Carousel Scheduling of Advertisement Contents on Digital Multimedia Broadcasting*

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Abstract. This paper functionally designs a broadcast scheduler for the advertisement system built on top of a digital multimedia broadcasting system for fast moving vehicles. The design goals lie in improving the advertisement efficiency by giving a higher frequency to the advertisement item more users are likely to be interested in. To overcome the lack of upstream communication paths and limited bandwidth, path prediction and past history analysis techniques are exploited in estimating the current vehicle distribution. The inference engine periodically adjusts the broadcast frequency of each item so as to meet the bandwidth constraint, taking into account the estimated vehicle distribution along with the position associated with each advertisement. According to the assigned frequency, the periodic generator fills the carousel queue, from which broadcast item is taken one by one.

Keywords: digital multimedia broadcasting, advertisement content, carousel scheduling, path prediction, channel efficiency.

1 Introduction

DMB (Digital Multimedia Broadcasting) is a stable digital radio transmission technology for sending multimedia to mobile devices, especially those on fast moving vehicles [1]. Hence, DMB technologies are considered to be one of the most cost-efficient and easy-to-install wireless carriers for electric vehicles. In addition to the legacy digital contents such as TV and music, the advertisement can provide receivers or drivers with useful information having location-dependent and time-dependent features. In this regard, we have built a DMB advertisement framework consisting of an advertiser interface, a content manager, and local broadcasting facilities [2]. This framework focuses on the automatic integration of advertisers and the advertisement system, guaranteeing fast response to the content update from advertisers.

It is predicted that many ubiquitous computing applications will be supported by advertising, following the trend of ad-supported Internet sites as pointed

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in [3]. We can find an interesting example that the nearby friend finder application can be supported by an advertisement which suggests meeting places. DMB is a special case of ubiquitous networks and also able to carry advertisement. However, compared with the general mobile advertisement, it lacks an upstream communication path, so the server has no way to know the exact distribution of vehicles. In addition, as real-time images dominate the channel, the advertisement broadcast suffers from bandwidth shortage. Accordingly, it is necessary to make use of the channel bandwidth as efficiently as possible to overcome those difficulties.

The efficiency can be achieved by broadcasting more often those advertisements in which more drivers are likely to be interested. For constantly moving vehicles, the driver′s interest in the advertisement is inevitably dependent on his or her current location. However, the unawareness of current vehicle distribution makes us rely on the statistics on the past history data. In some cases, a vehicle can restrictively report its location via another channel. For example, when an electric vehicle is being charged, it can temporarily connect to the charging facility via the standard V2G interface [4]. In addition, using the WiFi channel, which is very common in mobile devices, vehicles can report their locations just when they enter the WiFi coverage area. However, considering the long interval between the consecutive reports, real-time location tracking is impossible. In this case, the path prediction and location estimation is a reasonable policy to get the current distribution. According to this estimation, the broadcaster can give precedence to the advertisement contents close to more vehicles.

This paper is to functionally design a carousel scheduler which adjusts the broadcast period of each advertisement item according to the estimation of current vehicle distribution. To this end, we are to discuss useful path prediction strategies and exploit the history data analysis result for the case any estimation is not available at all. Specifically, the inference engine decides whether the period allocation can meet the bandwidth constraints considering the available DMB capacity, while the broadcaster takes the item one by one from the queue and transmits to the vehicles.

2 Related Work

Broadcast scheduling has been researched for a long time on the various system environments. First, [5] addresses a broadcast system that distributes a series of data updates to a large number of passive clients. The updates are sent over a broadcast channel in the form of discrete packets while the clients access the broadcast channel periodically to obtain the most recent update of interest such as traffic information and market updates. The design goal of this scheduling scheme is to minimize the waiting time, that is, the length of time duration a client needs to wait until it obtains the most recent update. This work assumes that each client has a different access pattern depending on the channel condition, computing power, and storage capabilities. It achieves those goals for all patterns universally.

Next, [6] handles the problem of scheduling in two separate channels, each of which has a different broadcast schedule. The multi-channel situation can be found when there are different types of receivers, some with better receiving capabilities than others. This work fixes the first channel with a schedule that is optimal for an average performance, and focuses on how to schedule the second channel, which is available only to some of the clients due to geography, power, or financial constraints. They propose the second channel be constrained to have equal number of packets for each item. Finally, their analysis discovers that schedules asymmetric in bandwidth and time domain are better than any symmetric schedules in terms of expected packet delivery time.

