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A Conditional E-Coupon Service For Location-Aware Mobile Commerce

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Abstract: This paper presents the concept and theory of a conditional electronic coupon (CEC) service as an optimal wireless targeted advertising scheme to promote location-aware mobile commerce. The key idea of CEC service is to advertise stores conditionally, i.e., distributing e-coupons for a store to mobile customers only if the number of mobile customers requesting such e-coupons exceeds a threshold. Using the CEC service, mobile customers stand a good chance to obtain e-coupons from some local stores shortly before they go shopping there, and participating stores are guaranteed to make maximum extra profits in a statistical sense by issuing e-coupons.

1. BACKGROUND

As more and more wireless devices are connected to the Internet, many have predicted that mobile commerce will take off soon, just like e-commerce booming in recent years. However, mobile commerce may not necessarily be an e-commerce copy over wireless connections, because location information of wireless service subscribers could play a significant role in mobile commerce scenarios.

Location-based wireless applications have been under intensive investigation since FCC required that wireless service providers must be able to identify the locations of cellular phone users making 911 calls after Oct. 1, 2001 [1]. Various commercial uses derived from this requirement have been proposed. For example, a mobile visitor can use his WAP phone to ask a server for information like "where is the closest restaurant?" [2]. For another example, a store may send e-coupons to mobile customers passing by the store and thus hopefully brings in more traffic [3]. The first example describes a location-assisted information retrieval service, which requires mobile customer's location information to be submitted to the server along with the query message. The second example describes a location-aware wireless targeted advertising scheme, which mandates the locations of nearby mobile customers to be monitored closely by some system on behalf of the store.

Since advertising is a huge business, location-aware wireless targeted advertising, as a brand new advertising scheme potentially, has caught tremendous attention. Although it is favored by wireless service providers who are eager to open new revenue source, at present it is not clear whether this idea will become a serious business, because there are many important issues unsolved.

One major issue raised by mobile consumer group is privacy. Although some preliminary market study shows that about 60 percent of participating mobile consumers think wireless targeted advertisements are valuable and 27 percent of them say they like to switch to wireless service providers carrying the wireless targeted advertising service [4], the privacy concern has been weighing in mobile consumer's mind and it might threaten the wireless targeted advertising business from taking off [5]. The argument herein is that mobile consumers have to worry about the fact that their 24/7 locations are purposely monitored, which might fall into mishandling hands.

Another major issue is a technical problem for wireless service providers. In order to send a targeted advertisement for a participating store to some mobile customers at right time in right place, the locations of these mobile customers must be monitored closely. To do so, all mobile devices must frequently send location data to the network, and thus cause significant uplink signaling traffic that may eventually overflow the network. The situation could get worse if location identification methods are network-based or network-assisted because they need consume significant computing resources from the network [6].

Probably the most important issue is a business question that will be asked by stores before they are willing to pay for the wireless targeted advertising service --- is wireless targeted advertising effective and cost-efficient compared with other advertising methods? The answer largely remains unknown, although it can be argued that wireless targeted advertising may be more effective because the potential customers (the targeted mobile customers) are physically close to the advertised stores when they receive the targeted advertisements, and that wireless targeted advertising should be of low cost because the advertisements are only broadcast in local areas of participating stores.

Bearing the privacy concern, technical problem, and business question in mind, we invented a new wireless targeted advertising scheme, called a CEC service, to promote location-aware mobile commerce. The rest of this paper will present details of the CEC service concept and demonstrate quantitatively that the CEC service is an optimal wireless targeted advertising scheme, which can benefit mobile customers, participating stores, and wireless service providers.

2. CONCEPT

2.1 Overview

The CEC service concept consists of three key ideas: (1) mobile customers send requests to a CEC server and indicate they wish to receive e-coupons from some local stores shortly before they go shopping; (2) in turn, the CEC server will distribute e-coupons for a store to these mobile customers and, optionally, all nearby mobile customers if the number of mobile customers requesting such e-coupons equals or exceeds a threshold; and (3) the store pays an advertising fee every time after its e-coupons are distributed. The CEC service provider (which could be a wireless service provider) never unconditionally pushes advertisements to mobile customers, as done by conventional advertising methods.

