A Hybrid Chain Based Incentive Mechanism for Resource Leasing in NDN

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Abstract. Since the main feature of Named Data Network (NDN) is in-net caching, it is crucial to motivate users to offer resource such as bandwidth and storage. However, few research works on incentive mechanism design for NDN. This paper proposes a market for NDN to lease bandwidth and storage from Access Points (APs). Since blockchain can supply a traceable and credible environment while public chain has long latency and low throughput, the paper combines permissioned chain with public chain, constructs a hybrid chain based environment without hurting its truthfulness. Furthermore, the paper formulates the market as a reverse auction running by a Content Provider (CP) who aims to serve more users for profit by leasing resource from APs, and investigates incentive mechanism for motivating APs. Especially, the paper designs an optimal mechanism, which could overcome defects of traditional mechanism, get the most profit for CP with guaranteeing interest of AP. Evaluation results compare effectiveness of mechanism proposed with traditional incentive mechanism, and prove that the mechanism we designed could get better results.

Keywords: Blockchain · Incentive mechanism · Named Data Network · Reverse auction

1 Introduction

Named Data Networking (NDN) is a promising framework fetching contents by name instead of IP address, which liberates content from host location, then users could fetch contents by cache instead of origin server. The design could ease storage and access pressure of Content Producer (CP), help users to fetch contents faster, alleviate the transmission pressure to network. Up to now, most of research on NDN focus on fetch content efficiently by cache and routing strategy design, while how can content be accessible is rarely researched. According to [1], the most potential scenario for deploying NDN would be that CPs lease resource from access network. CP needs to extend its users by providing access to its content and offloading its content to network, while it is not obligated to construct an access network to support this. Therefore,

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motivating nodes in network to contribute their own available unexploited resource for access is crucial. The paper introduces incentive mechanism into NDN networks for resource leasing.

To motivate nodes in a truthful way, the paper adopts blockchain to construct a marketplace for resource leasing. Blockchain is a technology which could record transaction in a transparent, tamper-resistant, secure way. Lots of works [2–4] have been done on blockchain based name resolution for NDN, which help users to retrieve contents and verify them in a credible way. On base of these works, the paper takes blockchain to deploy incentive mechanism for resource leasing. To improve efficiency and throughput of system, the paper combines public chain and permissioned chain to construct market.

Since monetary mechanism is the most flexible way to incentive users, it is widely adopted. Auction policy provides solution for CP to select APs and remunerate them. However, traditional auction policy used in resource leasing always ignore the requirement of Budget Balance (BB). Considering BB and Individual Rational (IR), the paper proposes an optimal mechanism for CP to get the largest profit with guaranteeing interest of AP.

Contributions of the paper can be summarized as follows.

(1) The paper designs a blockchain based marketplace for resource leasing in NDN, which supplies a credible environment for NDN. Contents can be fetched from AP without often using backhaul bandwidth, and users can verify contents easily.
(2) The paper divides the process of motivation into AP selection and remuneration. After proving the AP selection problem is NP-hard and designing greedy algorithm to work out it, the paper investigates several incentive mechanisms to remunerate APs, and designs an optimal mechanism.
(3) The paper provides performance comparisons and analyzes impact of different factors such as number of attending APs, files distribution, AP distribution, and profit per bandwidth.

This paper is structured as follows: Sect. 2 briefly introduces access NDN, incentive mechanism and blockchain. Section 3 describes the network architecture and construct a model of allocation problem for remuneration, whereas Sect. 4 proposes a mechanism to motivate APs. Section 5 describes experiments and analyzes of the proposed mechanisms. Finally, concluding remarks are presented in Sect. 6.

2 Preliminaries

2.1 Named Data Network

NDN is a promising architecture which makes caching be integrated into network layer. To motivate nodes to contribute their own resources, game theory is widely adopted. In [5], interactions between CP and Internet Service Providers (ISPs) are modeled as a Stackerlberg game, CP decides price for contents at first, Access ISPs act as followers to make caching decisions. In [6], the problem is modeled as a reverse auction, CPs claim bid for content while Access ISP choose content to cache. In researches above, motivation of Access ISP is profiting from selling contents to users.

