A Novel Design for Content Delivery over Software Defined Mobile Social Networks

Zhou Su, Qichao Xu, Haojin Zhu, and Ying Wang

Abstract

With the rapid development of mobile communication technologies, various kinds of content can be delivered among mobile users for content sharing. Due to the complexity of networks and particular features of mobile behaviors, to manage networks efficiently, SDMSNs are advocated where the control plane and data plane can work separately but cooperatively. In this article we outline how to deliver mobile content over SDMSNs. We first design the flow table based on the social features including social tie, mobility, and community. Then a novel social switch is introduced to deliver content among mobile users by using the proposed social degree and social stay time. In addition, the process of content delivery is presented according to different scenarios, and extensive experiments are given to prove the efficiency of this approach.

With the advance of mobile communication networks, except the traditional voice call, mobile devices have been able to provide various social services. It is now possible to interconnect different entities (people, devices, and systems) in different locations [1–4]. Nowadays mobile social networks (MSNs) have emerged as a new paradigm that has attracted increasing attention from both academia and industry. In MSNs, due to the expanding scale of mobile networks and the population of mobile users, there is an increasing demand for delivering various kinds of mobile content. How to deliver the large-scaled content has become one of the most important issues for MSNs.

However, content delivery in MSNs [5, 6] has different properties from other existing networks, with new challenges as follows.

- Content in MSNs is delivered based on the social features including social ties, community, and so on. But the conventional solutions for content delivery seldom consider these social characteristics when the delivery networks are designed. To improve the performance of mobile social content delivery, the current data flow and related forwarding process in MSNs should be ameliorated according to the social behavior patterns.
- The amount of content in MSNs is quite huge. Compared with traditional networks, the amount of content in MSNs is not of the same order of magnitude as others. Due to the mobility of social network users, the delivery of mobile content is even harder to control than in wired networks. It is highly desirable to reduce control traffic and data traffic in current MSNs by introducing a new design of controllers and switches.

Software defined networking (SDN) [7, 8] is advocated to resolve the above problems. On one hand, as the control plane can be designed separately from the data plane in the SDN, it will be possible to introduce new elements related to social behaviors to manage data flow and the forwarding process. On the other hand, because control in SDN can be programmable and logically implemented, it becomes possible to design a novel social control mechanism to deliver the large amount of mobile content.

In this article we present a novel design for content delivery over software defined mobile social networks (SDMSNs). We shed light on the current challenges faced in mobile content delivery and introduce the mechanism of SDN to improve MSNs. We first define two novel social elements called social degree and social stay, respectively, based on the social ties, mobility, and the status of the community. With the proposed social elements, we design a flow table in the SDMSNs to control data flow. Next we introduce a novel switch called the social switch, with which conventional switches and controllers can work cooperatively to reduce both the control traffic and data traffic. In addition, we present the process for content delivery in SDMSNs based on different scenarios, and the efficiency of our proposal is shown by simulation results.

Content Delivery in Mobile Social Networks

Mobile Social Networks

In MSNs, mobile users cannot only create their own content, but they can request content based on their social relations. MSNs may have different architectures according to different applications to spread information efficiently. Figure 1 shows an example of the architecture of MSNs. This architecture consists of two types of fundamental structures: centralized [9]

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and distributed [10]. Currently, as the coverage area of WiFi is still small in size, the centralized architecture is a conventional cellular network based on the client-server architecture. In this architecture, the sender sends the request to the server, and the server is responsible for storing the content. When the receiver needs to get this content, the receiver requests it from the server. In contrast, the distributed architecture does not rely on any server. Mobile users can communicate with each other directly through technologies such as Bluetooth, WiFi, and so on [11], where the content can be sent from multiple mobile users or access points to the destination. Besides the above two conventional architectures, there is also a hybrid architecture, in which mobile users can both get content from the server and exchange content with other users directly.