With these key ideas, the CEC service can significantly improve advertising effectiveness and cost-efficiency, because (1) e-coupons are distributed to mobile customers who explicitly request such e-coupons, hence they may probably shop the store after receiving desired e-coupons; and (2) e-coupons are distributed to a number of mobile customers, which equals or exceeds a threshold that assures, in a statistical sense, the store can make profit after paying the advertising fee to the CEC service provider. In addition, the CEC service gets rid of the technical problem for wireless targeted advertising because its operation is based on requests made by mobile customers. The accurate location information of mobile customers are conveniently embedded in these requests, and therefore mobile devices do not need to send periodical location update messages to wireless networks. The CEC service also eliminates the privacy concern, because it does not track the locations of mobile customers. A mobile user's location is exposed to the CEC service provider only at the moment when the user is making the request, and the user is willing to do so.

2.2 System Architecture

The exemplary system architecture given below is a high-level description with some data structures highlighted, which is presented to clarify the concept and theory of the proposed CEC service. It does not include all details for a real implementation.

In order to provide the CEC service, a CEC service provider needs to run a CEC server on the Internet, which is a combination of a CEC controller, a Web server, and a database. The Web server provides Web interfaces for mobile customers to browse local stores, to request e-coupons from some specific stores using store names or from a group of stores offering similar goods or services using keywords, to confirm redeem of e-coupons, and to request e-coupon quotas. The Web server also provides Web interfaces for participating stores to edit their mobile commerce profiles and to predefine e-coupons.

Every participating store has a mobile commerce profile in the CEC database, and the CEC service provider does not charge the store for maintaining its profile. The store profile data structure is given below in C syntax.

```
struct store_profile {
   char[32]  store_id;
   char[64] store_name;
   char[64]  store_address;
   char[64] billing_information;
   char[64] instant_contact_address;
   char[64]  business_type;
   int  number_of_coupons;
   struct e_coupon * first_e_coupon_pointer;
   int number_of_pending_requests;
   struct store_pending_request * first_pending_request_pointer;
   float estimated_number_of_redeems;
   int number_of_pending_redeems;
 struct pending_redeem * first_pending_redeem_pointer;

}
```

Where, instant_contact_address could be a phone number, an instant messaging address, or an email address, by which the CEC service provider can notify the store as soon as it distributed e-coupons for the store; business_type is described by a set of keywords, which can be used to determine whether the store is a candidate store in case that mobile customers use keywords instead of store names in their requests.

In the profile, the store also needs to define one or more e-coupons. Every e-coupon is associated with some conditions, including time (when e-coupons can be distributed), range (where e-coupons should be distributed), and a profit margin (how much profit the store can make from a mobile customer using this e-coupon). The data structure of e-coupon is given below.

```
struct e_coupon {
   struct timing time_condition;
   strcut  range  range_condition;
   float profit_margin;
   char[128]  coupon_text;
   struct e_coupon * next_e_coupon_pointer;
}
```

Where, profit_margin is the most important parameter, from which the CEC controller can calculate a threshold for the store and therefore can determine whether the store's e-coupon should be distributed.

Every mobile customer who signs on the CEC service has a mobile commerce profile in the CEC database. Its data structure is given below.

```
struct customer_profile {
```

```
    char[32] customer_id;
    char[64] instant_contact_address;
    int  coupon_quota;
    int   number_of_pending_requests;
    struct  customer_pending_request  *  first_pending_request_pointer;
    int   number_of_pending_coupons;
  struct pending_coupons * first_pending_redeem_pointer;

  }
```

Where, instant_contact_address could be a cellular phone number, an SMS address, or a mobile email address belonging to a cellular phone or other mobile device capable of supplying location information. Whenever a mobile customer uses his mobile device to contact the CEC Web server, his location information and his instant contacting address are included as header parameters in the HTTP request message and submitted to the CEC Web server.

