Novel Pre-pushing & Downloading Model in Mobile Peer-assisted Streaming Network

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Abstract

The popularization of streaming networks and mobile devices brings a new kind of network called mobile peer-assisted streaming network. In this network, service provider not only offers downloading services, but also pre-pushes resources to users for caching. Users can download their demanded resources while working as servers for uploading the cached data. Also the mobile characteristic makes high package losing probability in this network. So we study how the service provider pre-pushes or the user downloads resources efficiently and effectively while considering the package losing in this paper. We build utility models for service provider and user, and solve the models using Bellman's theory to achieve Nash Equilibrium which shows the service provider's optimal pre-pushing speed and user's optimal downloading speed. The numerical simulation demonstrates the efficiency and effectiveness of our proposed pre-pushing and downloading scheme by comparing to the traditional scheme.

Keywords: mobile peer-assisted streaming network, downlink bandwidth, pre-pushing & downloading

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1. Introduction

Multimedia plays an important role in nowadays, and people can get lots of information from it for learning, entertainment *et.al.* One of the modem online multimedia networks is peer-assisted streaming network.This type of network is composed by service providers and users. The service providers play two roles. Firstly, they offer video sources for users' downloading passively. Secondly, they pre-push resources to users actively for data distribution. The users also play two roles. Firstly, they actively download the video sources for themselves. Secondly, they need to offer downloading service for other users using the cached data. These peer-assisted streaming networks become very popular and the number of users was about 370 million and the market revenue was breakthrough 9 billion Yuan in 2012 in China[1]. Another report said that the total revenues of e Mobile Economyare forecast to reach US$2 trillion in 2017 worldwide [2]. In the peer-assisted streaming network, a key design point is that how the service provider pre-pushing resources to end users for caching. This scheme includes two aspects: the pre-pushing starting time and the pre-pushing speed.. In the traditional scheme, the service providers monitor the users' actions. And if one user has not used his computer for more than 20 minutes, the service provider will start the pre-pushing action, and the pre-pushing process uses the user's full downlink bandwidth[3, 4]. In this mechanism, the service provider does not farthest use the user's downlink bandwidth, for it does not make use of the user's downlink characteristic detailed. In Fig. 1, we show a certain user's downloading characteristic as an example.

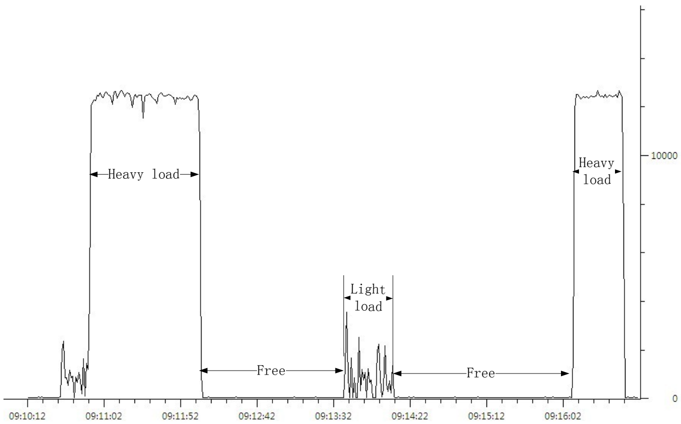

Fig. 1. User's downloading characteristic

From **Fig. 1** we can get the certain user's downloading characteristic and it can be mainly divided into three types. The first one is Heavy load which indicates that the user is very busy and he is using his full downlink bandwidth. The second type is Light load which indicates that the user is using his computer, but he has not used the full downlink bandwidth. The third type is Free which indicates that the user's computer is free. The traditional pre-pushing scheme only makes use of the third type in the condition of the continuous free time being more than 20 minutes. There should be a better way to use the user's downlink bandwidth more efficiently, for example using the second type.

Another phenomenon that we also should consider is that there are more and more people preferring using mobile devices watching online live videos. A notable report [5] predicted that there will be 2 billion end users using Smartphone in the world at the end of2013. This situation gives a new research area that how to architecture a peer-assisted streaming network in the mobile environment. In a wireless network, the bandwidth is much lower than in wired network and owning to the time-varying channel, users suffer from high package losing probability in wireless network. So the users' downlink bandwidth is more important than ever and researchers need to study how to achieve efficiency and effectiveness in user's downlink bandwidth usage.