With the short-range communication technologies, mobile users can communicate with each other within a communication area to exchange content [12]. However, because of the limited coverage and mobility of users, MSNs based on current technologies may be intermittently connected and can not control content delivery efficiently. During the delivery of mobile content in the MSNs, besides the communication status such as bandwidth, delay, and user interest, social features including social ties, community, and mobility should also be taken into consideration to improve performance. Further, as mobile users forward information based on an opportunistic contact, the mechanism of information spreading in MSNs proves to be a way of store-carry-forward.

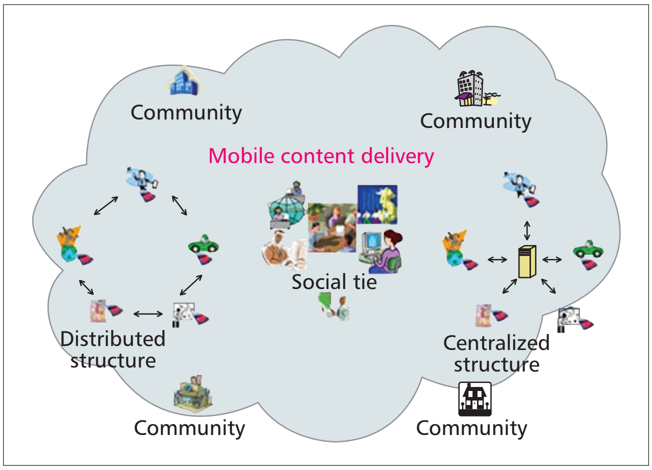

Figure 1. Mobile content delivery with social features.

Content Delivery

With the development of network applications and the increase of network population, content delivery has become a pivotal issue for current networks. There have been various paradigms for distributing content. The client-server structure is the conventional solution to deliver content to end users, where the proxy can be placed between the client and server to cache some popular content. However, because of the limited cache capacity and dynamically changed topology, the client-server structure could not provide an acceptable service for content services. Content delivery networks (CDNs) have been advocated for many years, where the replicas of original content are cached in a group of geographically distributed content servers [13]. As the content servers are placed near the clients, the request can be satisfied by providing the replicas in the content server to the clients, resulting in a reduction of response time. However, with the increasing scale of content, the scalability of CDNs has become a bottleneck. Peer to peer (P2P) networks [14] have also been applied to deliver content, where the P2P users can directly communicate with each other to share content, without relying on any centralized server. Compared with conventional solutions, in the P2P each node can act as the client to request content, and also the server to provide content. However, because of the limited stability and availability of P2P nodes, the performance of P2P is still limited.

MSNs have recently become an alternative solution to deliver content. Compared with the above CDNs and P2P, the main difference is that content delivery in MSNs is based on social features while the others are not. Content delivery in MSNs has its own inherent characteristics, as follows.

- Content is delivered based on social behaviors including social ties, communities, and so on. For example, if there is a social connection between two mobile users in the same community, the content may be distributed.
- The amount of mobile content is extremely large and continues to increase. The authors in [4] report that global mobile data traffic will contunue to increase nearly tenfold from 2014 to 2019. Each user in MSNs may not only request content frequently, but also create content to share with other mobile users who have the same interest.

Therefore, because content delivery in MSNs has the above different properties when compared with other existing networks, there are new challenges in managing MSNs. On one hand, data flow in MSNs should be processed based on social behaviors. On the other hand, the cooperation of controllers and switches is needed to reduce control traffic and data traffic caused by the delivery of a large amount of content. To resolve the above problems, a new paradigm with an integration of SDN is expected.

Software Defined Mobile Social Networks

Concept of SDN

In current networks there are three planes that need to work together. The control plane handles and controls network traffic, while the data plane forwards network traffic based on the commands of the control plane [7]. Between the control plane and the data plane, there is a management plane consisting of software services to remotely and functionally configure the control. However, because currently the control plane and data plane are both bundled inside the networking devices without any separation, it is hard to manage current networks to further improve performance, especially in the situation where both the scale and complexity of networks are continuing to increase.