All fields in customer_profile are under control of the CEC service provider. The mobile customer can only read some fields, such as instant_contact_address, coupon_quota, and number_of_pending_requests. Among these fields, the most important parameter is coupon_quota. At the first time when a mobile customer uses the CEC service or at the beginning of a long cycle (such a week or a month), a small value is assigned to coupon_quota in the customer profile. After the mobile customer requests an e-coupon, coupon_quota decreases by one. If he cannot get the desired e_coupon, or if he gets the e-coupon and redeems it at the store, coupon_quota increases by one. If coupon_quota is equal to zero, the mobile customer cannot request any e-coupons until the beginning of next cycle. The reason why the coupon_quota parameter is introduced in mobile customer's profile is to prevent an irresponsible mobile customer from abusing the CEC service, because a fundamental assumption for the CEC service is that a mobile customer will redeem at least one of e-coupons received upon his request at a very high probability. Using e-coupon quota is a good compromise between giving mobile customers maximum freedom and protecting store's interest. With a positive coupon_quota, a mobile customer can have a few chances not to redeem any received e-coupons if none of them is attractive. In order to encourage mobile customers to be co-operative, the CEC service provider shall issue some bonus e-coupon quota to a mobile customer after he redeems a certain number of received e-coupons.

2.3 How It Works

Before a mobile customer goes shopping, he uses his mobile device to contact the CEC Web server. He can request e-coupons from specific stores by specifying store names or from a group of stores by specifying keywords that describe the business type of stores.

After receiving the e-coupon request, the CEC Web server sends an HTTP response message back to the mobile customer, which tells the mobile customer remained quota and expected time to receive e-coupons (it is possible that the mobile customer cannot receive any e-coupon). The CEC Web server then passes the request message (along with location information and instant contact address of the mobile customer) to the CEC controller.

After receiving the request message, the CEC controller does not immediately decide whether e-coupons should be distributed to the mobile customer. Instead, the CEC controller makes such decision at the end of a processing cycle, which is about 5 to 10 minutes. Before a processing cycle ends, the CEC controller simply logs such request in the mobile customer's profile and all candidate store profiles. Where, a store is considered a candidate store if the time and range conditions for the store to issue e-coupons are satisfied and if the business type or store name is specified in the request message. To log a request made by the mobile customer, the CEC controller needs to complete the following jobs.

1. Creating a customer_pending_request record in the mobile customer's profile, which contains the request time and the IDs of all candidate stores.
2. Decreasing coupon_quota by one in the mobile customer's profile.
3. Creating a store_pending_request record in every candidate store's profile, which contains the request time and the mobile customer's ID.
4. Increasing estimated_number_of_redeems by a proper value for every candidate store, where the increment can be chosen to equal one divided by the number of candidate stores (this is why we need the assumption that a mobile customer will probably redeem at least one of e-coupons received upon his request; there could be better estimates for this increment).

The data structure of customer_pending_request is given below.

```
struct   customer_pending_request   {
   struct time request_time;
   int  number_of_candidate_stores;
   struct candidate_store * first_candidate_store_pointer;
   struct customer_pending_request * next_pending_request_pointer;
}
```

Where, request_time serves as an identifier of the pending request made by the mobile customer; number_of_candidate_stores is the number of stores where the mobile customer's request is pending; first_candidate_store_pointer points to the first candidate store that starts a chain of all candidate stores, which has the following data structure,

```
struct candidate_store {
   char[32]  store_id;
```

```
    struct   candidate_store*next_candidate_store_pointer;
}
```

The data structure of store_pending_request is given below.

```
struct store_pending_request {
    struct time request_time;
    char[32]  customer_id;
    struct   store_pending_request*next_pending_request_pointer;
}
```

When a processing cycle is finished, the CEC controller performs the following operations with every participating store in a random order (the store whose profile is processed later has more advantage, so the processing order must be randomly chosen if all participating stores pay the same advertising fee to the CEC service provider).

1. The CEC controller finds the effective e-coupon at current time in the store profile, and calculates the best threshold for the store, which is equal to the advertising fee divided by the product of estimated_number_of_redeems times profit_margin.
2. If number_of_pending_request is less than the threshold, the CEC controller does not distribute e-coupons for this store. Instead, the CEC controller increases estimated_number_of_redeems accordingly in profiles of other candidate stores that have not been processed (this is why the store whose profile is processed later has more advantage).
3. Otherwise, the CEC controller needs to distribute the store's e-coupon to mobile customers who requested it in this processing cycle. In this case, the CEC controller needs to complete the following jobs: (1) creating a pending_coupon record in the store profile, which includes a serial number, a redeem confirmation number, the e-coupon text, the issuing time, the expiring time, the number of mobile customers who will receive this e-coupon, and an estimated number of mobile customers who will redeem the e-coupon at the store; (2) sending the pending_coupon record to the store via its instant contact address; (3) creating a pending_redeem record in profiles of mobile customers who will receive this e-coupon, which includes a serial number, the request time, the issuing time, the ID of the issuing store, the e-coupon text, and the expiring time; and (4) the CEC controller sends the pending_redeem record to all mobile customers who requested the e-coupon in this processing cycle.
4. The CEC controller removes all store_pending_request records from the store profile and resets estimated_number_of_redeems to zero in the store profile.