This paper will analyze the service provider's pre-pushing scheme and user's downloading scheme in mobile peer-assisted streaming network. The motivation of this work is that the traditional pre-pushing scheme can not efficiently use the user's downlink bandwidth, for it needs to wait the certain user's continuous free time being more than 20 minutes and does not make use of the "Light Load" period. We should find a better strategy efficiently and effectively using the user's downlink bandwidth. In our designed scheme, the service provider can start pre-pushing action at any time that it wants and the optimal pre-pushing speed is gotten by game thoery. The user also optimizes the downloading speed using the game theory. We choose deterministic differential game as an analysis tool to build the network utility models for service provider and user respectively. The service provider's utility function is affected by pre-pushing speed, user's QoS reflection, and package error probability. The user's utility function is affected by downloading speed, bandwidth consumption, storage space consumption, and package error probability. Then, we use the Bellman's theory to achieve Nash Equilibrium and get the optimal speed of service provider and user which can maximize the two players' payoffs. To verify the efficiency and effectiveness of our proposed schemes, we give two numerical simulations. In the first one, we show the optimal values of pre-pushing speed of the service provider and optimal downloading speed of the user, and the amount of data being gotten by service provider and user with time elapse respectively. In the second simulation, we compare the pre-pushing schemes between traditional one and our proposed one. The results show that our schemes can work more efficiently and effectively.

The rest of this paper is organized as follows. Section 2 introduces some related work about peer-assisted streaming network. Network model is built in Section 3 for service provider and user. Section 4 solves the network model using Bellman theory. The numerical simulation is done in Section 5. And in Section 6, a conclusion is drawn.

2. Related Work

Nowadays, Multimedia has integrated into people's daily lives. Researchers should be responsible for designing better schemes to improve the performance of the streaming network to offer better services. There are lots of researches working on mobile streaming network [6-11] and peer-assisted streaming network [12-20]. However, to our knowledge, so far, there is few researches on the topic of how to pre-push resources in mobile peer-assisted network. The only ones that we can get are mentioned in [3, 4] which claimed that the pre-pushing action would be started when a certain user has not used his computer for more than 20 minutes. So in this Section we just show some outstanding works on improving the performance of streaming network.

In [6], the authors researched on efficiently provide heterogeneous media services in vehicular networks. Vehicular network has the following characteristics: limited resources, high mobility, opportunistic contact, and service time requirements. Using peer-to-peer algorithm, they developed fully dynamic service schemes to achieve the goals of maximizing the total user-satisfaction. Authors in [6] paid attention to the whole heterogeneous media service architecture while we concentrated on the pre-pushing mechanism in streaming network. The aim of these two papers is the same which is improving the streaming network performance in mobile environment.In [7], the authors analyzed the QoS problem in mobile streaming network. They said that users could enjoy ubiquitous services via intelligent mobile phones and wireless networks which were more and more popular nowadays. A shortcoming of the usage was the bandwidth available limitation and different device requirements. So they designed a network and device-aware strategy to fit for the end user's environment. Then they studied how to save bandwidth and terminal power using overall network environment. Lastly, they validated that the proposed method was feasible via simulation.

In [8], the authors stated that mobile video streaming network suffered from the poor service quality owning to the gap between bandwidth demand and the link capacity in the time-varying link conditions. To solve this problem, the authors used cloud computing technology and built a mobile streaming framework which was composed by adaptive mobile video streaming (AMoV) and efficient social video sharing (ESoV). AMoV was used for mobile user adjusting streaming flow using coding technique according to the link quality feedback. ESoV is used to monitor the mobile users' social network interactions for pre-fetching video resources in advance. The implementation of the proposed framework showed that it could provide effective adaptive streaming and video sharing.

In [9], the authors investigated the server's characteristic of mobile streaming network. They collected 212TB mobile streaming data with worldwide mobile end users. After analysis, they got the following conclusions. (1) The diversity of mobile device was a major challenge for providing streaming services. (2) A certain video needed to trans-code more than 40 versions to meet the various mobile devices' demand. (3) Mobile streaming resources were much smaller and shorter than traditional Internet streaming.