Software defined networking [8] appears as an emerging network paradigm to resolve the above limitation of current networks. SDN separates the control plane from the data plane, so the forwarding process in network switches can be easily carried out and the control can be programmable and logically implemented. Application programming interfaces (APIs) are introduced between the switches and the controllers. With these APIs such as OpenFlow [15], the controller can control the state of the data plane with the corresponding packet handling rules.

Integration of SDN with MSNs

Integrated with SDN, the SDMSN paradigm can be expected to deliver mobile content over MSNs with the following potentials.

- As current MSNs still rely on conventional switches to forward content, there is still no special consideration of social features. For SDMSNs, based on the analysis of mobile social behavior, by introducing novel elements in the flow table of the SDN-based switch, it is possible to carry out data forwarding by considering the features of social behavior.

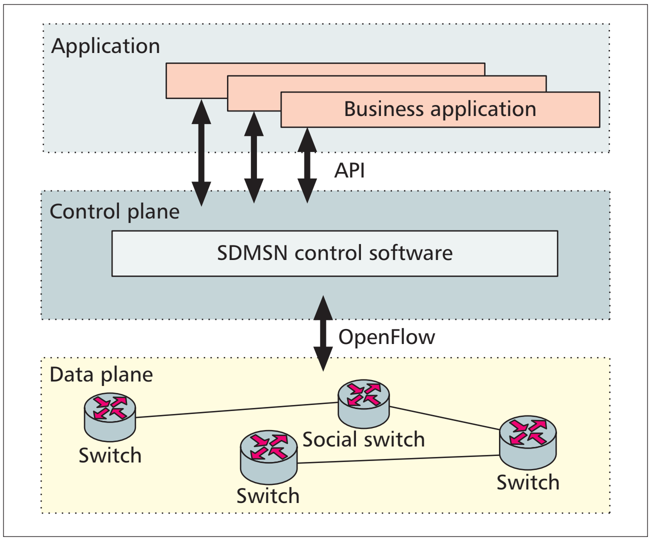

Figure 2. Structure of software defined mobile social networks.

- In current MSNs, the controller does not work well cooperatively with its connecting switches to provide social services. For SDMSNs, a novel social switch could be designed and placed among the controller and other switches to reduce both control traffic and data traffic, in order to face the new challenge that the amount of content is increasing rapidly in MSNs.

Architecture of SDMSNs

We present a structure of SDMSNs shown in Fig. 2, where there are three planes.

The first plane in SDMSNs is the data plane. Similar to the data plane in conventional SDNs, the data plane of SDMSNs consists of a number of switches that are used to forward messages to mobile users. In addition, the management part of the network is separated from the data plane. Compared with existing SDNs, the key innovations of SDMSNs are that the flow table in each switch can be rewritten and a novel social switch based on social behavior is added into the network. Specifically, each switch is allocated with a social switch, which can be used to construct a high speed path to deliver data between mobile users who have social ties. Besides the social switch, we add two new elements into the flow table in each switch. The first is social degree, which is used to determine whether two terminals of a communication are friends. The second is called social stay, which is used to record the time duration of a mobile user's connection with a switch.

The second plane of SDMSNs is the control plane, which is used to manage the network. In fact, with centralized control, the controller senses the status of the network quickly and then adjusts the strategy of control dynamically. In SDMSNs, mobile users should submit login information to the controller when they want to access the Internet. Then the controller will update the flow table in each switch to prepare the next strategy of control, such as the determination of the social relation between mobile users and the connecting switch of mobile users. If the controller has determined that two mobile users are friends, it will open its social switch to be the middleware to provide a high speed way to deliver content.

The last plane of SDMSNs is the applications plane, which can manage the underlying devices to control the entire network by the application program interface provided by the controller. For communication between the controller and switches, OpenFlow can be employed.