In addition to processing store profiles, the CEC also performs the following operations with every mobile customer profile.

1. The CEC controller checks whether a pending_redeem record has the same request_time value as that of some customer_pending_request record.

2. If this is not the case, coupon_quota increases by one in the mobile customer's profile.
3. The CEC controller removes all customer_pending_request records from the mobile customer profile.

The data structure of pending_coupon is given below.

```
struct pending_coupon {
  char[32]  serial_number;
  char[32] redeem_confirmation_number;
  struct time issuing_time;
  struct time expiring_time;
  char[128]  coupon_text;
  int  number_of_recipents;
  int  estimated_number_of_redeems;
  int number_of_redeems;
}
```

Where, serial_number is used for mobile customers to claim the e-coupon at the issuing store; redeem_confirmation_number is a secret number known only by the store, which may be used for mobile customers to confirm with the CEC service provider that they have redeemed their e-coupons; number_of_recipients, estimated_number_of_redeems, and number_of_redeems can be used for the issuing store to estimate the effectiveness of its e-coupon.

The data structure of pending_redeem is given below.

```
struct pending_redeem {
  char[32]  serial_number;
  char[32]  store_id;
  struct time request_time;
  struct time issuing_time;
  struct time expiring_time;
  char[128]  coupon_text;
}
```

Where, the value of request_time is equal to that of request_time in the corresponding customer_pending_request record.

After receiving desired e-coupons, the mobile customer can go to the issuing store and redeem the e-coupon. He has two methods to get back an e-coupon quota. One is to contact the CEC Web server from his mobile device when he is in the issuing store. In this case, the store's location information is submitted to the CEC Web server, which serves as the evidence that the mobile customer does have been attracted to the store by the e-coupon. The other way is to request the secret redeem_confirmation_number from the store and to report it to the CEC Web sever, which could be handled by the store directly.

2.4 Explanations

Conventional coupon distribution is a special case for CEC. If a store wants its e-coupons to be distributed to mobile customers unconditionally, it could simply set profit_margin to be infinity with a predefined e-coupon.

How to distribute e-coupons to mobile customers and how to send e-coupon distribution notices to stores are only discussed conceptually. It may be mapped to the cell broadcasting operation in GSM networks that support cell broadcast short message service [7]. It may also be carried out using individual point-to-point short message service [8]. If the former method is used, the distribution cost is independent of the number of mobile customers. In this case, the CEC service provider may charge a flat advertising fee for each distribution. If the later method is used, the CEC service provider may need to consider other pricing plan.

The CEC service provider should collect fees for every e-coupon distribution, no matter whether the distributed e-coupons can bring extra profit to the issuing store. The CEC service provider had better not promise to a store that an advertising fee is charged only after a deal is made for the store, because it is very difficult to identify that the deal is made thanks solely to the e-coupon. On the contrast, it is relatively easy for a store to verify that some extra traffic is indeed brought in by e-coupons.

3. THEORY

The purpose of this section is to quantitatively demonstrate the CEC service is an optimal wireless targeted advertising scheme, which can guarantee participating stores to make maximum extra profit in statistical sense.

3.1 Mathematic Model

The CEC service provider will charge a flat fee p against a participating store each time when an e-coupon for the store is distributed (if other fee plans are adopted, corresponding theories can be derived by following the analysis method shown below).

The goods or service offered to one customer has a profit margin m, which is the difference of the offering price minus the cost (excluding the advertising fee p).

There are $N(t)$ pending requests at the store during a processing cycle $[t,\ t+T)$, where $N(t)$ is a random process defined on $\{0,\ Z^+\}$ and T is the length of a processing cycle. Note that $N(t)$ may not necessarily be stationary. Nonetheless, $N(t)$ will be denoted as N hereafter for the sake of simplicity, since it will be shown that the best threshold is independent of the statistical distribution function of $N(t)$.