In [12], the authors stated that two most important characteristics of peer-assisted streaming networks were pre-fetching strategy and demanding differentiation. They used queuing models to build the models. Firstly, they prioritized the requests according to the significance which was affected by urgent playback, normal playback, and pre-fetching. Then they proposed a fine-grained stochastic supply-demand model to investigate the above two mentioned characteristics. From this model, they analyzed how to use the limited uploading bandwidth resources and other peers caching abilities to get an efficient system.

In [13], the authors declared that peer-assisted streaming was an optimal solution to the privately managed networks in which the streaming servers were alleviated. They stated that the network performance was heavily affected by system parameters and the distributions of the pre-downloading resources on the peers. They proposed a stochastic model to study this problem. The system parameters included number of peers, uplink and storage capacity of the peers, size of the video content library, size of contents and content distribution scheme. Finally, they claimed that the proposed model could substitute the long lasting or tedious real system measurements when studying the network performance after the modifications of the system environment.

In [14], the authors analyzed the peer-assisted streaming system in the condition of assuming users sharing their upload bandwidth for redistributing streaming resource which obtained by their downloading or server's pushing (cached locally). They aimed at characterizing the server's additional bandwidth requirements in the condition of satisfying all users' demands for watching a certain streaming resource. They proposed an approximate fluid model to find the affected stochastic factors among peer churn, non-stationary traffic conditions, upload bandwidth heterogeneity. Using their proposed model, they discovered several interesting properties of peer-assisted streaming networks.

In [15], the authors mentioned that P2P technology was an attractive solution to large-scale streaming applications. And two major challenges that the P2P streaming design should be considered were efficiently scheduling resources sharing between peers and encouraging peers contributing their resources. To solve these problems, they proposed a system called iPASS. In iPASS, dynamic buffering-progress-based peering strategy was chosen to maximize the peer's uploading bandwidth utilization and differentiated pre-fetching scheme was designed to incent peers' uploading. Finally, they claimed that their system could work well in the current network environment.

3. Network Model

In a mobile peer-assisted streaming network, there are two kinds of nodes: service providers and ordinary users. Service providers provide video sources to users, and users can get the source from service providers or other users (or Peers). In order to make the network more efficiently, service providers pre-push some scheduled video sources to the peers for caching in the network. In our model, we control the service provider's pre-pushing speed and user's downloading speed to maximize their payoffs. For simplicity, we just research on one service provider pre-pushing one video source to one peer, and the peer may download a certain video source for itself. The mathematical expression is as follows. The service provider SP's pre-pushing speed is DS_s ($DS_s \geq 0$) and its total downloads are D_s. The peer P's downloading speed is DS_c ($DS_c \geq 0$) and its total downloads are D_c. Next, we build the models for service provider SP and peer P.

For the service provider SP, its income is earned from pre-pushing the video source to a peer and can be expressed as $\alpha * DS_s^2$. The cost is the unhappiness of the peer which caused by pre-pushing, which can be treat as user's QoS reflection, and it can be expressed as $\beta * D_s$. So the transient payoff of service provider can be written as $\alpha * DS_s^2 - \beta * D_s$. According to the theory proposed [22], we can get the utility function can be modeled as

$$\text{Maximize } U_s = \int_0^T (\alpha * DS_s^2 - \beta * D_s) * e^{-rt} dt + e^{-rT} * E_s(D_s(T)) \quad (1)$$

$$\text{Subject to } D_s^{'} = DS_s - \lambda * D_s \quad (2)$$

Where α and β are constant parameters, r is a discount factor, $E_s(D_s(T))$ is the network reward for the service provider at the end of pre-pushing, and λ is the package error transmitting probability.

In this model, the first part $\int_0^T (\alpha * DS_s^2 - \beta * D_s) * e^{-rt} dt$ is the total payoff from the beginning to time T. r is brought from Economics and is the factor by which a future cash flow should be multiplied in order to get the present value. The second part $e^{-rT} * E_s(D_s(T))$ is the payoff of network reward at the end of pre-pushing. For example, more users want to share their downlink bandwidth, for the service provider's pre-pushing makes the network more efficiently. The constraint $D_s^{'} = DS_s - \lambda * D_s$ represents that the successful total downloads at a certain time point should be equal to the pre-pushing speed minusing the wrongly transmitted ones.