Details about the design of our SDMSNs will be introduced in the next section.

Framework Design and Performance Evaluation

In this section, we present the framework and performance evaluation for SDMSNs.

Features of Mobile Social Behaviors

With the advances in wireless technologies, including WiMAX, LTE, etc, mobile users can have interactions with each other. There are some typical social features in MSNs that can be used for content delivery. Specifically, MSNs have the following three unique features.

Social Ties: In MSNs there are social ties among mobile users, such as friends, relatives, colleagues, etc. For simplicity, in the following figure it is assumed that two users are friends if they have a social tie with each other. In addition, mobile users are inclined to communicate with their friends and the frequency of communications between two friends is also high. In fact, this feature is the most important one among others in MSNs.

Mobility: In MSNs mobile users usually do not stay in one place, so they can access networks through their mobile device with different switches when they move into different places. In other words, mobile users can communicate with each other anywhere and anytime. However, mobile users do not move all the time and usually move between the same locations. For example, a student on campus often appears and accesses networks in the classroom, laboratory, or dormitory.

Community: Community is also a significant feature in MSNs. Mobile users having the same interest can form a community, where they are friends of each other in the same community. In particular, mobile users in the same community can know the information of others. For example, students who have the same course are friends and can form a community to know each other.

Flow Table

In SDNs, the flow table can be seen as the core of the network. Each flow table contains several items that are related to the forwarding rules of content delivery, and each item includes some of the same elements including source, destination, counters, and actions. The source and destination are the sender and receiver of the content, respectively. The counters are used to record the information of the data flow. For example, a counter in an item can record the times when this item was matched by data flows. The actions are used to command a switch to manage the data flow when an item is matched. Typically, the switch can forward or drop data flow.

Different from the typical flow table in the traditional SDNs, we present two novel elements based on social features, to design the flow table in SDMSNs. First, a social degree (SD) is defined and added to the item of the flow table in each switch, which is shown in Fig. 3a. The SD is used to measure the degree of closeness of two mobile users. For a mobile user i ($i = 1, \ldots, I$) and another mobile user i' ($i' = 1, \ldots, I$), to deliver content from user i to i', the degree of closeness of mobile users i and i' can be obtained by $SD_{i,i'} = Scount_{i,i'}/T$, where $Scount_{i,i'}$ is the frequency of communications between two mobile users and T is the statistical time.

In SDMSNs, each switch records the SD in its flow table to show the degree of closeness between mobile users. For every time T, the switch can carry out actions according to the value of SD. Here, a social threshold δ is introduced to measure whether two users are friends. If the value of SD is larger than δ, the switch will submit the item containing this SD to the SDMSN controller.