The estimated number of redeems is denoted as M. We won't directly use this number in our derivation. Instead, we introduce a new notation r, called the e-coupon effective ratio, which is equal to *M/N*. The effective ratio essentially is a random variable, but we can estimate it based on individual mobile customer's redeem history recorded by the e-coupon quota system. Hence, it is treated as a regular variable for the sake of simplicity.

A threshold θ is defined with regard to the number of pending requests *N*. That is, if $N >= \theta$, the CEC controller should distribute e-coupon to the *N* mobile customers. The reason why we do not define the threshold θ with regard to the estimated number of redeems *M* is that *N* could be modeled as a Poisson random variable, but it is difficult to model *M*.

The extra revenue that the CEC service can generate for the store during a processing cycle is a function of the threshold θ,

$$f(\theta) = mrNu(N - \theta)$$

Where, u(x) is the step function, i.e., u(x) = 1 for $x >= 0$ and u(x) = 0 for $x < 0$.

The advertising cost that is charged by the CEC service provider for distributing an e-coupon in a processing cycle is also a function of the threshold θ,

$$c(\theta) = pu(N - \theta)$$

The expectation of the extra profit that the store can make from the CEC service in a processing cycle is given by,

$$P(\theta) = E(f(\theta) - c(\theta)) = \sum_{n=\theta}^{\infty} (mrn - p)\Pr(N = n)$$

Where, $\Pr(N = n)$ is the probability of $N = n$ We have $\Pr(N = n) > 0$ for any *n*.

3.2 Problem Statement

The objective for a participating store is to find the best threshold θ such that the store can maximize the expectation of extra profit from the CEC service. This is equivalent to maximizing the expectation of extra CEC profit in any processing cycle. That is,

$$Max\{P(\theta)\}$$

Actually, the store doesn't solve the maximization problem by itself, because the effective ratio *r* varies in every processing cycle. Instead, the store only gives the profit margin *m* in its profile, based on which the CEC controller finds the best threshold and makes decision for the store accordingly.

The objective for the CEC service provider is to find the best price *p* such that the CEC service provider can maximize the CEC revenue from all participating stores, subject to that the stores all adopt best thresholds respectively. Without loss of generality, this problem can be downsized to maximizing the CEC revenue that the CEC service provider earns from one participating store.

3.3 Best Threshold

It is surprisingly that the best threshold can be easily determined and it doesn't depend on the randomness of *N*.

Theorem 1

The best threshold for a store is equal to ceil(p/mr), no matter what kind of statistical distribution N obeys, where ceil(x) is the smallest integer that is no smaller than x.

Proof:

Let θ_m be the best threshold and $P(\theta_m)$ be the maximum CEC profit. That is,

$$P(\theta_m) = Max\{P(\theta)\} = \sum_{n=\theta_m} (mrn - p)\Pr(N = n)$$

Assume $\theta_m = \theta' <$ ceil(p/mr), we have

$$P(\theta_m) = \sum_{n=\theta'}^{ceil(p/mr)-1} (mrn - p)\Pr(N = n) + \sum_{n=ceil(p/mr)}^{\infty} (mrn - p)\Pr(N = n)$$

Because the first term in right of above equation is always negative, we have,

$$P(\theta_m) < \sum_{n=ceil(p/mr)} (mrn - p)\Pr(N = n) = P(ceil(p/mr))$$

This is contradictory to the assumption that $P(\theta_m)$ is the maximum CEC profit, so it has to be $\theta_m >=$ ceil(p/mr). Similarly, assume $\theta_m = \theta' >$ ceil(p/mr), we have

$$P(\theta_m) = \sum_{\theta'}^{\infty} (mrn - p)\Pr(N = n)$$

$$< \sum_{n=ceil(p/mr)}^{\theta'-1} (mrn - p)\Pr(N = n) + \sum_{\theta'}^{\infty} (mrn - p)\Pr(N = n) = P(ceil(p/mr))$$

This is because the first term in the second row is always positive. This is also contradictory to the assumption that $P(\theta_m)$ is the maximum CEC profit, so it has to be $\theta_m <=$ ceil(p/mr).

Combining these results, we have $\theta_m =$ ceil(p/mr). Note that the function form of $\Pr(N = n)$ is not needed in above proof. That is, the best threshold θ_m doesn't depend on the statistical distribution of *N*. The proof is complete.