For the peer P, its income is earned from downloading the video source for itself and it can be expressed as $\chi * DS_c^2$. The cost is the bandwidth and storage space consumption, and it can be expressed as $\gamma *(DS_c + DS_s)$ and $\eta * D_c$ respectively. So the transient payoff of peer can be written as $\chi * DS_c^2 - \gamma *(DS_c + DS_s) - \eta * D_c$. Also, according to the theory proposed [22], we can get the peer's utility function can be modeled as

$$\text{Maximize } U_c = \int_0^T (\chi * DS_c^2 - \gamma *(DS_c + DS_s) - \eta * D_c) * e^{-rt} dt + e^{-rT} * E_u(D_c(T)) \quad (3)$$

$$\text{Subject to } D_c' = DS_c - \lambda * D_c \quad (4)$$

Where χ, γ and η are constant parameters, and $E_u(D_c(T))$ is the network reward for the peer at the end of pre-pushing. The model's explanation is as the service provider's.

4. Nash Equilibrium Solutions

In this Section, we will use the feedback Nash Equilibrium theory to solve the models that we built [22]. Bellman in [21] proposed a dynamic programming technique which was frequently used to solve the Nash Equilibrium problems. The theorem was stated in [22] as follows:

(Bellman's Dynamic Programming) A set of control $u^*(t) = \phi^*(t,x)$ constitutes an optimal solution to the control problem (5) if there exit continuously differentiable functions $V(t,x)$ defined on $[t_0,T] \times R^m \to R$ and satisfying the Bellman equation (6):

$$\begin{cases} \max_u \{ \int_{t_0}^T g[s,x(s),u(s)]ds + q(x(T)) \} \\ x(s) = f[s,x(s),u(s)] \end{cases} \quad (5)$$

$$\begin{cases} -V_t(t,x) = \max_u \{ g[t,u,x] + V_x(t,x) f[t,x,u] \} \\ \qquad = \{ g[t,x,\phi^*(t,x)] + V_x(t,x) f[t,x,\phi^*(t,x)] \\ V(T,x) = q(x) \end{cases} \quad (6)$$

Where $x(s)$ denotes the state variable and $u(s)$ is the control

4.1 Nash Equilibrium for Service Provider

Invoking by the Bellman's theorem, we build our service provider's Bellman equation as:

$$-W_t(t,D_s) = \max_{DS_s} \{ \lfloor (\alpha * DS_s^2 - \beta * D_s) \rfloor e^{-rt} + W_{D_s}(t,D_s) \lfloor DS_s - \lambda * D_s \rfloor \} \quad (7)$$

$$W_t(T,D_s) = e^{-rT} * E_s(D_s(T)) \quad (8)$$

In order to find the optimal pre-pushing speed DS_s, we take a derivation with respect to it, and we get the optimal pre-pushing speed expression being:

$$DS_s^*(t) = -\frac{1}{2\alpha} W_{D_s}(t, D_s) e^{rt} \quad (9)$$

Substituting the optimal pre-pushing speed $DS_s^*(t)$ into (7), we can get:

$$-W_t(t, D_s) = (\alpha * (\frac{1}{2\alpha} W_{D_s}(t, D_s) e^{rt})^2 - \beta * D_s) e^{-rt} + W_{D_s}(t, D_s)(\frac{1}{2\alpha} W_{D_s}(t, D_s) e^{rt} - \lambda * D_s) \quad (10)$$

To solve the equation (10), we set the following assumption:

$$W(t, D_s) = (M(t) * D_s + N(t)) e^{-rt} \quad (11)$$

Taking a derivation with respect to time t and service provider's downloads D_s in (11), one obtains:

$$\begin{cases} W_t(t, D_s) = -r(M(t) D_s + N(t)) e^{-rt} + e^{-rt}(M'(t) D_s + N'(t)) \\ W_{D_s}(t, D_s) = M(t) e^{-rt} \end{cases} \quad (12)$$

Substituting the differential values of $W_t(t, D_s)$ and $W_{D_s}(t, D_s)$ into (10), and using the boundary conditions, one obtains:

$$\begin{cases} M'(t) = (r - \lambda) M(t) + \beta \\ N'(t) = rN(t) + \frac{1}{4\alpha} M^2(t) \\ M(T) = e_s \\ N(T) = 0 \end{cases} \quad (13)$$

Solving this equation set, we can get:

$$M(t) = (e_s + \frac{\beta}{r - \lambda}) e^{(r-\lambda)(t-T)} - \frac{\beta}{r - \lambda} \quad (14)$$

So the optimal pre-pushing speed of service provider should be written as:

$$DS_s^*(t) = -\frac{1}{2\alpha} W_{D_s}(t, D_s) e^{rt} = -\frac{1}{2\alpha} * M(t) = \frac{\beta}{2\alpha(r - \lambda)} - \frac{1}{2\alpha}(e_s + \frac{\beta}{r - \lambda}) e^{(r-\lambda)(t-T)} \quad (15)$$

If service provider uses this pre-pushing speed pre-pushing video source to the user, it will get the maximized payoff.

