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MMTC Communications – Review

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TABLE OF CONTENTS

Message from the Review Board Directors

Welcome to the December 2018 issue of the IEEE ComSoc MMTC Communications – Review.

This issue comprises three reviews that cover multiple facets of multimedia communication research including network function virtualization cooperative video caching, and offloading in information centric networks. These reviews are briefly introduced below.

The first paper, published in IEEE Transactions on Network and Service Management and edited by Dr. Qin Wang, developed an optimal mapping algorithm with huge reduction of the algorithm execution time for virtual network embedding.

The second paper is published in IEEE Transactions on Multimedia and edited by Dr. Jinbo Xiong. It proposes a cooperative video caching methodology for device to device communications.

The third paper, published in IEEE Access and edited by Dr. Xiaohu Ge, investigates the use of offloading in balancing computational tasks in device to device networks.

All the authors, nominators, reviewers, editors, and others who contribute to the release of this issue deserve appreciation with thanks.

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A Novel Optimal Mapping Algorithm for Virtual Network Embedding

A short review for "A Novel Optimal Mapping Algorithm with Less Computational Complexity for Virtual Network Embedding"

Edited by Qin Wang

H. Cao, Y. Zhu, G. Zheng, and L. Yang, " A Novel Optimal Mapping Algorithm with Less Computational Complexity for Virtual Network Embedding," IEEE Transactions on Network and Service Management, vol. 15, no. 1, Mar. 2018.

Network virtualization has been recognized as one of the key technologies for the future network [1]-[5]. Network virtualization is widely accepted as the right candidate to overcome the ossification of current Internet to fundamental changes.

Though a great interest in network virtualization [1] has been stimulated, several challenges still exist and prevent network virtualization from being implemented in real networking environment. One main challenge is how to effectively and efficiently map multiple virtual networks (VNs), with individual virtual node and link requests, onto the shared substrate networks with limited node and link resources. This mapping challenge is known as virtual network embedding (VNE)[2]. Since VNE requires a simultaneous optimal assignment of virtual nodes and links of each VN, it is complex in computation and known as a NP-hard problem. Multiple VNE algorithms have been proposed in the literature [2][3][4]. However, for simplifying the VNE, these algorithms either assume that the shared SN supports the path splitting, or conduct the node and link embedding in two separate stages. Consequently, the mapping results of these algorithms are not optimal..

This paper presents an optimal mapping algorithm with huge reduction of the algorithm execution time for virtual network embedding. The proposed algorithm is named as CAN-A (Candidate Assisted). Compared with existing non-optimal heuristic algorithms, CAN-A algorithm insures the optimal mapping solution for any given virtual network request. At the same time, the computational complexity of CAN-A is much lower compared with previous optimal VNE algorithms. The key idea of CAN-A algorithm lies in constructing the candidate substrate node subset and the candidate substrate path subset before conducting the integer linear programming based mapping. In CAN-A algorithm, four types of node and link constraints are considered, which are deduced from realistic network attributes, and make CAN-A applicable to real VN operation. Those constraints are node capacity, node location, link bandwidth, and link propagation delay. Virtual node location and virtual link propagation delay are not considered as constraints in previous VNE algorithms. Extensive simulation results show that the

execution time of CAN-A is hugely cut down, compared with the optimal VNE-MIP algorithm [5]. In addition, the CAN-A algorithm outperforms the selected typical heuristic algorithms in terms of other performance metrics such as average VNR acceptance ratio and average virtual link propagation delay

Thus, the authors' major contribution is to propose a novel VNE algorithm CAN-A, which is optimal and less computationally complex. The reduction of computational complexity is achieved by constructing two substrate candidate subsets, one for substrate nodes, the other one for substrate paths. The volume of each subset is much smaller than the corresponding full set. Afterwards, integer linear programming based approach is applied to calculate the optimal mapping within the reduced subsets.

The virtual node locations and the virtual link propagation delays are formulated as constraints in the CAN-A algorithm, which are not considered as constraints in previous papers. With the increase of delay sensitive services on the network, strict and guaranteed transmission delay is needed for this kind of new services. The authors formulate the link propagation delay as a constraint into CAN-A algorithm, so as to the mapped virtual network provides delay guaranteed services to meet future service requirements. Location constraint is a natural attribute of network node. Location constraint in VNE algorithm makes VNE applicable to engineering networks.