The independence between the best threshold θ_m and the statistical distribution of *N* is a nice feature, which makes it very easy for the CEC controller to choose the best threshold that is valid all the time for every participating store.

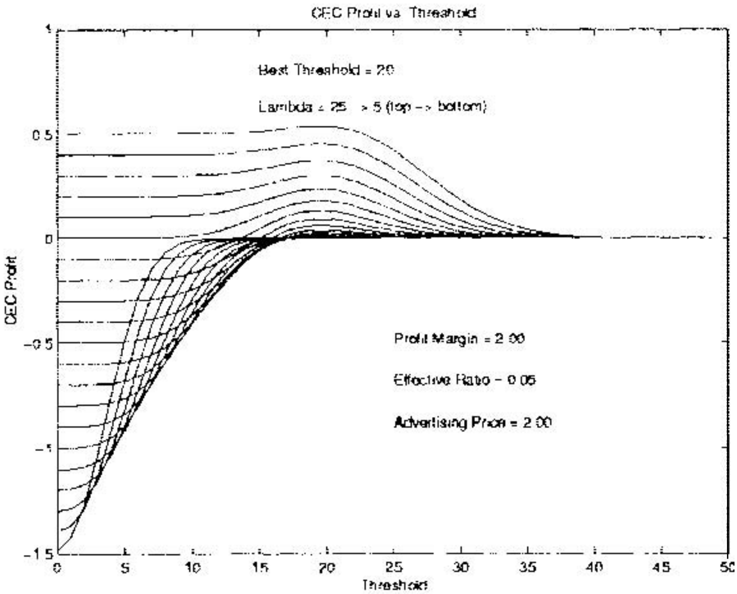

Figure 1. "CEC profit vs. threshold" curves for a participating store

A "CEC profit vs. threshold" curve for a participating store is shown in Fig. 1, which plots 21 curves from top to bottom, corresponding to that N obeys a Poisson distribution with the parameter λ varies from 25 to 5. The advertising price is 2.00. The profit margin is 2.00. The effective ratio is 0.05. As it is shown in Fig. 1, no matter how λ changes, the best threshold that warrants the maximum CEC profit is always equal to 20.

3.4 Maximum CEC Profit

Another important property for the best threshold is given below.

Theorem 2

Choosing the best threshold θ_m, a participating store can always earn a positive maximum CEC profit $P(\theta_m)$, no matter how big the price p is.

The proof is straightforward and thus is omitted here.

Note that the maximum CEC profit does depend on the statistical distribution of N, although the best threshold θ_m doesn't. If N obeys a Poisson distribution with a parameter λ, the maximum CEC profit is,

$$P(\theta_m) = mr\ \lambda \Pr(N \geq ceil(p/mr) - 1) - p\Pr(N \geq ceil(p/mr))$$

Where, Pr(*N*) is the Poisson probability distribution function with an arriving rate λ.

$$\Pr(N = n) = \frac{\lambda^n}{n!} e^{-\lambda}$$

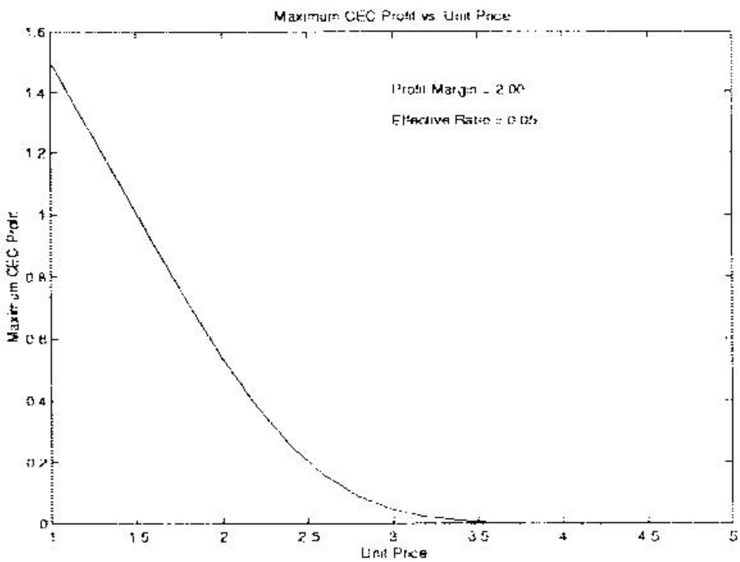

Figure 2. "Maximum CEC profit vs. unit price" curve for a participating store

A “maximum CEC profit vs. price” curve for a participating store is shown in Fig. 2. Where, *N* obeys a Poisson distribution with a parameter λ = 35. The profit margin is 2.00. The effective ratio is 0.05. It can be seen that the maximum CEC profit for the participating store will never be negative, although it approaches to zero rapidly as the advertising price increases.