4.2 Nash Equilibrium for User

The process of solving user part Nash Equilibrium is more or less the same as solving service provider part Nash Equilibrium. And we build our user's Bellman equation as:

$$-W_t(t,D_c)=\max_{DS_c}\{\lfloor(\chi*DS_c^2-\gamma*(DS_c+DS_s)-\eta*D_c)\rfloor e^{-rt}+W_{D_c}(t,D_c)\lfloor DS_c-\lambda*D_c\rfloor\} \quad (16)$$

$$W_t(T,D_c)=e^{-rT}*E_u(D_c(T)) \quad (17)$$

In order to find the user's optimal downloading speed DS_c, we take a derivation with respect to itand get the optimal expression being:

$$DS_c^*(t)=\frac{1}{2\chi}(\gamma-W_{D_c}(t,D_c))e^{rt} \quad (18)$$

Substituting the optimal downloading speed $DS_c^*(t)$ into (16), we can get:

$$\begin{aligned}-W_t(t,D_s)&=(\chi*(\frac{1}{2\chi}(\gamma-W_{D_c}(t,D_c))e^{rt})^2-\gamma*(\frac{1}{2\chi}(\gamma-W_{D_c}(t,D_c))e^{rt}\\&+\frac{\beta}{2\alpha(r-\lambda)}-\frac{1}{2\alpha}(e_s+\frac{\beta}{r-\lambda})e^{(r-\lambda)(t-T)})-\eta*D_c)e^{-rt}\\&+W_{D_c}(t,D_c)(\frac{1}{2\chi}(\gamma-W_{D_c}(t,D_c))e^{rt}-\lambda*D_c)\end{aligned} \quad (19)$$

To solve the equation (19), we also set the following assumption:

$$W(t,D_c)=(M(t)*D_c+N(t))e^{-rt} \quad (20)$$

Taking a derivation with respect to time t and user's downloads D_s in (20), one obtains:

$$\begin{cases}W_t(t,D_c)=-r(M(t)D_c+N(t))e^{-rt}+e^{-rt}(\dot{M}(t)D_c+\dot{N}(t))\\W_{D_c}(t,D_c)=M(t)e^{-rt}\end{cases} \quad (21)$$

Substituting the differential values of $W_t(t,D_c)$ and $W_{D_c}(t,D_c)$ into (19), and using the boundary conditions, one obtains:

$$\begin{cases}M'(t)=(r-\lambda)M(t)-\eta\\M(T)=e_u\\N(T)=0\end{cases} \quad (22)$$

Solving this equation set, we can get:

$$M(t)=(e_u-\frac{\beta}{r-\lambda})e^{(r-\lambda)(t-T)}+\frac{\beta}{r-\lambda} \quad (23)$$

So the optimal downloading speed of the user should be written as:

$$DS_c^*(t) = \frac{1}{2\chi}(\gamma - W_{D_c}(t, D_c))e^{rt} = \frac{1}{2\chi}(\gamma - M(t)e^{-rt})e^{rt} = \frac{\gamma e^{rt}}{2\chi} - \frac{1}{2\chi}((e_u - \frac{\eta}{r-\lambda})e^{(r-\lambda)(t-T)} + \frac{\eta}{r-\lambda}) \quad (24)$$

If user uses this downloading speed downloading video source for himself, it will get the maximized payoff.

5. Numerical Simulation and Analysis

In this Section, we will build two numerical simulations to show the efficiency and effectiveness of our proposed scheme. In the first simulation, we set the following Scenario. A service provider wants to pre-push a video resource to a certain user. The user is using his downlink for watching live video. Then we can get the optimal values of pre-pushing speed of the service provider and optimal downloading speed of the user with time elapse, and the amount of data being gotten by service provider and user with time elapse respectively. In order to compare with traditional pre-pushing scheme, we give the second simulation. In this simulation, we set the user's downloading action characteristic and analyze the service provider's cumulative resources obtained via two different pre-pushing schemes.

