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System utility based resource allocation for D2D multicast communication in software-defined cellular networks ☆

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ABSTRACT

Device-to-device (D2D) multicast communication is a useful way to improve the communication efficiency of local services. This study considers a scenario of D2D multicast communication in software defined cellular network and investigates the frequency resource allocation problem. Firstly, we build the system model and formulate the optimization problem. Secondly, a hierarchical scheme to achieve a suboptimal solution is proposed. To select appropriate user equipments (UEs) as potential D2D transmitters (PDTs), a social aware PDT selection method is proposed. Then, a resource allocation algorithm considering users' priorities is proposed. Furthermore, to study the resource allocation for general system that UEs without priorities, a non-priority considered allocation algorithm is proposed also. Numerical simulation results show that the proposed schemes are effective in improving the system utility and reducing the resource consuming for D2D communications.

1. Introduction

With rapid development of smart devices, high data transmission rates applications becoming increasingly prevalent, which is putting new traffic pressure on cellular network. As an essential way of local communication, device-to-device (D2D) communication has become a research hot-spot in recent years [1,2]. Different from the traditional cellular communication, user equipments (UEs) can communicate to each other directly without the relay of base station (BS) via D2D communication, which can reduce the traffic load of the core network. D2D communication was introduced systematically in [3]. Unlike small cell BS, the setup of D2D communication is not costly, and the maintenance of D2D communication is not overly complex. As an underlay to cellular communication, D2D communication may generate harmful interference to cellular user equipments when they share the same frequency resources. Therefore, it is crucial for D2D communication networks to allocate frequency resource properly. To improve performance of D2D communication, various complicated methods have been employed in D2D communication system [4,5], such as network coding [6], graph theory method [7], game theory [8–10], and machine learning [11].

Based on the existing studies about D2D communications, there are two important issues to deal with. Firstly, considering limited memory and energy resources, not all UEs want to be D2D transmitter selflessly. Secondly, with the development of study on D2D communication, resource allocation algorithms have grown in complexity, which brings challenges to network. To deal with the first issues, researchers have begun to study socially aware based D2D communications [12–14]. A socially aware distributed caching strategy based on a learning automation for D2D communications was proposed in [12], which was proved to improve system throughput gain significantly. In [13], Wu etc. proposed a price-based multicast video distribution system and a grid-based clustering method. Furthermore, based on users' social attributes, Wu's team proposed a video coding sharing scheme in [14]. Those schemes have stronger applicability than traditional study of D2D communications.

Software defined network (SDN) is a promising technology to settle the second problem. As a new paradigm which decouples the control plane and the data plane, SDN enabling network administrators to program the network in a dynamic and flexible manner [15,16]. There are several benefits of SDN-based D2D communication. Firstly, a hybrid D2D communication architecture where a centralized SDN controller can reduce the number of communication links thereby improving energy efficiency. Secondly, since SDN controller has a global view of the network, operators can manage and optimize resource allocation efficiently in response to time-varying network conditions. In addition, SDN

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enables fast control over devices in a vendor independent way by means of standardized interfaces [17]. There are some articles studying the software defined D2D communication [18]. F. R. Yu's research team has investigated the resource allocation of SDN-based D2D communications [19,20]. Literature [20] illustrated the system model of SDN-based cellular network and proposed a resource allocation algorithm with imperfect CSI. However, those researches are mainly focusing on SDN-based D2D unicast communication. Few research studies SDN-based D2D multicast communication. With the recent popularity of smart terminals, the demand for multimedia and video services is growing rapidly. The adoption of D2D multicast technology can significantly improve the transmission efficiency with the better reuse of the spectrum.

Based on the above statements, in this paper, we study about applying D2D multicast communication into software defined cellular networks (SDCNs) and propose a resource allocation scheme. Firstly, we build the system model and formulate the optimization problem. Secondly, a social aware potential D2D transmitter (PDT) selection method is proposed. Then, to obtain the improvement of system utility and guarantee the performance of UEs with high priority, a resource allocation algorithm with priority considered is proposed. Further, to study the resource allocation for general system that UEs without priorities, a non-priority considered resource allocation algorithm is proposed also. Simulation results show that the proposed schemes improve the system utility and reduce resource consumption.