Four sub-algorithms of CAN-A are proposed and evaluated in this paper. Each sub-algorithm adopts an objective function to optimize specific performance index. Four objectives are: total substrate cost function **CF**, total virtual link propagation delay function **LDF**, substrate cost and load balancing function **CLBF**, substrate cost and virtual link propagation delay function **CLDF**, respectively.

Extensive simulations are conducted in this paper, aiming at validating CAN-A efficiency. The computational complexity of CAN-A is compared with the pure mixed integer programming (MIP) algorithm, which is widely accepted as the optimal VNE algorithm. The simulation results indicate that the complexity of CAN-A is reduced hugely compared with VNE-MIP algorithm. In addition, simulation results validate that average VNR acceptance ratio and average virtual link propagation delay of CAN-A outperform typical heuristic algorithms.

In summary, this paper presents an optimal VNE mapping algorithm CAN-A with less computational complexity. The CAN-A algorithm can significantly reduce the algorithm complexity by constructing candidate substrate node and path subsets which are much smaller than the full sets, before performing the integer linear programming based mapping. Comprehensive simulations are conducted to assess the CAN-A algorithm. Results vividly show that the CAN-A algorithm outperforms typical heuristic algorithms. In terms of average VNR acceptance ratio, the difference between the heuristics and CAN-A is, at least, 10%. The node utilization of CAN-A is higher than the heuristics because CAN-A is able to accommodate more proposed VNRs than the heuristics. With

respect to the average virtual link propagation delay of each given VNR, CAN-A outperforms the best-behaved heuristic. All possible mapping assignments are considered in CAN-A. Therefore, the optimal mapping with the lowest average virtual link propagation delay, is able to be achieved by the CAN-A algorithm.

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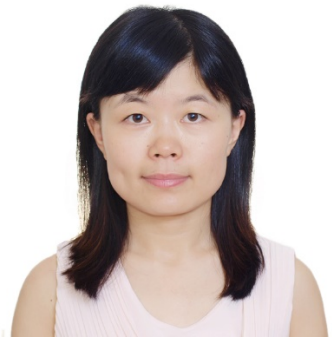

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A User-centric Device-to-Device Video Caching and Delivery Mechanism

A short review for "Cache Less for More: Exploiting Cooperative Video Caching and Delivery in D2D Communications"

Edited by Jinbo Xiong

D. Wu. Q. Liu, H. Wang, Q. Yang and R. Wang, "Cache Less for More: Exploiting Cooperative Video Caching and Delivery in D2D Communications," IEEE Transactions on Multimedia, vol. 21, vo. 7, July 2019.

To deal with the increasing mobile data demand and Base station (BS) overload issues, device-to-device (D2D) communication defined in 3rd Generation Partnership Project (3GPP), was proposed to allow mobile devices in close proximity to transmit data between each other, under the control of BS. As a result, the network traffic load on BSs will be alleviated and system capacity can be effectively improved [1].

Existing works on video streaming in cellular networks can be summarized as the following strands: video multi-casting, content distribution network (CDN), precache scheme, and video quality adaptation [2]-[3]. However, exploiting D2D communication in video streaming is still an open problem, and it is further complicated by the mobility of users, unstable channel conditions, and high quality of experience (QoE) requirements. Particularly, the movement of users makes D2D links exhibit a discontinuous feature in both temporal and spatial domains, which may cause channel errors and packet losses in video transmissions process. Furthermore, interrupted video transmissions or transmissions with large jitters/delays, would significantly degrade a user's QoE, which should be reduced as much as possible. Therefore, how to efficiently deliver videos to mobile users via D2D communications, while ensuring QoE of users, is one of the critical design problems for multimedia wireless networks [4]-[5].

In this paper, a user-centric D2D video caching and delivery mechanism is proposed by using user devices instead of traditional access points (Aps), and each user who subscribes to the video service has a dynamic service set that consists of its neighboring users. Besides, the main difference between Aps and user devices is that users have mobility and individual rationality in this scenario. Thus, the proposed solution jointly considers users' sharing willingness, location distribution, storage capacity, and their QoE requirements, to enhance data transmission efficiency.

Thus, the authors' major contribution is to propose a user centric video transmission mechanism based on D2D communications that allows mobile users to cache and share videos between each other, in a cooperative manner. The proposed solution jointly considers users' similarity in accessing videos,

users' sharing willingness, users' location distribution, and users' quality of experience (QoE) requirements, in order to achieve a QoE-guaranteed video streaming service in a cellular network. Specifically, a service set consisting of several service providers and mobile users, is dynamically configured to provide timely service according to the probability of successful service.

