectors (sparse representation). To achieve the minimum of the criterion function and the optimal representation, the optimization is implemented iteratively by optimizing each set separately, while keeping the other set fixed. Thus, the optimization problem becomes an l1-regularized least squares optimization with an l2-least squares constraint, which can be solved efficiently.

To ensure regular geometric structures among the data points in image representations, the authors adopt manifold assumption in their algorithm GraphSC, that is, if two points in the original data set were close, they remain close in the representation too. Hence, the authors modify the previous mean-square error objective minimization function to a weighted version, where the binary weights are assigned to each pair of points according to a graph of neighborhoods: two points are either connected (the weight equals 1) in case they belong to each others' k-nearest neighborhood or disconnected (the weight equals 0) otherwise.

The iterative optimization process consists of two phases: learning graph and learning dictionary. In the first phase, the graph of neighborhoods and image representation are optimized given a fixed dictionary. Each representation vector is updated in a loop until the locally optimal solution is achieved. Then, in the second phase, the

dictionary is optimized given a fixed graph. This optimization problem is, in fact, a least squares problem with quadratic constraints and it is efficiently solved using Lagrange multipliers [2].

The authors demonstrate application of the algorithm GraphSC and sparse representation in image classification and clustering. In classification, the performance is superior to two other algorithms for a wide span of data set size. In clustering, the method is compared to four other algorithms for different number of clusters and using several databases. The proposed method GraphSC shows a steady improvement as compared to the others. On top of that, the authors also provide an analysis of the influence of different parameter values on the final clustering performance.

In summary, the proposed method in this paper provides a sparse representation of images with regard to preservation of manifold structures of the data space. The image reconstructions are regularized using graphs of neighborhoods retaining in that way geometrical coherence in images. The applications in image classification and clustering show that sparse representations can considerably improve the performance by extracting important components of images. Even though the area of sparse image representation has been well analyzed in the past, the authors demonstrate that geometric regularity of images plays an important role in image content understanding. They have also motivated a further research along these lines to examine the limits of performance improvements in image classification and clustering for various sets of selected parameters.

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How computers can recognize Parent-Child Relationships in photos

A short review for "Understanding Kin Relationships in a Photo"

Edited by Guillaume Lavoué

Siyu Xia, Ming Shao, Jiebo Luo and Yun Fu, "Understanding Kin Relationships in a Photo", IEEE Transactions on Multimedia, Vol. 13, No. 3, June 2011, pp. 432-442.

We are in the era of social media and people are at the center of social media. There is an urgent need to organize and manage images of people automatically due to the recent explosion of such data on the Web in general and in social media in particular. In this excellent work, the authors propose to solve a brand new social media problem of kinship recognition directly from photos, which can open up a new direction in social media analytics. The idea is to infer the social relationships of humans in large-scale photo albums. The success of such work will lead to broad impact, with compelling real-world applications in multimedia search, electronic customer relationship management, and social networking.

From their preliminary and current research, the authors have observed that facial appearance from photos is an important cue for genetic similarity as children resemble their parents more than other adults of the same gender, and that there is differential resemblance between two parents depending on the age and gender of the child. Analogously, another important finding is that faces of parents in images captured while they were young more closely resemble their children's compared with images captured when they are old. Based on these keen observations, the authors have collected and publicized the first comprehensive KinFace database, which consists of face images of children, their young parents and old parents from family albums/photos.

The authors then propose a new transfer subspace learning based method, aiming at reducing the large divergence in the appearance distributions between children and old parents, so that large age-induced variations are mitigated effectively. The key idea is to utilize an intermediate data set close to both the source and target distributions and naturally the young-parent image data set is ideally suitable for this task. Moreover, they consider the context and semantics in family photos and treat kinship verification as a joint tagging problem, mining deeper knowledge than mere pair-wise verification. The authors have conducted quantitative evaluations with both subjective test and objective test. Results have demonstrated that the proposed algorithm can effectively annotate the kin relationships among people in an image and that semantic context can further improve the accuracy.

Their subjective experiments also provide some interesting insights into the ability of human subjects to identify kinship relations
The preliminary paper of this work was published in JCAI 2011, which was cited for more than 10 times within one year from other researchers and in addition caught much attention in press coverage. It is conceivable to predict an increase in citations given that follow-up research will appear in the next few years. As time goes, this timely and innovative work is expected to have lasting impact on the field of social media analytics, with all kinds of visual data going through explosive growth, especially when visual data meet social relationships and other visual context.

Acknowledgement:

This paper is nominated by the MMTC VAIG.

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