There may be another economic relationship between CPs and nodes maintaining access resources. Different with CP sells content to Access ISP, CP can also lease access resource from APs. In [7], Access Points claim bid for access resource including storage and bandwidth while CP choose which AP to serve users. However, incentive mechanism it adopted may cause CP out of budget balance under extreme conditions. The paper follows the scenario in [7] and designs an optimal mechanism for resource leasing in NDN.

Besides resource leasing, content verification is another crucial problem for NDN. As users must verify content regardless of where it comes from, they must have public key of CP before they request it. Reference [8] pointed that NDN need a rootless scheme to supply name resolution. As a tamper-resistant distributed ledger, blockchain become a solution to this. Reference [4] designs a blockchain based identifier management system for NDN.

Since CPs need to construct blockchain for name resolution, and motivation should be executed truthfully, the paper designs incentive mechanism for resource leasing and deploys incentive mechanism into the blockchain.

2.2 Incentive Mechanism

Incentive mechanism is a field in game theory which aims to encourage players to reveal true information. Up to now, incentive mechanisms are always classified as three types: reputation based mechanisms, Tit-for-tat, and monetary mechanisms [9]. Reputation based mechanisms aim to identify selfish nodes and punish them, and Tit-for-tat takes services as incentives to discourage free-ridding behaviors. These two types of mechanisms are always limited to apply to long-term users and lack formal specification. Monetary mechanisms encourage players by designing payoff structure, which is more flexible. For these reasons, monetary mechanism is widely adopted in resource leasing especially in spectrum leasing and data offloading.

Common monetary mechanisms including auction mechanisms and pricing mechanisms are based on the Stackerlberg game. Reference [5, 10, 11] design pricing strategy with Stackerlberg game to motivate access network to distribute contents. Reference [7, 12] use Vickrey–Clarke–Groves (VCG) auction policy to motivate APs to contribute their access resources. Reference [13] proposes a VCG based multi object auction for access resource leasing. However, VCG auction policy has its defect: it cannot ensure BB. While Arrow-d' Aspremont-Gerard-Varet (AGV) auction policy could ensure BB at the cost of IR. Reference [14] proposes an AGV auction policy to motivate nodes for content delivery. According to [15], an auction policy which could meet IR and minimize the cost of acquirer is optimal. In fact, some optimal auction policies have been designed for task assignment in crowdsensing [16, 17], while rarely used in resource leasing.

The paper creates a reverse auction model for CP and AP, designs an optimal mechanism for it, and proves it is Incentive Compatible (IC), IR and BB. Finally, the paper provides performance comparisons of these proposed mechanisms.

2.3 Blockchain Based Resource Management

Blockchain is a technology meant to store, read and validate transactions in a distributed data-base system [18]. In blockchain, a group of anonymous strangers can work together to share and secure a perpetually growing set of data without anyone having to trust anyone else [19]. Smart contracts are self-executing scripts that reside on the blockchain, which allow for proper, distributed, heavily automated workflows operated in blockchain [20].

Some attempts on resource allocation with blockchain have been tried in these years. Public blockchain for Internet source transactions is proposed in [21], which could record Internet core transactions like IP address assignments, domain name assignments and AS-Path advertisements, thus allowing Internet peers to verify core Interment resource usage and assignment authorizations.

Specifically, blockchain also be used in spectrum access in [22], which provided a verification and validation scheme to ensure the security of the network by introducing public chain as a CA without central node. In this way, the robustness and security of the system can be strengthened, however, there are several problems:

1. The prospect of public chain is unpredictable. Public chains rely on a whole community of developers contributes to the open-source code, the process lacks formal governance [23]. To motivate other nodes to record the transaction into blockchain, who invoke smart contract need to pay a few fee. As the fee is also defined by the public chain, value trend of digital currency is unpredictable too.
2. As public blockchains have to coordinate the resources of multiple unaffiliated participants, they are slower and less private than traditional databases [23].

To solve reliability and efficiency problem of public chain, there are lots of solution been proposed, such as lightning network [24], and hybrid chain which combining permissioned chain [25]. Lightning network solve it by complete transactions off the public chain, lots of operation can be executed without consensus. While permissioned chain reduces the scale of consensus by limiting the node who can attend the blockchain.

