ENCOURAGING CELLULAR TRAFFIC OFFLOADING: A STRATEGIC PLAN

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ABSTRACT –
Congestion issues on cellular networks (4G, for example) are becoming increasingly common. It's an intriguing concept to offload some cell phone traffic onto other networks like WiFi and Delay Tolerant Networks (DTNs). Mobile users may experience noticeable delays if cellular traffic is redirected to these networks, as they may only be able to connect with these networks intermittently. The longer users have to wait, the less satisfied they become. In this research, we analyze the tension that arises between offloading effectiveness and customer satisfaction. To encourage users to take advantage of their delay tolerance for dumping cellular data, we provide a novel incentive structure. The incentive cost of a given dumping aim could be reduced by prioritizing customers who are both delay-tolerant and have high offloading potential. By placing bids on how much of a delay they are ready to take, users can actively participate in our incentive system. By doing so, we can keep track of how users' delay tolerance evolves over time. We also demonstrate how to utilize random analysis to speculate on the various offloading options available to users in DTN and WiFi networks. Large-scale trace-based simulations confirm the efficacy of our incentive strategy for dumping cellular traffic.

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1. INTRODUCTION

Since the advent of cellular networks (4G, for instance), mobile users have constant access to the World Wide Web. The exponential growth in both the number of users and their demands for bandwidth-intensive multimedia content is causing significant strain on cellular networks. As more and more people use their mobile devices to send and receive data, the quality of the cellular network suffers. Adding more cells to the cell network is the simplest solution to these issues, but it is also the most costly and inefficient. Researchers investigated how delay tolerance may be used to direct traffic toward the few nodes that truly needed it. It is both possible and likely that the problem of overload can be solved by redirecting part of the cell phone traffic to other networks. A recent research project investigates the most effective strategies for shifting cellular data loads to DTNs and WiFi access points. Finding the maximum amount of cellular traffic that can be offloaded is the primary focus. Data download times are typically longer than they should be in networks that can take over cellular traffic since mobile consumers only need intermittent and flexible network connections. Mobile customers are likely to become more impatient and dissatisfied if they are told they must wait longer before receiving data from cellular networks, even though this could lead to additional offloading opportunities.

We present a novel method of rewarding users for allocating their delay tolerance to offloading traffic, and we investigate the tradeoff between user satisfaction and throughput. If members are willing to wait longer to get their data, they receive a reduction on their monthly membership fee. The user will reliably receive the remaining data over the cellular network once the delay period has expired. Nonetheless, it is possible that some cellular data traffic will be routed to the aforementioned networks during that time. The primary objective of designing such an incentive system is to minimize the incentive cost borne by the cellular network provider. The overall discount offered to mobile subscribers in exchange for offloading a predicted volume of traffic is included here. To accomplish this, one must consider the users' patience and ability to wait. Customers that are patient and have plenty of opportunities to unload cellular traffic should be prioritized.

To begin, a lesser discount is preferred by consumers who can wait longer because of the time they lose in happiness. A reverse auction-based incentive mechanism, which has been proved to determine a fair price, is provided so that the ebb and flow of consumers' delay tolerance can be reflected in the pricing structure. Users take on the role of sellers on our platform, submitting bids that indicate their desired waiting time and desired discount. The term "coupon" will hereafter be used to describe these types of user-requested discounts. As the seller, the network provider then determines the acceptable level of user latency.

Better offloading customers can free up more information in the same amount of time[1]. During the delay period, a user that frequently requests popular data can simply offload by receiving data bits from other contacted peer users. People who spend a lot of time in public places or at cafes can benefit from offloading as well. We provide you with two reliable prediction models—one for the DTN scenario and one for the WiFi situation—to help you comprehend how customers can unload.

To determine the optimal auction outcome given an offloading objective, one must first determine the maximum amount of delay users are prepared to tolerate. While the auction winners negotiate with the network operator for the amount of time they must wait and the coupon they earn, those who did not win the sale can continue to use cellular networks to download data at the standard rate. In particular, the study contributes the following three points:

Using the concept of a reverse auction, we offer a new incentive system we call Win-Coupon. As a result, consumers will be more likely to exploit their delay tolerance to offload cellular data. This framework has three major advantages: it is straightforward, it promotes autonomy in decision-making, and it is simple to implement. We provide a method for using stochastic analysis to estimate the offloading potential in the DTN scenario by considering user access patterns and mobility. We introduce a Semi Markov chain-based WiFi prediction model that accounts for people's migratory patterns and the physical locations of WiFi access points.