Theorem 2 simply says a participating store won’t lose money in a statistical sense. This is a powerful statement for the CEC service.

3.5 Upper Bound of Price

There exists an upper bound of unit price *p* for the CEC service provider to charge every participating store for each e-coupon distribution. The CEC service provider can make the maximum CEC revenue from a participating store if the price is set to be the upper bound. This can be seen from the “CEC revenue vs. price” curve shown in Fig. 3.

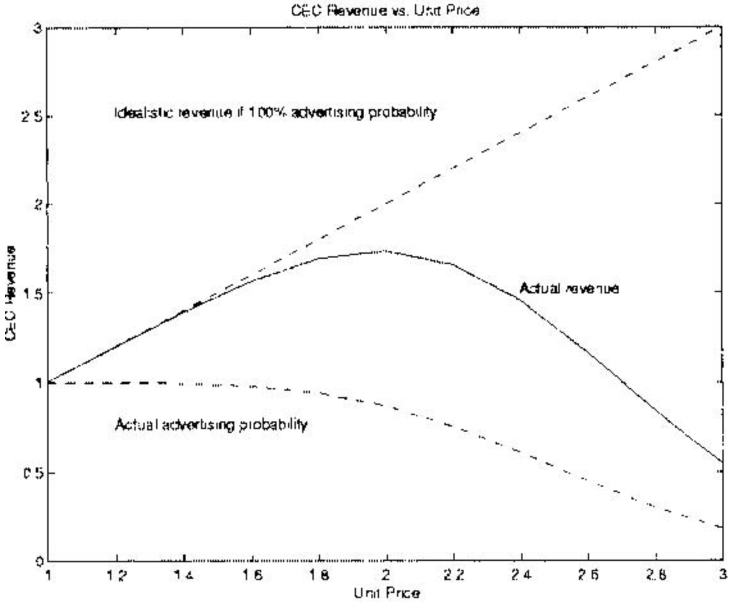

Figure 3. "CEC revenue vs. price" curve for a CEC service provider

In Fig. 3, the dashed line on the top shows that the idealistic CEC revenue that a CEC service provider can earn from every e-coupon distribution for a participating store increases linearly as the advertising price increases. However, this is the ideal case, assuming the participating store chooses an unconditional e-coupon distribution scheme. If the participating store chooses the CEC service with the best threshold, the best threshold increases rapidly as the advertising price increases. This causes the probability of distributing e-coupons for the participating store decreases rapidly, which is shown by the dashed curve in the bottom. Therefore, there exists the maximum CEC revenue for the CEC service provider to earn from the participating store at some price point, as shown by the solid curve in the middle. This price is the upper bound price, because even if the CEC service provider sets a higher price, he cannot earn more CEC revenue. The value of upper bound depends on the statistical distribution of *N*.

In real world, a CEC service provider shall set the price below the upper bound in order to expand the base of participating stores and competing with other CEC service providers.

4. CONCLUSIONS

The CEC service is an optimal wireless targeted advertising scheme to promote location-aware mobile commerce. It eliminates privacy and technique issues that loom existing wireless targeted advertising ideas in the literature. The key idea of the CEC service is to distribute e-coupons for a store to mobile customers only if the number of mobile customers requesting such e-coupons equals or exceeds a threshold that in statistical sense assures the store can make profit after paying the advertising fee. A theory is established to optimize the CEC service. It tells how to calculate the best threshold for stores such that they can maximize their CEC profits, and how to calculate the upper bound of unit price for advertising fees such that CEC service providers can maximize their CEC revenue subject to store CEC profits being maximized. In addition to benefiting participating stores and wireless service providers, the CEC service also let mobile customers stand a good chance to save money by requesting e-coupons from local stores right before they go shopping.

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