The paper adopts permissioned chain to build a marketplace for resource leasing. To execute leasing truthfully, CP could add smart contract to its origin system, while all bidding process be recorded in blockchain. Besides, the paper presents several possible incentive mechanisms for the scenario.

3 System Model and Problem Formulation

As auction should be operated truthfully, while there is no need for all operation to be credible in global, the paper introduces permissioned chain to make up the deficiency of public chain in performance. After creating a credible market, motivation of CP and APs to attend the market is discussed. Then, we construct the auction as a problem model.

3.1 Hybrid Chain Based Auction Market

The whole architecture can be demonstrated as Fig. 1. Within CP, authorization management module distribute certificates to nodes inside CP, consensus module package transactions into block, these blocks construct a permissioned chain. And, authorization management module set rules into smart contract and publish it into permissioned chain. By exposing itself in public chain, CP can be accessed and verified by AP and Mobile Clients (MCs). APs attend bidding by invoking smart contract in permissioned chain, selected APs would become NDN router and help MCs to fetch contents from CP.

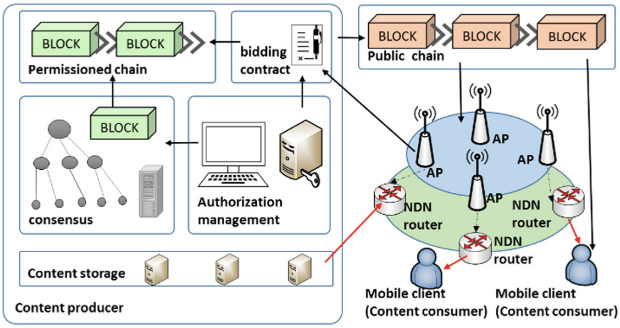


Fig. 1. System architecture

The process for building a credible marketplace can be divided into three steps as following. Firstly, ensure the credibility of CP, then AP and MC could verify information published by CP. Secondly, construct NDN network, MC could get data via AP credibly. Thirdly, build permissioned chain and develop smart contract for APs.

(1) Ensure the credibility of CP

As central authority may introduce risks and bottlenecks into the whole system, the paper adopts a decentral way to ensure the credibility for CP.

By generating a pair of asymmetric keys according to rules of public chain, CP could get an identity. Taking its own critical message as a transaction, CP need to signature the transaction with private key and broadcast it to the whole public chain. Then the transaction will be packaged into a block. Constructed by blocks, public chain is shared among each participant by consensus. As records in blockchain are tamper-resistant, message published by CP is credible. In other word, everyone can confirm the message is published by the CP. They can communicate with the CP via the access address claimed in the message, and verify contents published by CP with its public key, which is the source of transaction including the message.

Taking location of the message in public chain as name, CP can get a unique name, and others can find its access address, public key according it in a credible way. For instance, if the message can be found in 108th record in 10th block, it can be named as 10.108. As NDN is name based, creating credible name mapping service is the basis of NDN. After this, CP could supply credible service.

(2) Ensure content credible for NDN

At the beginning, it is necessary to make content credible. Users need retrieve desired content by name and authenticate the result regardless of where it comes from, which means the network should supply a framework for content verification.

Since there may be lots of content creators inside CP, the paper adopts permissioned chain for their cooperation. Credibility in permissioned chain relies on relationships in reality instead of proof algorithm, so consensus among permissioned chain is more efficient.

Not like self-generated public key in public chain, permissioned chain is compatible with traditional certificate system. Taking key in (1) as root certificate for the whole permission, CP could build a credible system for content verification.

Since each content is signed by its content creator with private key, certificate include public key would be transmitted with content. Mobile consumer could verify certificate gradually until public chain, thus identify source of content and confirm integrity of content.

(3) Attract AP to bidding

To deliver content to users, CP could lease bandwidth and storage from AP to construct NDN access network. Operations in AP should be executed by a client combining blockchain and NDN. Auction records are recorded in blockchain, and smart contracts supply faces for APs to attend bidding.

