Financial Data Broadcasting Using VBI Teletext

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Abstract

Teletext is a one way information broadcast system. Pages of information are broadcast to all users in a cyclic manner. Therefore, access time and information update delay are the important performance factors of teletext systems. These factors are related to the rate of transmission. Full channel teletext is currently being used by information providers for distributing real time financial data because of its high data rate. In this paper, we propose to use the VBI teletext transmission. Its data rate is much slower as compared with the full channel transmission. The performance degradation due to the slower data rate is compensated by the use of extension packets of teletext together with the storage capabilities of modern terminals. A queueing model is developed to analyze both the access time and the update delay.

I. Introduction

Teletext is an information delivery system which provides a variety of services to its users. Information is organized into units called pages. Pages of information are broadcast to all users in a continuous manner [1][2]. Teletext has the attractive feature of being able to support an unlimited number of users with no effect on system access time performance.

In a teletext broadcasting system, access time is defined as the elapse time between a user request for a page and the next transmission of that page. Update delay is defined as the delay time between updates or changes received in the information center and the updates received by the users. Access time to obtain the requested page is one of the major performance criteria for a teletext service. The shortening of the update delay was not important previously because the teletext was only used to broadcast TV program time tables, advertisements, news etc. which are quite static. This is not the case for some modern systems broadcasting real time financial data which are very dynamic. Both the access time and the update delays are extremely important to these systems. This is because the remote users would like to have the most up-to-date information as though as they were inside the trading center. The high data rate full channel teletext is very suitable for these applications. Unfortunately, it requires either an expensive wide bandwidth network or it occupies a full TV channel.

In this paper, we propose to use VBI teletext transmission in a financial data broadcasting system. For VBI transmission, the encoded financial data is transmitted with the TV signal on the unused lines in the vertical blanking interval [2]. By using this method, no extra TV channel need to be allocated. Since the data rate of VBI teletext transmission is much lower than full channel transmission, the access time and update delay may become unacceptably long if no special technique is being used. In this paper, we propose to use the extension packets [3][4] together with the storage capabilities of modern terminals to improve both the access time and the update performance.

II. System Model Overview

In our model, all the pages will have the same mean access time and update delay. This is important for real time financial information if all the users are to be satisfied. Therefore, previous researches using broadcast schedules [5][6] to shorten the delay are not suitable.

All user terminals are assumed to have a mass storage facility, this is made possible with the recent advances in computer technology that have led to the development of inexpensive modern PC/terminals [7]. This equipment provides users with inexpensive mass storage systems which were not possible a few years ago. The key to reducing the access time is to use more memory and capture pages in advance. If the memory is large enough and stores all the information pages from a data base cycle, the waiting time will be just the data retrieving time from the local memory, which is negligible. For example, 2000 teletext pages require less than 2MB memories.

The strategy to shorten the update delays is based on the fact that the data changing rate of teletext is much slower than its data transmission rate [8]. Each packet of all pages is considered as one unit. If changes occur on any of the packets as a result of information update, these packets would be sent using the ghost rows (extension packets) of each page. Packet numbers 24, 25, 29 or 31 are suitable for this purpose [3]. If the updates of a page reach the users before the next transmission of that page, the delay would be reduced.

III. Performance Analysis

It would be pointless to have instant access time if the financial information viewed was not up to date. Therefore, the reductions of update delay is very important in a real time financial data system.

In our system, the updated information may be broadcast using the extension packets. The system may be modeled as having two queues as shown in Fig. 1, the main queue transmits the database continuously and cyclically like other conventional systems on packets 0 to 23 [1][2]. The ghost row queue is used to transmit the updated information. If the original transmission rate is u_0 pages per second, the original number of packets per page is r and the number of ghost rows used per page is e. The new transmission rate for the main queue and the secondary queues are u pages per second and u_e packets per second respectively.

$$u = u_0 \cdot \frac{r}{r+e}, \qquad u_e = u \cdot e \tag{1}$$

For users using terminals without the capability of receiving ghost rows and/or without the suitable decoding software, the operation remains unchanged except that the average access time will appear to be slightly longer. The percentage of decrease in transmission rate is

$$\text{Percentage decrease in transmission rate} = \frac{100e}{r+e}\% \tag{2}$$

Since $r >> e$, the increase in access time is only small.