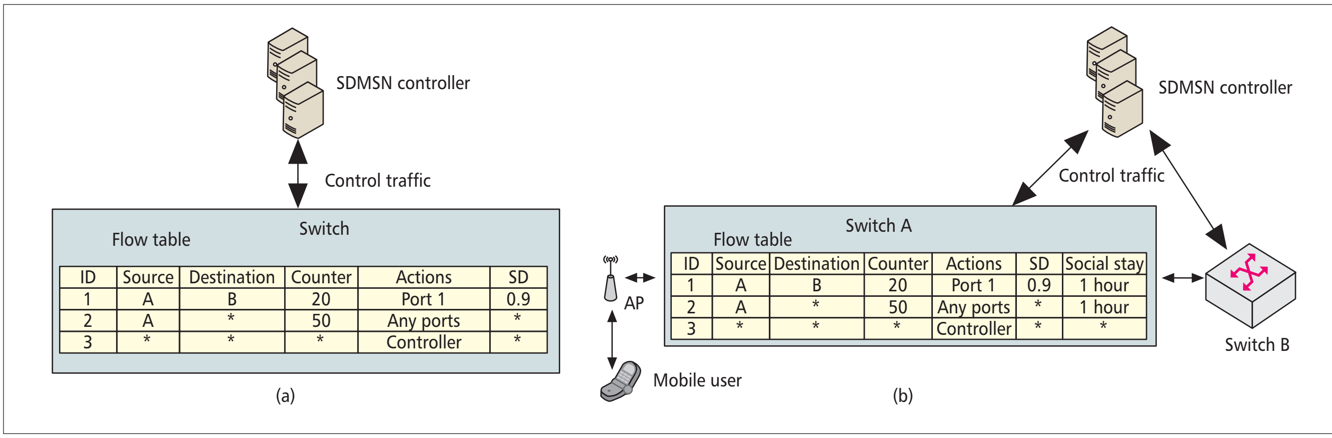

Figure 3. a) Flow table of each switch in SDMSNs; b) flow table of the first switch that the mobile user connects.

According to the mobility related to the social features in MSNs, mobile users usually access networks with a few access points (APs), e.g. in the classroom and dormitory. For the mobile user $i (i = 1, \ldots, I)$, if they have connected to a switch $k (k = 1, \ldots, K)$ for J times during his access of networks, for the j-th time ($j = 1, \ldots, J$), the connection time is denoted by $S_{i,j,k}$. We call $S_{i,j,k}$ the social stay of user i during the j-th connection with this switch k, and continue to define $T^{i,k}_{stay} = \Sigma_j S_{i,j,k}$. If there is a switch whose $P_{i,k} = T^{i,k}_{stay}/T$ is greater than a threshold η, we define this switch as the primary switch of mobile user i. Here, η is used to judge whether this switch can be the primary switch of the mobile user.

As shown in Fig. 3b, to record the online time of a mobile user, we add the second new element, social stay, into the flow table of the first switch to which the mobile user connects. Here, if mobile users want to access networks, they will be required to submit their login information including user name and password to the controller through a switch, which is called the first switch. Then the controller updates the flow table of this switch by creating and adding a flow table that contains the element of social stay. Similarly, when the mobile user quits networks, he should submit a leaving message to the controller. Then the controller collects the social stay from the switch and updates $T^{i,k}_{stay}$. So, according to $P_{i,k}$, the controller can judge whether this first switch is the primary switch of the mobile user.

Social Switch

Although some related works in MSNs [5] and SDN [15] have been given, there is still no consideration given to designing switches with social features. Except the conventional switch in SDMSNs, in this article we design a particular switch to deliver content between mobile users, which we call a social switch. Specifically, each SDMSN controller has only one social switch and the social switch stops working if there is no communication between friends in the network. Once two mobile users are determined to be friends by the controller according to the element of *SD*, the controller will open the social switch and add the corresponding item into the flow table of the social switch. In addition, if there is no item that can be matched by the data packet, the social switch will drop this data flow, which is different from conventional switches to inform the controller. The advantage of this design is that the content can be delivered to the destination through one switch and the control traffic between the social switch and the controller can be reduced.

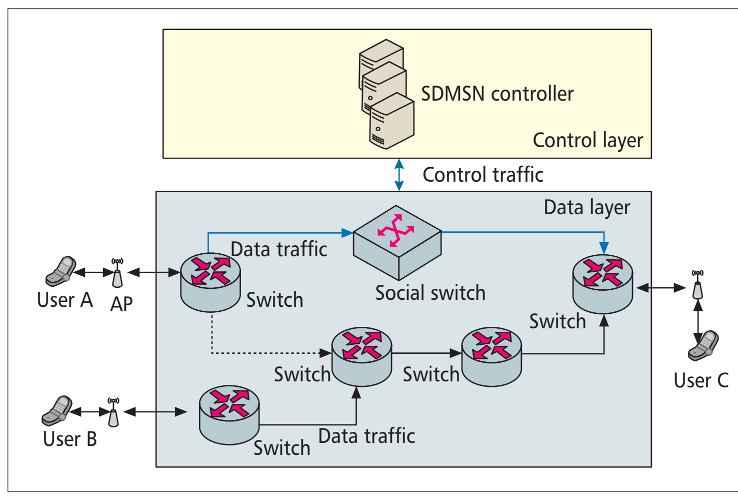

Figure 4. Schematic diagram of SDMSNs, where mobile users are in the same region.