The remaining sections of the paper are structured as follows. In Section 2, we provide a high-level overview of the work that came before. Our methodology and the context in which it was developed are briefly described in Section 3. Section 4 demonstrates why our incentive structure is so crucial, and it takes a lot of time to explain why. In Section 5, the effectiveness of Win Coupon is evaluated using trace-driven models, and in Section 6, unanswered research problems are discussed. The paper concludes with Section 7.

2. RELATED WORK

Some experts believe that DTNs might be used to reroute traffic as a means of addressing the issue of excessive cell phone use. When a reliable DTN connection becomes available, the operator can instruct users to switch interfaces and pull data from a new set of peers. This straightforward approach was developed by Ristanovic and is known as the "Mix-Zones." To determine how many copies the cellular network should send and to whom, Whit Beck et al. developed a system called Push-and-Track that employs DTNs to manage the data. Provide us with three easy-to-implement techniques for utilizing DTNs to facilitate information sharing amongst mobile phone users and so reduce network congestion. The rate at which information can be accessible in DTNs is a major topic of research. The authors theoretically examine both the constant and varying phases of information flow. Some recent efforts leverage the social networks available to mobile users to spread the news. In this research, we propose a realistic model to illustrate the potential traffic transmitted to DTNs, which will facilitate the development of our system. Public WiFi is another option for avoiding cell phone interference. Authors create Hot Zones according to user's mobility profile and WiFi hotspot locations, allowing users to activate WiFi modules only when they anticipate a connection. The authors collect GPS data to evaluate the capacity of public hotspots. Lee et al. conduct research into both asynchronous and synchronous WiFi offloading from the perspective of a more general mobile scenario. To aid in the development of an offloading strategy, studies have been conducted to predict when WiFi would be made available in the future. Data transfers from mobile devices can now be pre-scheduled for times of day with higher predicted WiFi speeds, thanks to a method developed by researchers. For mobile devices with cellular network and WiFi interfaces, the optimal energy-delay tradeoff is proposed using a method called SALSA, which is based on the Lyapunov framework. This study offers a novel approach to accurately estimating the amount of traffic that may be offloaded through WiFi hotspots if a mobile user is prepared to wait a predetermined amount of time, as compared to earlier research.

The possibility that increased waiting times can reduce consumer satisfaction has been overlooked in all previous studies of traffic unloading. The goal of our proposed auction-based reward system is to encourage users to make advantage of their tolerance for delays by sharing their cellular data with others. The field of network design has made extensive use of auctions. One of the most effective uses of bids is in spectrum leasing. There has been a lot of talk about selling wireless spectrum in recent years. Ten years ago, the FCC actually organized auctions for unused radio spectrum. It has also been possible to utilize auctions to incentivize data-hungry nodes to distribute their data to more generous nodes. However, no one has yet attempted to eliminate cell phone traffic via auctions.

Our previous research focused mostly on exploring ways to encourage the usage of DTNs as a means of offloading cellular traffic. What we learned there is greatly supplemented by this investigation. In this research, we present an overarching framework that may be applied to both DTNs and the WiFi scenario. Using trace-driven simulations, we examine how effectively the model we develop can foretell users' offloading potential in the WiFi instance. To further evaluate our approach, we update the data query model to reflect a more realistic Zip-like distribution.

Fig. 1. The basic premise of Win-Coupon.

3. OVERVIEW

The Big Picture

In this section, we'll take a look at the Win-

Win-Coupon employs a reverse auction-style incentive mechanism to motivate users to assist in mobile data traffic offloading. Based on what we see in Fig. 1. Provider networks are like retailers who reward patient consumers with discounts when they have the opportunity to discharge their traffic. Bids should be included in data requests made to the network provider. Those interested in each deal specify a waiting time and the percentage off coupon they would like to receive in exchange. This will allow network administrators to gauge how much delay their customers can tolerate. The users' selling power should be considered while selecting how to close the auction. Using network modeling, it is possible to speculate on the future value of system metrics such users' data access and movement tendencies. In turn, this can be utilized to make educated guesses about the burden people can shed. either inputting the range of access points or by connecting with friends who have the information saved. After the timeout, the cell network will transfer the remaining data bits to user u1. Figure 1 depicts u3, a user who placed the third-to-last bid and is presently receiving base-price data over a cellular network.