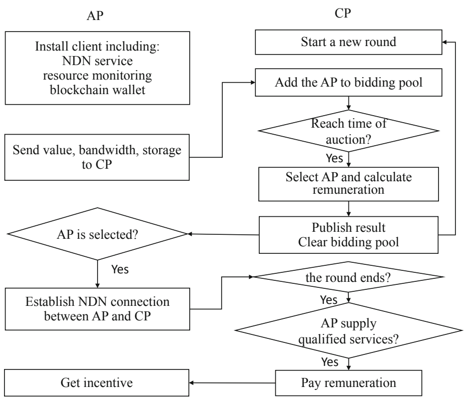


Fig. 2. Bidding process

The core logic should be like Fig. 2. At the beginning, AP installs a client which could monitor resource occupation, convert NDN packet, generate blockchain based identity. APs submit information to CP to attend current bidding, supply service when it is selected, if it supplies services as it promised, it will get incentive as bidding result. When an auction come to AP selection, next round would start for coming APs, and when APs in current round end services, new round would come to AP selection.

By the design, content can be verified in a credible way, bidding and remuneration can be executed automatically and traceably, a market for resource leasing in NDN is formed. What drives different roles to attend the market is discussed in next part.

3.2 Motivation of Different Roles

Motivation of different roles including CP and AP to attend the market is discussed in this part.

Firstly, we discuss motivation for CP. According to model defined in Sect. 3.1, the major business of CP is distributing contents. More accurately, CP profit from MCs, and the more users it serves, the more income it can earn. Hence, CP want to supply more connections to cover more MCs. However, building access networks is beyond service scope of CP, there is no need for CP to complete that. Hence it is necessary for CP to lease bandwidth to distribute contents. In addition, by introducing in-network caching ability into network, MCs may get contents from APs instead of CP, access pressure to CP can be significantly reduced. In summary, CP has ample motivation to construct a market to get resources from AP.

Secondly, we discuss the motivation of AP. To attend the market, AP submits to CP the bid consists of $\left[\hat{v}_j, \hat{b}_j, \hat{s}_j\right]$,$v_j$ represents the cost, b_j represents the backhaul bandwidth that AP j obtains, while s_j represent the storage that AP j can share. Let p_j be price paid by the CP to lease AP j. The utility function can be expressed as (1):

$$u_j = \begin{cases} p_j - v_j, & \text{if AP } j \text{ is selected} \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

According to IR, the utility of each player is always non-negative. Only if u_j is non-negative, AP would attend to bid. It is noteworthy that the bidding of AP may not be truth. When CP has collected the information of APs, it will decide to lease which AP and how much should pay to AP. It is obvious the process can be divided into two parts: AP selection and p_j computation.

3.3 Problem Formulation

This part would construct problem model for CP to design appropriate mechanism for remunerating. The notation used in this paper is summarized in Table 1.

Table 1. Symbol of parameters

Symbol	Quantity
P	*Average profit per unit of bandwidth*
C	*Cache miss lost per unit of bandwidth*
A	*Set of AP*
M_j	*Set of MCs covered by AP j*
h_j	*Hit ratio of AP j*
t_i	*Traffic demand of MC i*
$r_{i,j}$	*Maximum WiFi access rate for AP j and MC i*
$d_{i,j}$	*Distance between AP j and MC i*
$x_{i,j}$	*Binary variable that indicates whether MC i is connected to AP j*
y_j	*Binary variable that indicates whether AP j is selected*
F	*The objective function of the problem*

Since all variables are integers, this problem is an Integer Linear Programming (ILP) problem. And, the problem can be formulated as follows:

Maximize:

$$P\sum_{i\in M}\sum_{j\in A}x_{i,j}d_i - \sum_{j\in A}y_jv_j - \sum_{i\in M}\sum_{j\in A}x_{i,j}d_i(1-h_j)C \tag{2}$$

Subject to:

$$\sum_{i\in M}\frac{x_{i,j}t_i}{r_{i,j}} \le 1, \forall j \in A \tag{3}$$

$$\sum_{i\in M}x_{i,j}t_i(1-h_j) \le b_j, \forall i \in M_j, \forall j \in A \tag{4}$$

$$x_{i,j} \le y_j, \forall i \in M, \forall j \in A \tag{5}$$

$$x_{i,j} \in \{0,1\}, \forall i \in M, \forall j \in A \tag{6}$$

$$y_j \in \{0,1\}, \forall j \in A \tag{7}$$

The objective function (2) maximizes the total revenue of the system, which is given by (1) the traffic-proportional profit the CP is going to obtain for serving the MCs' demand: $P\sum_{i\in M}\sum_{j\in A}x_{i,j}d_i$ (2) the cost for procuring the selected APs: $\sum_{j\in A}y_jv_j$, (3) the cost for cache misses: $\sum_{i\in M}\sum_{j\in A}x_{i,j}d_i(1-h_j)C$, while h_j is proportional to s_j. In the paper, (4) represents social welfare.