As a theoretical study on broadcast, [7] handles several scheduling problems. This work assumes that there are n pages of information, and clients request pages at different times. Multiple clients can have their requests satisfied by a single broadcast of the requested page. First problem is to minimize the maximum response time over all requests. Second problem is to maximize the number of requests that meet their deadlines when every request has a release time and a deadline. The authors reveal that both these problems are NP-complete, and use the same unified approach to give a simple NP-completeness proof for minimizing the sum of response times. Furthermore, this work gives a proof that FIFO is a 2-competitive online algorithm for minimizing the maximum response time and that there is no better deterministic online algorithm. After all, the main contribution of this work is a unified approach to prove NP-completeness in several different objective functions for broadcast scheduling.

3 System Design

3.1 System Architecture

For the DMB-based advertisement, it is necessary to connect advertisers, content creators, communication facilities, and clients. Figure 1 shows the framework we have built in the last project year. This architecture consists of an advertiser interface, an advertisement processing system, and a local broadcasting center. After the content manager endorses the advertisement content submitted by an advertiser via the Internet, it will be registered in the content server. This step is necessary to prevent illegal content from being displayed to the public clients. The leased optical line carries the contents from the server system to the local DMB facilities. Then, the scheduler encodes and multiplexes a group of items to a TPEG stream and corresponding DMB signals. The broadcast equipment transmits the signal through the DMB carrier [8].

According to our implementation, the advertisement item the advertiser creates or modifies will be present on the receiver display within 10 seconds. For advertisement broadcast, 8 *kbps* is allocated in our system. Actually, it's not sufficient for image transmission so large size contents are desirably embedded in DMB receivers. Then, the advertisement is broadcasted in text. This framework is very useful for instant coupons, hot deals, seat availability, and current gasoline price, in addition to the basic information on the contact point, menu, and location, for shops, restaurants, and the like.

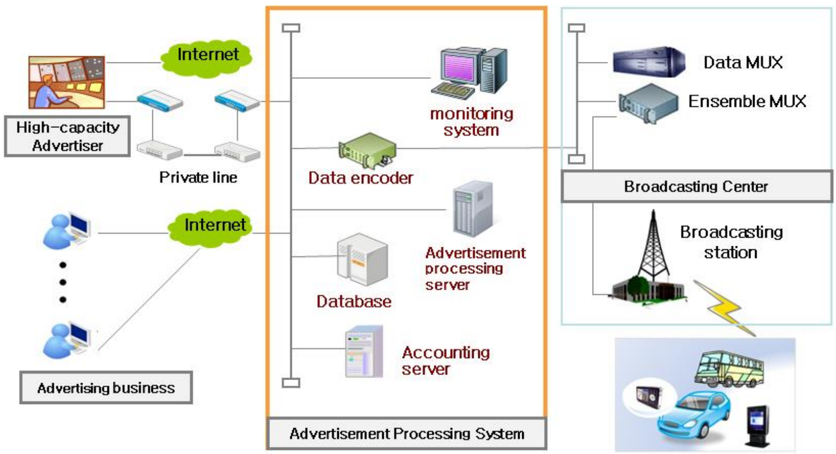

Fig. 1. Advertisement framework architecture

3.2 Availability of Vehicle Location Information

Even if restricted, when the location of each vehicle is given, we can estimate the location of vehicles using the prediction schemes for vehicle movement. First, according to J. Krumm's work, segmentation finds a total of 4300 discrete trips from their movement history data to compute statistics about the trips. This step finds out that the average temporal length of each trip is 14.4 minutes, while the average number of trips per day is 3.3 [9]. The assessment on driving behavior and destination prediction is conducted on the grid placed over the Seattle area, with each square cell equal to 1 km^2 [10]. The destination prediction is based on the assumption that drivers chose the efficient routes. They quantify efficiency using the driving time between points on the driver′s path and candidate destinations. Between each pair of cells, the driving time is estimated. Then, using the spots sporadically reported to the center, particularly the combination of the last two points, the prediction module calculates the probability that a grid will be the destination of the vehicle.

In addition, [11] proposes a trajectory clustering scheme for objects moving on road networks to the end of efficient path prediction. From the viewpoint that a trajectory can be defined as a sequence of road segments a moving object has passed by, a similarity measurement scheme is designed based on the length of common road segments. Then, this work describes a clustering algorithm according to the similarity measurement criteria, modifying FastMap and hierarchical clustering schemes to implement the idea. Trajectory clustering identifies initial clusters of trajectories based on the similarity among trajectories, while the final clusters are built by iteratively changing the centroid of each trajectory cluster. This statistics can predict the future location of a vehicle by comparing the partial trajectory which the vehicle has taken from the start to the current position with the existing ones [12].

As the prediction is not always available, past movement history is important. Our previous work has conducted the analysis on the location history data for tens of vehicles in a real-time taxi tracking system [13]. From the 1.3 M location records accumulated for the 1.5 test month, we first select the locations and time instants of passenger pick-up and drop-off by sequentially tracing the change of the status field which indicates whether a passenger is one or not. According to the pick-up point, each session is classified to the respective area group. From the pick-up point, distances between the two points from the two consecutive records are added up to the last record to calculate the trip length. The travel pattern specific to each pick-up point allows us to estimate the vehicle distribution over the city area. For example, almost every passenger travels less than 10 km. The travel from the airport area takes relatively long route, compared with other areas, because the travel mainly needs to cross the multiple areas.