Process of Data Delivery in SDMSNs

We use two examples to demostrate the process of content delivery in SDMSNs. It is assumed that there are three mobile users, denoted by user A, user B, and user C, who want to deliver content. Specifically, user A and user C are friends, while user B and user C are strangers to each other. In addition, the controller in the network cannot manage all switches and it can only control a limited number of switches in a region.

As shown in Fig. 4, in the first example, mobile user A, user B, and user C are often in the same region. For example, although they keep moving, they are working in the same building. When each mobile user accesses the network, they should submit the login information to the controller through the first switch it connects to. Then the controller adds the social stay into the flow table of this switch. After time T, the switches upload the *SD* and social stay for the controller. Then the controller determines whether the mobile users are friends and the first switch is the primary switch of the mobile user, respectively. In fact, according to the features of MSNs, user A and user C have frequent communications, while there is little content to be delivered between user B and user C. In this example, once it is determined that mobile users A and C are friends, the controller will command all switches to delete the flow table about content delivery between user A and user C except their primary switches. Finally, the SDMSN's controller opens the social

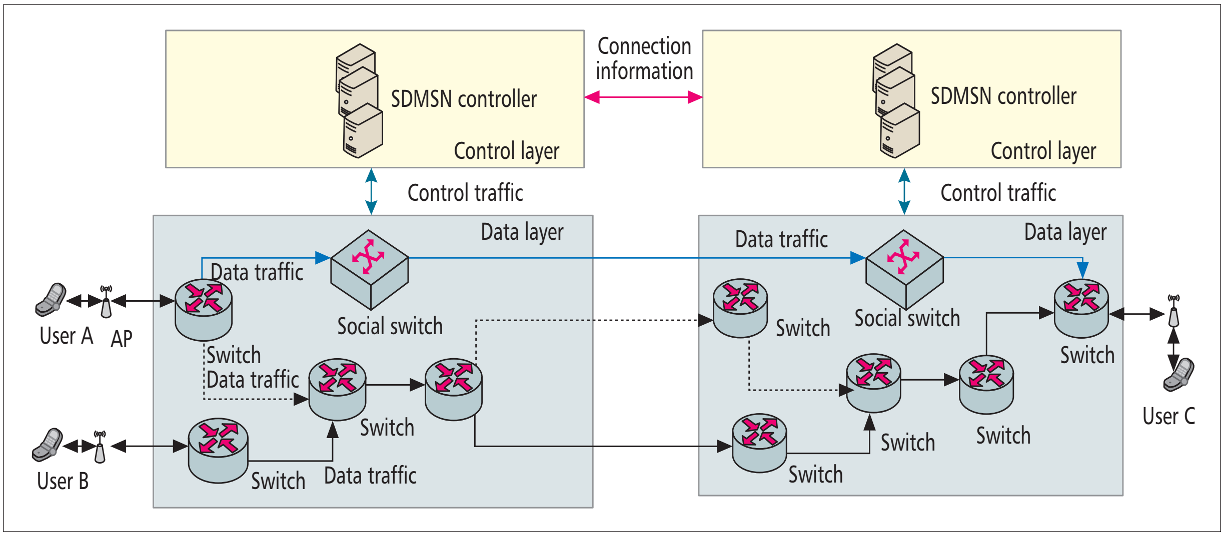

Figure 5. Schematic diagram of SDMSNs, where mobile users are in the different regions.