User Delay Tolerance

If the rapid decline in satisfaction with increasing download times is any indication, people are very patient. To characterize the adaptability with which customers can deal with delays, we construct a satisfaction function S(t) that decreases monotonically with delay t. How much the user is willing to wait for their data service. The user, the information he requests, and other contextual circumstances inform the satisfaction function. In this paper, we assume that users have a threshold for waiting on each category of information. If the internet connection is slow, users will become dissatisfied and stop paying for it. Figure 2 depicts an example of the user satisfaction function S(t) for the given data. In this case, tbound represents the maximum amount of time a user is willing to wait for data. In this graph, where p is the base price of the service, the user's perceived value of the data increases as the waiting time increases. The longer the delay (t1), the less willing the user is to pay (from p to p1). The happiness loss due to delay t1 is denoted by the symbol p p1.

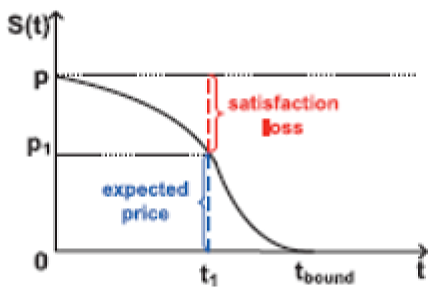

Fig.2.Satisfaction function.

Auctions

Auctions are frequently employed in economics when the market value of a good or service is uncertain. Many companies have made use of this. Forward auctions, in which a single vendor lists items for sale and numerous buyers compete for them, are by far the most frequent form of auction. One buyer and multiple sellers make up a reverse auction. Buyers evaluate the sellers' offers and settle on a final purchase. To begin, let's define a few terms. Bidder i has made an offer of $bi for the item or service up for auction. Value (xi) that is determined privately is the true price that bidder I is willing to pay for the resources. Only I have access to this number. The market price, denoted by pi, at which the item was purchased. The prices I've proposed guarantee that this rate will remain stable.

When all costs are factored in, the market price of a resource (pi) is compared to the bidder's private valuation of the resource (xi) to determine utility. It is assumed that those who place bids on the sale are astute and risk-averse. Many auctions are organized using the assumption that participants would act rationally.

To begin, for an auction to be rational on an individual level, it must be fair for all parties involved. Smart bidders strategize their approach to maximize their chances of success. The number of prospective customers, denoted by "N,". An example of a "weakly dominant strategy" would be one that:

Only when ui(i, i) > ui(i, i), i >= i is bi = i weakly dominating for user i.

At present, i = 1, 2, 3,..., i1, i+1

The set of proposals from other bidders that do not contain bidder i is denoted by |N|. The strategy is poorly conceived.

identifies the optimal use for i across all bid conditions. If each bidder has a slightly dominating strategy of setting their price to their own private value, then the auction is fair, according to the strategy proof.

Bidders in an auction, who we'll refer to as "i," must each employ a strategy that gives them a negligible advantage over their competitors.

= xi. Since everyone is telling the truth, there is no market manipulation. Costs associated with aggressive bidding strategies are avoided as well. It ensures efficient use of resources by rewarding bids that reflect genuine interest. Because of their transparency, Vickrey Clarke-Groves (VCG) auctions have been the subject of extensive research. VCG, however, can only ensure truthfulness when the optimal allocation is determined. When combined with approximate techniques, it typically cannot ensure veracity. Unfortunately, the Win-Coupon selection problem is NP-hard. Research shows that an allocation technique must be monotonic for its claims to be valid. To preserve the trustworthiness, we devise a deterministic monotone approximation strategy. This means that our system of rewards is robust, sensitive to individual intelligence, and computationally efficient.

4. MAIN APPROACH OF WIN-CUPON

We'll provide several examples to illustrate how Win-Coupon operates. In a Win-Coupon reverse auction, the winning bidder receives a discount from the network provider in exchange for user wait times. The buyers and sellers are all mobile phone users who are willing to barter their tolerance for delay in exchange for incentives. The Win-Coupon technique diagram is shown on the right side of Figure 1. The network operator initially solicits bids to gauge the potential for dumping and the bidders' tolerance for delay. The data is then utilized to set a price and distribute the available units. The administrator of the system then notifies the successful bidders of the auction's outcome. The first order of business is to discuss the bidding procedure. The topic of auctions is up next.

technique, and then describe its features. Finally, we demonstrate how to speculate on the potential offloading capacity of bids in both DTN and WiFi networks

Bidding

The user's dissatisfaction persists after t seconds. Since the user wants the coupon with a value larger than or equal to p S(t) for delay t, p S(t) reveals the user's private value to the delay. The user's secret number increases by xk (k 1, l) = S(k) for each subsequent delay t.