Mobile users in this paper are divided into two groups, namely service providers (SPs) and service consumers (SCs). When a SC successfully subscribes to a video service, its serving BS will check the SC's video accessing history and generates a cooperative cache list (CCL) that contains the videos that are likely to be accessed by the SC in the future. By comparing the similarity between a SP and the SC, regarding to their video accessing history, the CCL of a SP will be identified. From the CCL, a SP determines which videos need to be cached in its local storage. Based on the amount and quality of videos that a SP can provide; a group of SPs are selected to construct the SC' service set. After the service set is established, videos are pushed to SPs at off-peak time, if possible, to avoid network congestion caused by concurrent video transmissions during peak time. Considering that the storage capacity of the mobile device is limited, the user cannot cache multiple demand videos. Besides, in order not to affect the other operations of consumer, e.g., limited work space, only SPs receive the video pushed by BS. Thus, the user can prefetch data to reduce latency when network congestion happened. After the so-called base station to device (B2D) communication, videos will be cached on the SPs. Later on, when the SC and SPs are in close proximity, cached videos are transmitted to the SC via D2D communications, in a "many-to-one" manner, that is, a consumer obtains videos from multiple potential providers. The mode can be regarded as the independent operation of several D2D links. When the requested video is completely delivered to the SC, the BS will update the SC's and SPs' CCLs accordingly.

Besides, considering the chance that users may cooperatively cache videos for each other, it is essential to investigate how likely a user is willing to serve as a SP for others. In addition, the user preferences, which describe the long-term behavior of users, are stable. Thus, the probability that a SP can provide caching service for a certain video is determined. Based on the probability, a service set is iteratively established so that selected SPs in the service set can cooperatively transmit requested videos to the SC, while guaranteeing the SC's QoE.

Extensive experiments demonstrate the improved performance of the proposed solutions. Simulation results show that the proposed communication scheme can significantly improve users' QoE and network performance. Compared with other existing schemes, the proposed solution can achieve the highest users experience rate, and the data offload rate.

In summary, this paper explores the possibility of caching videos on individual users in a cellular network, and allowing users to share videos among each other, via a hybrid communication mode, i.e., B2D+D2D. In particular, the cooperative cache list is constructed by considering users' similarly in accessing

videos to determine if the videos need to be cached.

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An Optimized Scheme for Precedence-Constrained Device-to-Device Computation Offloading in Information-Centric IoT

A short review for "D2D Computation Offloading Optimization for Precedence-Constrained Tasks in Information-Centric IoT"

Edited by Xiaohu Ge, Authored By Y. Jia

J. Xie. Y. Jia, Z. Chen, Z. Nan and L. Liang, " D2D Computation Offloading Optimization for Precedence-Constrained Tasks in Information-Centric IoT," IEEE Access, vol. 7, Aug. 2019.

While mature process technology brings mobile devices much more powerful computing capabilities for data analysis, it indicates that smart mobile devices constitute to intelligent groups. In order to achieve the multiplexing gain of available resources on these intelligent devices, device-to-device (D2D) communications and mobile edge computing (MEC) are integrated to enhance the computation capacity of system [1] and support task collaborative execution [2] with assistance of base station (BS). This advantage is highlighted by applying D2D and MEC into information-centric Internet of things (IC-IoT) [3] [4], where mobile devices can share not only the communication and computing resources among each other but also the popular task contents.

In the integrated structure, user device floods interest packet to request execution help and send data packet to provide task content for helper devices while helpers send back task execution results in a data packet to user. However, appropriate helper selection in dynamic networks is a big challenge. Because of time-varying communication resource volume and computing capability offered by helpers, the transmission and task execution cost are sophisticated and unpredictable. Thus, the framework requires to update cost of possible task-helper pairs according to the live system information.

Another crucial part regarding task offloading is weather to offload or not, which is usually called binary offloading decision. Existing binary offloading decisions focus on an integrated task schedule and an optimal edge node selection. Obviously, it is not acceptable to the case when a task is relatively large and has to be processed by multiple devices in the mobile edge. Therefore, a task is considered to be divided into several smaller subtasks, and partial offloading is carried out to discuss how much and what should be offloaded [5]. To meet user specified needs, there are certain precedence relations among these subtasks, such as sequential precedence and parallel precedence, which determine the execution order and processing time of subtasks. In practice, the precedence of a large delay-constrained task cannot be simply described as sequential or parallel precedence, such as mobile games. Considering data transfer delay and game rules, there are some hard

precedence constraints on execution steps. Few works concentrate on computation task offloading problem with this type of precedence relations.