Constraints (3) and (4) limit the number of MCs assigned to each AP, give radio access network and backhaul Internet connection a bounded capacity. Constraint (3) imposes that the total demand served by an AP does not exceed the capacity of radio access network. Constraint (4) considers the fact that backhaul Internet connection serves only the aggregate demand that generates a cache miss. Constraint (5) ensures that MCs can associate only to the APs selected by mechanism. Finally, the sets of constraints (3) and (7) express the integrality conditions on decision variables.

Taking the selection of AP as a knapsack problem, CP would choose some AP to lease access resources. Similarly, Choosing MCs to serve is another knapsack problem for AP. Since knapsack problem is NP-hard, AP selection is NP-hard. The paper chooses greedy algorithm to solve it as Algorithm1.

Algorithm1 **The greedy algorithm to solve the model**

Input: *M,A,b,s,d,r,h,R,C,P*
Output : y,p,x

L <= sort($j \in A$, $\frac{b_i}{(1-h_i)}(P - C(1-h_i)) - v_i$,descend)
while demand of CP has not been met
  j=next(L), $y_j = 1$; //next AP is selected
  V_j<=sort($i \in M_j$,$d_{i,j}$,ascend)
  while AP j satisfy constraints (3-4)
    i=next(V_j)p; $x_{i,j}$=1;
    if constraints (3-4) are not satisfied
      $x_{k,j} = 0$;
    end
  end
end

In the algorithm, CP always select the AP which helps it profit most from all APs until all its demand is met, the demand maybe offloading data enough or covering users enough. To cover users, CP aim to get enough bandwidth, while offloading data means get enough storage. When an AP is selected, it would serve the nearest MC until its access ability is run out according to constraints (3–4).

4 Proposed Mechanisms

In VCG based mechanism, payment for an AP is the extra profit to system because its participation, while may cause CP out of BB. In AGV based mechanism, each AP contributes a participation fee for paying other APs. In this way, CP need not supply remuneration, CP could gain most by this way while it cannot satisfy IR for APs. Reference [26] pointed that, if a mechanism is Bayesian incentive compatible and individually rational, then the mechanism is optimal. According to [27], an optimal leasing mechanism should satisfy following:

1: The offered surplus is of the form:

$$p_i(\hat{v}_i, \hat{q}_i) = p_i(\bar{v}_i, \hat{q}_i) + \int_{\hat{v}_i}^{\bar{v}} X_i(v, \hat{q}_i)dv \tag{8}$$

2: Expected allocation $X_i(v_i, \hat{q}_i)$ is nonincreasing in the cost parameter $\hat{v}_i$ suppliers.

In (8), p_i refers to payment for AP i, $\hat{v}_i$ is bid of AP i, while $\hat{q}_i$ is quality of resource supplied by AP i. $\bar{v}_i$ is the mean bid for selected $\hat{q}_i$. (8) pointed that the payment for AP i should be the highest bid of selected AP which have the same quality with AP i, and incentive for its low price. Instead of taking quantity as $\hat{q}_i$ in [26], the paper take maximum profit may get from AP i as $\hat{q}_i$, and sort AP with (10).

$$q_i = \frac{b_i}{(1-h_i)}(P - C(1-h_i)) - v_i \tag{9}$$

$$H_i(v_i, q_i) = v_i + \frac{F_i(\frac{v_i}{q_i})}{f_i(\frac{v_i}{q_i})} \tag{10}$$

Aim to meet requirements as above, we set X as follows:

$$X_i(\hat{v}_i, \hat{q}_i) = \int_{\underline{v}}^{\hat{v}_i} x_i(v, \hat{q}_i)dv \tag{11}$$

$x(\hat{v}, \hat{q})$ is a binary value represents that whether select AP when it bidding as value is $\hat{v}$ and quality is $\hat{q}$. It is obvious that (11) can satisfies the above properties and hence is optimal. Pseudocode is shown in the following:

Algorithm2	**payment function for optimal mechanism**
Input: *M,A,b,s,d,r,h,R,C,P*	
Output : y,p,x	
1	(y, x) <=Solve the model while order by H
2	Calculate distribution of $x(\hat{v}, \hat{q})$ and get $X(\hat{v}, \hat{q})$
3	**foreach** $j \in A$ **do**
	$p_j = \hat{v}_i y_j + \int_{\hat{v}_i}^{\overline{v}} X_i(v, \hat{q}_i)dv$
4	**end**

The algorithm proceeds in three steps. Step 1 computes the maximum revenue allocation. Different with VCG or AGV, when optimal mechanism solve model with Algorithm 1, it needs to sort APs with H. Step 2 calculates $X(\hat{v}, \hat{q})$ for step 3, while step3 computes incentives for APs.

Theorem 1: The payment rule satisfies trustfulness property (IC).

Proof 1: Since AP always wants to get more pay with less storage and less bandwidth. If AP j wants to bid $(\hat{v}_j, \hat{q}_j)$ untruthfully, there would be $\hat{v}_j > v_j, \hat{q}_j < q_j$.

$$
\begin{aligned}
u_j(\hat{v}_j, \hat{q}_j) &= \rho_j(\hat{v}_j, \hat{q}_j) + (\hat{v}_j - v_j)X_j(\bar{v}, q_j) \\
&= p_j(\bar{v}_j, \hat{q}_j) + \int_{\hat{v}_j}^{\bar{v}} X_j(y, \hat{q}_j)dy + (\hat{v}_j - v_j)X_j(\bar{v}, q_j) \\
&= p_j(\bar{v}_j, \hat{q}_j) + \int_{\hat{v}_j}^{v_j} X_j(y, \hat{q}_j)dy \\
&+ \int_{v_j}^{\bar{v}} X_j(y, \hat{q}_j)dy + (\hat{v}_j - v_j)X_j(\bar{v}, q_j) \\
&\le p_j(\bar{v}_j, \hat{q}_j) + \int_{v_j}^{\bar{v}} X_j(y, \hat{q}_j)dy \\
&\le p_j(\bar{v}_j, q_j) + \int_{v_j}^{\bar{v}} X_j(y, \hat{q}_j)dy \\
&= u_j(v_j, \hat{q}_j)
\end{aligned} \tag{12}
$$

From (12), it can be seen that AP would get most when it bid truthfully.

Theorem 2: The payment rule maximizes revenue of CP.

Proof 2: As $p(v, q)$ is increasing in q and non-increasing in v, we can ensure CP pay the lowest price to AP. Since the profit get from MCs is stable when it selects APs from certain set, CP maximizes revenue in optimal mechanism.

Theorem 3: The payment rule satisfies IR property.

Proof 3: According to (8) (11), $u(v, q)$ is non-negative, thus mobile users always could get profit.

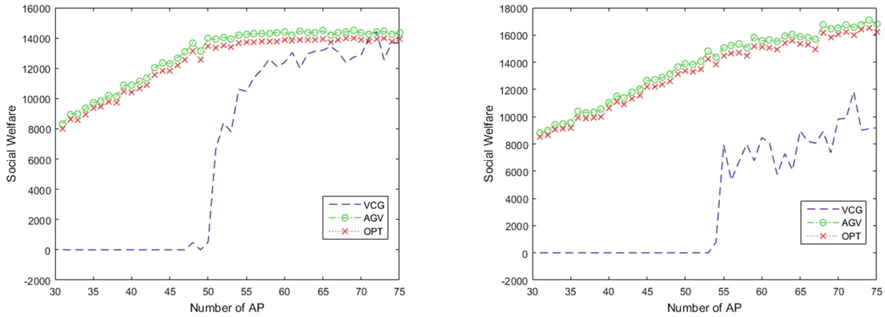
5 Evaluation Results

Reference [27] has evaluated that time consumption for reaching consensus in permissioned chain would be almost 3 ms. Reference [28] evaluated throughput and verification speed. Without considering performance of blockchain, the section calculates social welfare gains by each proposed algorithm, and discusses impact of different factors. To be concise, this part use VCG, AGV, OPT to represent VCG, AGV based mechanism and optimal mechanism respectively. To make results more accurate, each scenario has been performed for 20 times and adopts data in the narrow 95% confidence intervals.