The contributions of our work are: (1) Software defined network technology is applied to cellular network to assist with resource allocation of D2D communications. (2) This paper mainly studies D2D multicast communication, which would lead to an improvement of resources' utilization. (3) A social aware PDT selection method is proposed to select appropriate PDTs. (4) The resource allocation algorithms for UEs with priorities and without priorities are studied respectively and simulation results are performed.

The rest of this paper is organized as follows. System model and the optimization problem are introduced in Section 2. In Section 3, we give a detailed introduction to the proposed hierarchical scheme, which includes PDT selection and resource allocation. Numerical simulation results and analysis of results are given in Section 4. Finally, Section 5 concludes the paper and highlights our findings.

2. System model and problem formulation

2.1. System model

We consider a SDCN with D2D communication whose system model can be seen in Fig. 1. Components with both control and data functions in traditional network are partitioned. Specifically, Serving gateway (SGW) divided into SGW Control Unit (SGW-C) and SGW Data Unit (SGW-D). Similarly, PDN gateway (PGW) divided into PGW Control Unit (PGW-C) and PGW Data Unit (PGW-D). Mobility management entity (MME), SGW-C, PGW-C are implemented as part of the SDN controller. The control plane and data plane communicate with each other via OpenFlow protocol. The PDT m means that one UE which can be selected to be a D2D transmitter. Let Φ be the set of PDTs, $\Phi = \{1, 2, \ldots, m, \ldots, M\}, m \in \Phi$. There is an especial case which with eNB to be transmitter. When $m = 0$ means that eNB is the transmitter for user. Then we set $\Phi_0 = \Phi \cup \{0\}$. Ψ is the set of receivers, $\Psi = \{1, 2, \ldots, N\}$, we denote receiver $n \in \Psi$. Therefore, there are I $(I = M + N)$ UEs in the system. The independent homogeneous Poisson point process (HPPP) is used for the location of UEs. Receivers' locations are modeled by a HPPP with density λ_r. $\Theta = \{1, \ldots, K\}$ denotes the set of all sub-channels in the system. We assume that frequency resource allocated to D2D communication is orthogonal to that of cellular communication, and the location information about each UE can be gain from SDN controller. The wireless link between two nodes is subject to independently Rayleigh fading, propagation path loss, and additive white Gaussian noise (AWGN).

2.2. Problem formulation

It is assumed that receiver n has a content request $C^{(n)}$ for network. Let $a_m^{(n)}$ be the content distribution indicator, namely, $a_m^{(n)} = 1$ indicates that content $C^{(n)}$ is readily stored in the memory of transmitter m, otherwise, $a_m^{(n)} = 0$. The size of $C^{(n)}$ denoted by $s_{c^{(n)}}$. Similarly, the binary variable $b_m^{(n)}$ denotes whether or not transmitter m is allocated to receiver n. In addition, let $c_{m,k}^{(n)}$ be the allocation indicator variable, i.e., if sub-channel k is allocated to the link between receiver n and transmitter $m, c_{m,k}^{(n)} = 1$, otherwise, $c_{m,k}^{(n)} = 0$. $e_m^{(n)} = 1$ indicates that receiver n receives content from

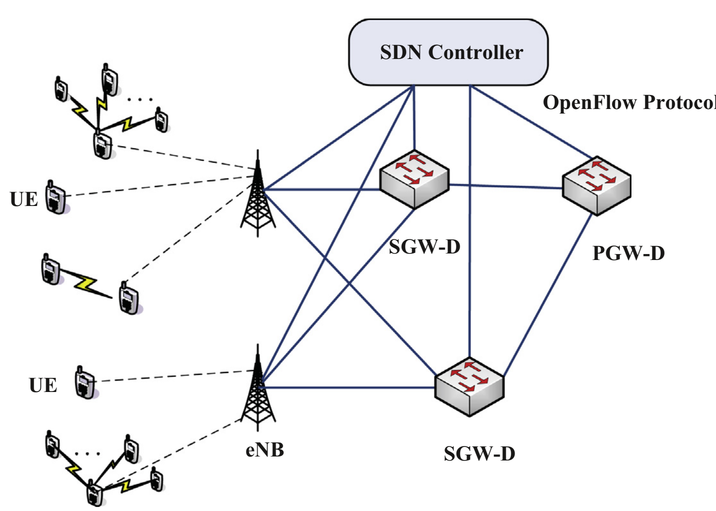

Fig. 1. System model of software defined cellular network.