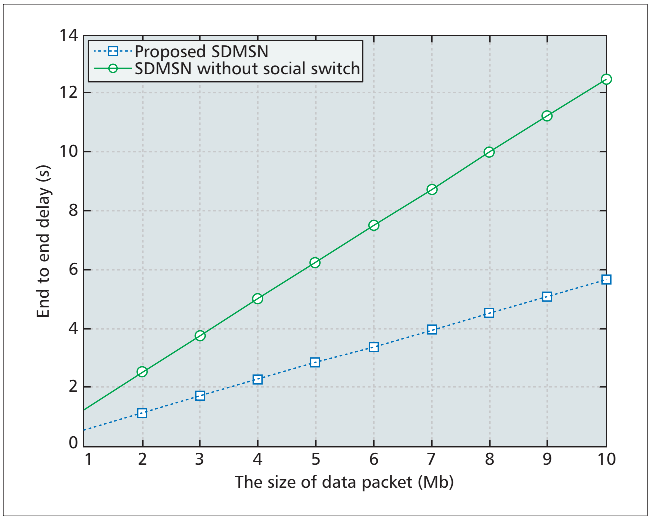

Figure 6. End to end delay with different sizes of data packet.

switch to connect their primary switches for content delivery between user A and use C. Obviously, this mode can be seen as a special and high speed channel to deliver content. In addition, the controller cannot determine the social tie between mobile users B and C, so the content delivery between them is still on the original channel.

In Fig. 5, as a second example, mobile user A and mobile user B are in the same region, while mobile user C is in another region. Therefore, content delivery between user A and user C or user B and user C is managed by at least two SDMSN controllers. Similar to the first example, mobile users should submit their login information to controllers through switches when they access the network, then each controller updates the flow table in these switches. After time T, the controllers can determine the social ties among mobile users and users' primary switches. For example, user A and user C can be determined as two friends, while user B and user C cannot be determined since the *SD* of user B and user C is too low. Next, each switch will delete the flow table of user A and user C except their primary switches. Different from the first example, in the second example the controller that controls the primary switch of user A will send requesting information to the controller of the primary switch of user C for connection. Then the controller of the primary switch of user C agrees to connect. Next, the controller of user A will manage its social switch to connect the social switch of the controller of user C. If user A wants to deliver data to user C, the social switches are used as a high speed channel to forward content. The advantage of this design is that there are only two intermediate switches to deliver content between two friends who are in different regions, while content delivery usually needs a large number of switches in conventional networks.

Performance Evaluation

In Fig. 6 we test the end to end delay of the proposed scheme compared with the situation without a social switch. Here the traditional SDMSN means that there is no social switch in the network and the content is delivered only through conventional switches. We carry out the experiment to test the performance under different sizes of data packet. In the simulation, there are five conventional switches in the network and user A sends a data packet to user B every 1 second. The bandwidth between conventional switches is 2Mb/s. In the proposed scheme, SDMSN, T is 10 seconds and the bandwidth between the social switch and the conventional switch is 10Mb/s. The social threshold δ is 0.9, and η is 0.8. The simulation time is 100 seconds. Figure 6 shows that the proposed scheme can achieve a lower end to end delay than the traditional scheme. In the proposed scheme, when the controller determines that user A and user B are friends, the social switch is open and connected to the primary switches of user A and user B. Thus, content is delivered through the social switch with a high speed, while in the traditional scheme the content is still delivered through conventional switches with a low speed.

Conclusion

In this article we have outlined the design of SDMSNs, with the integration of the social features of MSNs and the current properties of SDN. The SDMSNs can be advocated and expected to resolve the challenges in the traditional MSNs. On one hand, based on the social features including social ties, community, and mobility, novel elements have been introduced into the flow table, where the data flow can be managed with social considerations. On the other hand, a novel social switch is designed to cooperatively work with the controller and other conventional switches. With the social switch, both the control traffic and the data traffic can be reduced. Simulation results have proven the efficiency of our design.

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