Hence in the paper, the authors combine all those aspects and consider the strategy of task offloading with system dynamics and specified precedence relations among subtasks. In particular, a new task graph model is used for representing the relationship among subtasks of an application. For the precedence constrained task, the problem formulation aims to minimize the cost of task offloading jointly considering subtasks delay constraints, association states between user and helpers and available resources constraints.

Thus, the authors' major contribution is to propose an efficient task offloading scheme based on weighted bipartite graph matching to pair subtasks and helpers. By constructing appropriate weight of bipartite graph according to the time-varying system information, it searches minimum cost (weight) subtask-helper pairs as the optimal offloading policy.

Specifically, to realize the offloading of task with precedence constraints in IC-IoT, the formulated problem is modeled as a dynamic generalized assignment problem with multi-resources constraints, which is a proved to be an NP-hard problem [6]. In general, key challenges of solving the problem are devices mobility and dynamic private task generation that causes the available resources changing with time. Dynamic environment urges the authors to sense the system information such as association states between user and helpers, and available devices resources in each time interval. For reducing the complexity of sense, the association states among mobile devices are predicted at first according to the mobility information analysis with individual mobility model. After association states sensing, how to find optimal subtask-help pairs for lowest cost in every time interval is the important component of proposed task offloading algorithm.

With feasibility discussion of the matching theory, subtask-helper matching by Hungarian algorithm, and computational complexity analysis of the proposed scheme, it demonstrates that the computation complexity of the proposed task offloading algorithm is quite acceptable in practice. Besides, the BS can also leverage multiple processors to adopt some parallel implementations for graph matching.

Extensive simulation experiments are provided, which demonstrate the improved performance of the proposed task offloading algorithm. Specifically, the performance of proposed task offloading scheme is evaluated by comparing with priory-based offloading and random helper selection. Besides, the effects of tradeoff parameter and maximum private load percentage of helper on the performance of task offloading are carefully discussed.

In summary, the proposed computation offloading scheme is quite efficient for precedence-constrained task in IC-IoT. It minimizes the weighted sum of task processing delay and resources rental fees jointly while the constraints of task delay, association states and available resources are taken into account. It is highly encouraged to be chosen as the

first candidate offloading algorithm in comparison with priority-based offloading scheme and random selection.

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Paper Nomination Policy

Following the direction of MMTC, the Communications – Review platform aims at providing research exchange, which includes examining systems, applications, services and techniques where multiple media are used to deliver results. Multimedia includes, but is not restricted to, voice, video, image, music, data and executable code. The scope covers not only the underlying networking systems, but also visual, gesture, signal and other aspects of communication. Any HIGH QUALITY paper published in Communications Society journals/magazine, MMTC sponsored conferences, IEEE proceedings, or other distinguished journals/conferences within the last two years is eligible for nomination.

Nomination Procedure

Paper nominations have to be emailed to Review Board Directors: Qing Yang (qing.yang@unt.edu), Roger Zimmermann (rogerz@comp.nus.edu.sg), Wei Wang (wwang@mail.sdsu.edu), and Zhou Su (zhousu@ieee.org). The nomination should include the complete reference of the paper, author information, a brief supporting statement (maximum one page) highlighting the contribution, the nominator information, and an electronic copy of the paper, when possible.

Review Process

Members of the IEEE MMTC Review Board will review each nominated paper. In order to avoid potential conflict of interest, guest editors external to the Board will review nominated papers co-authored by a Review Board member. The reviewers' names will be kept confidential. If two reviewers agree that the paper is of Review quality, a board editor will be assigned to complete the review (partially based on the nomination supporting document) for publication. The review result will be final (no multiple nomination of the same paper). Nominators external to the board will be acknowledged in the review.

Best Paper Award

Accepted papers in the Communications – Review are eligible for the Best Paper Award competition if they meet the election criteria (set by the MMTC Award Board). For more details, please refer to http://mmc.committees.comsoc.org/.

MMTC Communications – Review Editorial Board

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MMTC examines systems, applications , services and techniques in which two or more media are used in the same session. These media include, but are not restricted to, voice, video, image, music, data, and executable code. The scope of the committee includes conversational, presentational, and transactional applications and the underlying networking systems to support them.