- 1) − S(k). An individual's search for a purchase of at least $x is illustrated in Figure 3.

For x1 seconds, it waits, for x1 + x2 seconds, and for x1 + x2 + x3 seconds, it waits. Bids are often customizable by the user. But we'll prove that the Win-Coupon auction is legitimate, with participants always bidding their own private value (bk = xk, for all k).

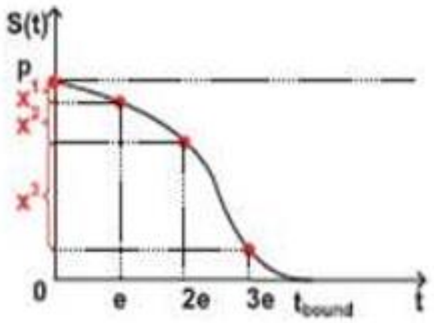

Fig.3.Private value.

Each bidding round includes a Win-Coupon round. Bidders would have to wait longer than is practical for the auction to close. This is in contrast to long-term scenarios, such as an FCC-style spectrum lease, when hundreds of people may all desire cellular data service at once. Furthermore, the delay caused by auctions can be disregarded because potential bidders are assumed to be patient. After that, we go into the meat and potatoes of an auction: the bidding and the merchandise.

Auction Algorithms

Each bidding round includes a Win-Coupon round. Bidders would have to wait longer than is practical for the auction to close. This is in contrast to long-term scenarios, such as an FCC-style spectrum lease, when hundreds of people may all desire cellular data service at once. Furthermore, the delay caused by auctions can be disregarded because potential bidders are assumed to be patient. After that, we go into the meat and potatoes of an auction: the bidding and the merchandise.

4.2.1Allocation

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, t|N|} which minimizes the total incentive cost ,subjectto a given off loading target.

$$\min_{t_i} \sum_{i \in \mathcal{N}} \sum_{k=1}^{t_i} b_i^k \qquad (1)$$

$$s.t. \sum_{i \in \mathcal{N}} V_i^d(t_i) \geq v_0 \qquad (2)$$

$$\forall i,\ t_i \in \{0, 1, 2, \ldots, l_i\}. \qquad (3)$$

In Eq.(1), $\sum_{k=1}^{t_i} b_i^k$ denotes the value of the coupon that thenetwork operator needs to pay bidder*i*in

```
Perform initialization phase of algorithm 2 (lines 1–4);
ξ ← 4; θ ← 16;
δ ← ⌊min{N/ξ, n_B/θ}⌋;                ▷ Initialize threshold δ
while |I| > 0 do
    ε ← θ/(n_B+1);
    while |I| > δ do
        Perform bidding and assignment phase of algorithm 2 (lines 9–15);
        ε ← ε · ξ;
    end while
    δ ← δ/ξ; θ ← θ · ξ;
end while
```

For the sake of the delay, if you will. Buyer i is prepared to wait delay t after downloading the data set d, therefore in Eq. It's clear from (2) just how much traffic can be diverted. In Section 4.3, we discuss the DTN instance, and in Section 4.4, we discuss the WiFi scenario. Prediction of V di (t) is discussed in detail in both parts. Given that we anticipate each bidder would only be interested in a single set of data during any given bidding round, we may confidently link each i to a single d. The offloading objective v0 cannot drop below the threshold you specify. The third equation ensures that li's patience threshold is not exceeded. If we assume that li = 1 for every i, then our distribution problem can be reduced to the 0-1 knapsack problem. It has been proved that our problem, like the 0-1 knapsack problem, is NP-hard. Then we determine the optimal approach to the fresh challenge by means of dynamic programming (DP).