According to [7], bids of APs are uniformly selected in the [7, 15], the traffic-proportional cache miss cost is set to 5 Mb/s, while CP profit 15 from per Mb/s. Considering simulation settings in [7] [29], we choose the backhaul Internet bandwidth uniformly in the set {6; 8; 10; 15; 20} Mb/s, whereas the size of the leased caching storage is uniformly selected in the range [10, 100] GB. Since the paper does not consider network selection, geographical conflictions between APs is neglected. The paper assumes the radio access network is composed of 802.11n wireless APs, and adopts datasheet of Atheros AR9342 chipset [30].

According to [31], the density of mobile user population in dense city is 12,000 mobile users per km^2. The paper assume MCs is uniformly distributed around AP as the density. Demands of every MC are generated in the range [0.5, 3] Mb/s.

Considering two different scenarios: getting access bandwidth or offloading data, we perform two groups of simulation. In the first group, CP aims to lease 600 Mbps bandwidth for access, while lease 3000 GB for data offloading in second. In the following simulation, CP has 10000 files being requested with zipf parameter is 0.8.



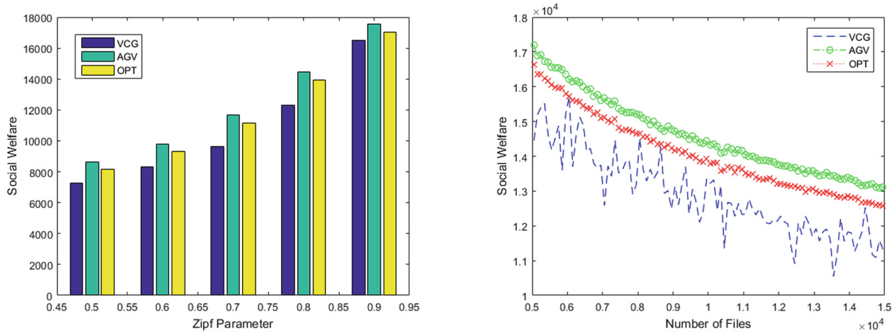
(a) (b)

Fig. 3. Social welfare (a) getting bandwidth (b) offloading data

From Fig. 3, it can be observed that:

1. In each case, AGV based mechanism can get the best revenue, because APs pay others, while CP need pay APs in OPT and VCG. Since OPT mechanism pay APs as little as possible, social welfare of OPT is close to AGV. VCG gains least, which is consistent to our expectation.
2. The two scenarios demonstrate a similar trend. When attending AP is less, VCG may loss budget balance because it has to choose all AP with no choice, while profit of AGV and OPT are growing linearly. When CP has enough choices, VCG profit rises dramatically and tend to be stable quickly while AGV and OPT profit turns to be slow gradually.
3. Comparing (a) and (b), the fluctuation of VCG in (b) is more extreme. Since bandwidth affects social welfare by network traffic while storage affect it by hit ratio, effect of bandwidth would be more directly. To AGV and OPT, when bandwidth is stable, social welfare would get stable.

To find impact of file distribution on performance of incentive mechanism. We first adjust the parameter of Zipf. According to [32], the zipf parameter α always be approximately around 0.5–0.9. The larger α is, the more concentrated the requests for files are, and hit ratio would be higher. Besides, the less files CP has, the higher hit ratio would be reached by each AP, so we adjust number of files (Fig. 4).



(a) (b)

Fig. 4. Social welfare (a) Zipf parameter (b) number of files

As shown above, the more hit ratio would be reached by each AP, the more profit CP could gain. The phenomenon is consisted with our common sense, as the more hit ratio means less cache miss cost and less backhaul bandwidth occupied, the more users can get access to CP efficiently.

6 Conclusion

To motivate users to contribute their available resources to NDN, the paper proposes a hybrid chain based auction market for resource leasing. By combining public chain with permissioned chain, a transparent and credible marketplace is constructed. To overcome defects in traditional auction mechanism, the paper designs an optimal mechanism, which could obtain the most profit for CP with guaranteeing interests of AP. Proof and simulation results show the mechanism we proposed is efficient.

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