Parameters used in the first simulation are listed in **Table 1**. The parameter values are demonstrative ones. Users can change them according to the actual environment.

Table 1. Simulation parameters

Parameter	Value	Description
α	4	Earning parameter for service provider
β	5	Cost parameter for service provider
λ	0.009	Package error transmitting probability
e_s	2	Network reward for the service provider at the end of pre-pushing
r	0.01	Discount factor
T	500	Time involved
γ	9	Earning parameter for user
χ	3	Cost parameter for user's bandwidth consumption
η	2	Cost parameter for user's storage space consumption
e_u	2	Network reward for the user at the end of pre-pushing

Fig. 2 shows the optimal values of the service provider's pre-pushing speed and optimal downloading speed of the user with time elapse. From this figure we can get the following conclusions. For the service provider, it should use a big pre-pushing speed at the beginning and slow down its speed with time elapse. Using this strategy, the service provider can get the maximized payoff. For the user, he should not download any source for himself at the beginning, and start the downloading action at a certain time point with the increasing downloading speed. Using this strategy, the user can get the maximized payoff. The explanation is that a big pre-pushing speed of service provider can guarantee fast resource dissemination. The total downlink bandwidth is constant, so the user should use a small downloading bandwidth. With time elapse, there are more and more resource copies in the network, so service provider's pre-pushing speed should be decreased while the user's downloading speed should be increased.

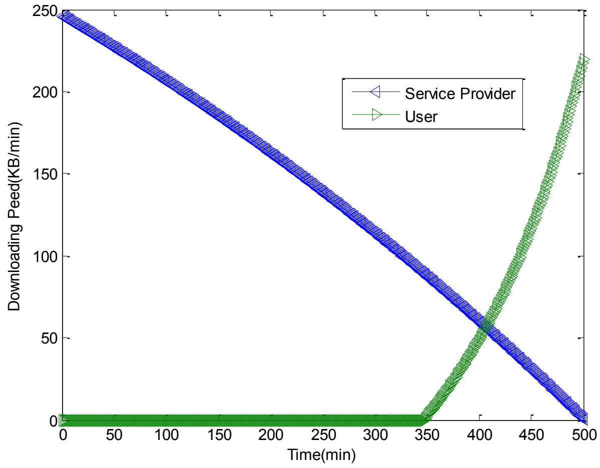

Fig. 2. optimal pre-pushing and downloading speed

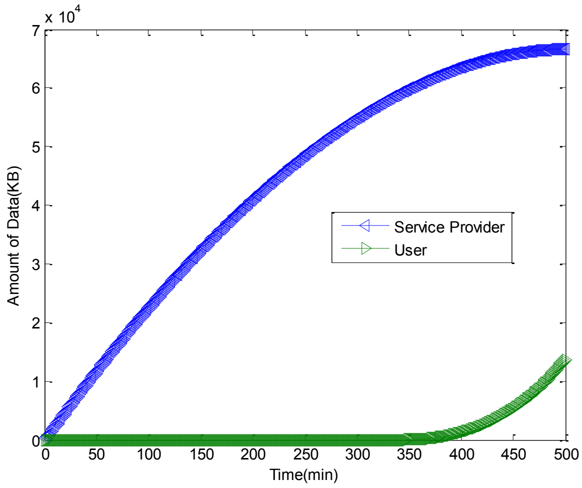

Fig. 3. Cumulative resources achieved by service provider and user

Fig. 3 shows the amount of data being gotten by service provider and user with time elapse. From this figure we can get the cumulative resources being achieved by service provider's pre-pushing and user's downloading. There is an important notification that we should mention. In our built models, we optimized the utilities for service provider and user, and the cumulative amounts of resources are not optimal factors, so the values of cumulative resources achieved by service provider and user are demonstrative. If we consider optimizing this factor, the sum of optimal pre-pushing and downloading speed should equal to the user's downlink bandwidth. However, we do not research on this topic in this paper.