4.2.1Auction algorithm

To better understand how auctions function, it is helpful to first provide an issue of economic equilibrium that is equivalent to the assignment problem. Imagine for a moment that everyone behaved like a shrewd businessperson and the market was utilized to pair people and goods. Say the price of Object j is P and the recipient is responsible for paying that amount. If and only if (ai)j(pi) = (maxj)(1,...,n)aij(-pi), then item j has value to individual I. Therefore, I hope that I will be given responsibility for the most valuable object ji.

If this is settled solely by the bids, and the lowest bidder takes home the prize, then everyone involved is happy. The prices that reveal purchasers' willingness to wait and their ability to dump are both relevant here, though. Where ti is the amount of delay that the network operator wishes to acquire from bidder i, fti demonstrates the allocation process. Since the waiting period for each buyer is the same, ti is always a whole number. Bidder [8] loses the game only if ti equals zero. If this condition holds, then there is equilibrium between the prices and assignments. This signifies that the issue of how to distribute Win-Coupons has been addressed. Naturally, economists are curious about equilibrium assignments and prices, and these concepts are intrinsically linked to the assignment problem: an equilibrium assignment provides the greatest overall benefit, which resolves the assignment problem, and the corresponding set of prices resolves a dual optimization problem. This is a logical application of the duality theorem, a staple of linear programming.

Let's consider how that equilibrium in nature might be achieved. I'm going to refer to this technique as the "naive auction algorithm" because of a major flaw that will become apparent in a moment. Even so, spotting this flaw will prompt development of a more robust, error-free strategy.

Any task and any set of prices can be used to kick off the simple auction process, which then proceeds through a number of "rounds" (also known as "iterations"). Each iteration begins with a set of prices and a task to complete. Once consensus is reached on them, the process will end. Someone who is likely to get upset if not chosen. Now, let's imagine that person i is in the market buy a priceless artifact, and they stumble into ji.

The formula looks like this: ji arg maxj =1,...,n aij - pj if and only if

a) At the beginning of the round, Ji makes a deal with the player whose turn it is,

b) Decides that the best item jI is equivalent to the second-best item at the price pji.

We have i = vi + wi, and pji = pji + i.

The best object value is denoted by the phrase vi=maxj aijpj, whereas the second-best value is denotedby the expression wi=maxj6=ji aijpj.

The only thing that matters when figuring out the allocation answer in a standard reverse auction are the bids. That's why the lowest bidder always wins. However, in this scenario, we need to consider more than just the offers that indicate the length of time that potential buyers are ready to wait. We should also consider the sellers' willingness to lower their prices. Where ti is the amount of delay that the network operator wishes to acquire from bidder i, fti demonstrates the allocation process. Since the waiting period for each buyer is the same, ti is always a whole number. Bidder [8] loses the game only if ti equals zero. Win-Coupon's allocation dilemma can be understood by mathematical analysis.

4.2.2.Pricing

When there is only one seller and little available cash, the VCG pricing approach is often employed in forward transactions.

price, and there are a number of potential purchasers. Since the highest bidder wins and must cover the "opportunity cost" that their involvement causes to the other bidders (2), this pricing algorithm incentivizes truthful bidding. Our pricing strategy [9] takes use of this concept by compensating the highest bidder (i) with a coupon whose face value is equal to the "opportunity cost" borne by the other bidders due to i's presence.

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5. DISCUSSIONS

In this study, we concentrated on the downloading case because this represents the vast bulk of cellular traffic. We also examine Win- Coupon layout independently of WiFi and DTN. In fact, our framework is quite flexible and may be adapted to a wide variety of contexts. The two components that make up Win-Coupon are the auction-based incentive mechanism and the forecasting. The incentive mechanism can be used for coupon distribution and pricing in situations involving uploading, downloading, DTN alone, WiFi only, or a hybrid of the two as long as the volume of offloaded traffic V di (t) can be forecast. Prediction is the sole variable that changes under different conditions.

6. CONCLUSION

In this research, we put forth an innovative incentive structure for offloading cellular traffic. To put it simply, the goal is to encourage mobile customers with high delay tolerance and big offloading potential to shift some of their traffic to networks that only have spotty connectivity, like DTN or WiFi hotspots. We develop a reverse auction-based incentive mechanism to capture the changing characteristics of customers' delay tolerance. The honesty, individual sanity, and minimal computing complexity of our approach have all been demonstrated. In addition, we create two reliable models to foretell the users' offloading potential in both DTN and WiFi scenarios. Our incentive paradigm has been proven effective and useful by extensive trace driven simulations.

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