3.3 Carousel Scheduler

DMB is a kind of data broadcast system that distributes a series of dynamic data updates from a single information source to a large number of mobile clients. It is a push-based approach, where the server proactively transmits the data over the broadcast channel. As shown in Figure 1, the DMB facility gets advertisement items from the content manager and builds the broadcast schedule. At least, the contents are equally transmitted one by one, while the item is replaced independently. The modified item must wait by up to one cycle. On the contrary, with broadcast scheduling, the server divides a broadcast cycle into groups, each of which is broadcasted with a different frequency in a broadcast cycle. The broadcast frequencies of groups are in proportion to the probability of access in order to gain the optimal access time of the system.

For weighted broadcast scheduling, a mobile advertisement faces critical problems on how to target potential customers, how to evaluate the effectiveness of a specific advertisement, and how to ensure privacy [3]. The first step is to segment the population into different groups and find a better target for the advertisement item. Different segments will be exposed to different types of media and advertisement contents. In some scenario, street signs have sensors that detect which radio stations passing cars have tuned in to find the demographics group the driver belongs to. In DMB environment, the location information is most important. The advertisement for the location having many vehicles is more likely to change as the vehicles possibly make a new reservation. So this content must have a short period.

The scheduler adjusts the broadcast frequency periodically, considering the above-mentioned factors. Advertisement items, for example, restaurants, souvenir shops, charging stations, and the like, are necessarily bound to a location. The relative affinity between each pair of advertisements and vehicles is calculated by the network distance using the A* algorithm on the given road network represented by a cost matrix. For advertisement items currently included in the broadcast set, $A = \{A_1, A_2, ..., A_n\}$, the broadcast frequency is allocated

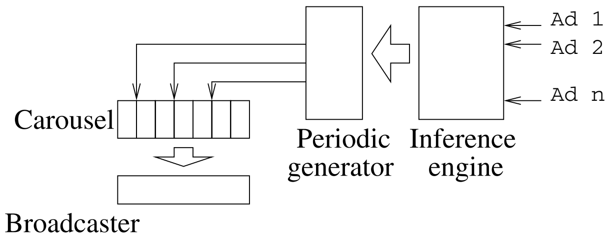

Fig. 2. Advertisement service scenario

according to the affinity to vehicles. Then, the utilization checker tests the following constraint every time a importance of an item changes and thus its period is to be shortened. Namely,

$$\sum \frac{L_i}{P_i} + O_v \leq 1.0, \tag{1}$$

where L_i is the time length for A_i to be broadcasted over the channel, P_i is the period assigned to A_i, and O_v is the overhead ratio for the unit time including frame overhead, mandatory idle time between the adjacent frame, and so on. Here, P_i can have a value in the set of permissible fixed periods, namely, $\{T_1, T_2, ..., T_v\}$, where $T_i \geq T_j$ for $i \leq j$.

Without any estimation, all $A_i's$ commonly have T_1. It is analogous to the simple carousel in which each advertisement is broadcasted equally. When the vehicle density for A_i increases by the predefined bound, its period will decrease by one level. If the current period allocation does not meet Ineq (1), the periods, if not T_1, will go down by one level for all A_i. When an item moves to the broadcaster, the carousel queue removes the entry. If the queue length reach the lower limit, the periodic generator refills the carousel queue.

4 Concluding Remarks

This paper has functionally designed a broadcast scheduler for the advertisement system built on top of the DMB technology, which is one of the most cost-efficient wireless carriers capable of delivering multimedia to fast moving vehicles. This design is aiming at improving the advertisement efficiency by giving a higher frequency to the advertisement item in which more users are likely to be interested. Here, we assume that the degree of interest for an advertisement is dependent on the network distance to each vehicle. To overcome the lack of upstream communication paths and limited bandwidth, path prediction and past history analysis techniques are addressed to estimate the current vehicle distribution. The inference engine periodically allocates and adjusts the broadcast frequency for each item, taking account into the estimated distribution along with the position associated with each advertisement. It also checks the bandwidth constraint, and if fails, the adjustment is repeatedly executed. According to the assigned frequency, the periodic generator fills the carousel queue, from which broadcast item is taken one by one. Finally, the transmitter broadcasts the DMB TPEG frame.

As future work, we are first planning to evaluate the performance of our design on the already-built advertisement framework, mainly in terms of hit ratio from the driver-side access, accuracy of content items on the broadcast, and the like. Next, more accurate model will be developed to quantify the interest to the advertisement item from drivers.

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