In the following Section, we will build the second numerical simulation. We compare the efficiency and effectiveness between traditional pre-pushing scheme and our proposed pre-pushing scheme. The scenario is shown in **Fig. 4.** The user wants to download video source for himself at some time periods which are [0 h -0.5h], [2.5 h -3.5h], and [4 h -4.5h]. The service provider also wants to pre-push its video source during the time period [0-4.5h]. According to the traditional scheme, the pre-pushing action can only start at the time point of

20 minutes later that user is not operated, which means that service provider can only pre-push at the time periods of [50min-150min] and [230min-240min]. In our proposed scheme, the pre-pushing action can start at the beginning. The parameters and factors used in this simulation is the same as in first simulation except the involved time T being changed to 270min.

Fig. 4. User's downloading action characteristic

The outcome is shown in **Fig. 5.** From this figure we can get that our proposed pre-pushing scheme can pre-push more data to the user while earning more payoff. The explanation is as follows. In the traditional scheme, there is no completion between service provider's pre-pushing and user's downloading, so they cannot farthest use the user's downlink bandwidth. In our given scheme, we consider the user's downloading characteristics in detail and bring in completion between service provider and user using the utility functions. Service provider and user selfishly maximize their payoffs respectively. The completion outcome is that the service provider and user can efficiently and effectively use the user's downloading bandwidth while optimizing the their payoff.

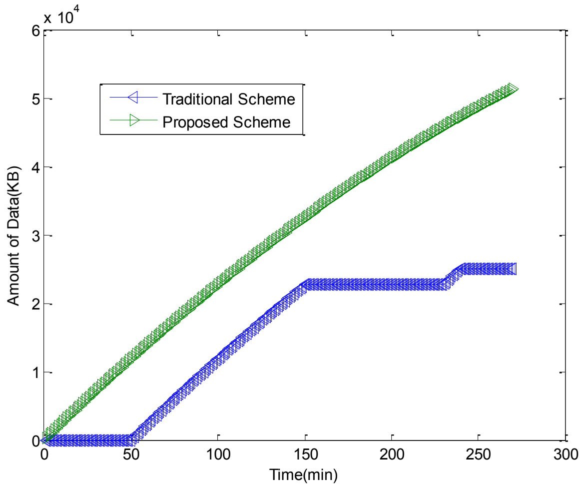

Fig. 5. Cumulative resources achieved by traditional pre-pushing scheme and proposed pre-pushing scheme

6. Conclusion

In this paper, we focused on the service provider's pre-pushing scheme and user's downloading scheme in mobile peer-assisted streaming network. Nowadays, the widely usage of mobile peer-assisted streaming network faces two important shortcomings. The first one is that traditional service provider starts pre-pushing video sources until the user's continuous free time is more than 20 minutes, and this scheme does not use the user's downlink characteristic detailed. The second one is that there is a high package losing probability in mobile network, so this factor should be considered when analyzing the pre-pushing or downloading. We solved these problems in the following ways. Firstly, we built the utility functions for service provider and user. The service provider's payoff was related to pre-pushing speed, user's QoS reflection, and package error probability. And the user's utility function was related to downloading speed, bandwidth consumption, storage space consumption, and package error probability. Then, we used Bellman's theory as a solution tool to solve the built models to get Nash Equilibrium, and got the optimal values of service provider's pre-pushing speed model and user's downloading speed model. These two obtained speed models could optimize the mobile peer-assisted streaming network in user's downlink bandwidth sharing aspect. To show the efficiency and effectiveness, we gave two simulations. The first simulation demonstrated the optimal values of pre-pushing speed of the service provider and optimal downloading speed of the user, and the amount of data being gotten by service provider and user with time elapse respectively. The conclusion was that the service provider should use a big pre-pushing speed while the user should use a small downloading speed at the beginning. With time elapse, the pre-pushing speed should be decreased while the downloading speed should be increased. The other simulation compared the traditional pre-pushing scheme with our proposed scheme. The conclusion was that using our strategy, the service provider could pre-push more cumulative resources which indicated that our scheme could be efficiently and effectively used in mobile peer-assisted streaming network. This paper only considers that service providers and users are cooperative. We have not considered the non-cooperative situation. For example, if a user is selfish, how the network performs. We believe that this is future work.

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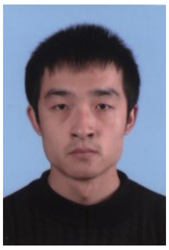

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