The ghost row queue model is as shown in Fig. 2. It is modeled as a single server with different types of messages, each type of message represents a row in a teletext page and in a first come first served (FCFS) discipline. The message arrival processes are assumed to be Poisson with arrival rate λ packets per second. This is appropriate because the number of pages in a teletext system is normally large. The service time of all message types is u_e packets per second as defined above.

If the ratio of the arrival rate to the service rate ρ is less than unity $(\lambda < u_e)$.The queue is reasonably short. If $\rho \rightarrow 1$ or even worst $\rho > 1$, the queue length and queue time will grow without bounds. This is solved based on the following facts. Since the changed information of a page will eventually reach the users at the next transmission of that page, it would be of no use if the changed information using the ghost row queue arrives later than the next transmission in the main queue. Therefore, if the queue time in the ghost row is long and that the time to transmit that packet is later than the next transmission of the page containing this packet, this packet should not be entered into the ghost row queue and should be discarded. Also, any old information in the teletext is always replaced and overwritten by new information. It is therefore, pointless to send a packet waiting in the queue if this packet has already been changed or updated. When a packet arrives and finds that the same packet is already in the queue, this obsolete packet in the queue will then be replaced by the new packet. Because of these two factors, a packet of a page will enter the queue only if the same packet is not already in the queue and the packet will reach the user faster than the next transmission of that page. If the total number of teletext pages is N and is finite, the number of packets in the ghost row queue must be finite. The system therefore reaches a steady state for all values of ρ.

Consider a system with a total of N teletext pages and originally r packets in each page. Therefore, the total number of different packets is $N \cdot r$.

If a packet in a page i changes, assume that the time between the occurrence of this change and the next transmission of that page is τ. This packet arrives at the ghost row queue and finds that there are n packets in the queue. The queue time would be $q_t = \dfrac{n+1}{\mu_e}$ if this packet enters the system at the end of the queue. Using the above argument, we get the following probability.

$P(n)$ - probability of n messages in system at equilibrium,

$$P(notq) = \frac{\binom{N \cdot r-1}{n}}{\binom{N}{n}} = \frac{N \cdot r - n}{N \cdot r} \qquad \text{(packet not already in the queue)} \tag{3}$$

$$P(\tau <= q_t) = \frac{q}{T_{cyc}} = \frac{n+1}{N \cdot e} \tag{4}$$

$$P(\tau > q_t) = 1 - P(\tau <= q) \tag{5}$$

Three cases need to be considered.

Case 1 : that packet is not already in the queue and the queue time q_t is shorter than the time required in the main queue $(q_t < \tau)$. This packet enters the system at the end of the ghost row queue.

$$P(enter) = P(n) \cdot \frac{N \cdot r - n}{N \cdot r} \cdot (1 - \frac{n+1}{u_e}) \tag{6}$$

Notice that $P(\tau <= q_t) = 1$ when $n = N \cdot e - 1$,i.e. the updated packet will never enter the ghost row queue, therefore, the maximum number of packets in the ghost row queue is $N \cdot e - 2$.

Case 2 : that packet is not already in the queue and the queue time q_t is longer than or equal to the wait time required for the next transmission in the main queue $(q_t >= \tau)$. This packet is discarded and the updates depend on the normal transmission in the main queue.

$$P(discard) = P(n) \cdot \frac{N \cdot r - n}{N \cdot r} \cdot (\frac{n+1}{u \cdot e}) \tag{7}$$

Case 3 : that packet is already in the queue in position k, new packet replaces the old packet and remains in the kth position. $k = 1$ to $N \cdot e - 2$.
Note that the probability of $(q < \tau) = 1$, otherwise this packet would not have entered the queue in the first place.

$$P(replace) = P(n) \cdot (\frac{n}{N \cdot r}) \tag{8}$$

To calculate $P(n)$, consider the system with n packets in an equilibrium state. (Note: this system is always in equilibrium as discussed above). From [9], we have

$$P(n) = P(0)\frac{\lambda_0\lambda_1\lambda_2\ldots\lambda_{n-1}}{\mu_1\mu_2\mu_3\ldots\mu_n} = P(0)\prod_{j=0}^{n-1}\frac{\lambda_j}{\mu_{j+1}} \tag{9}$$

There are no two packets of the same type in the queue simultaneously and the number of packets in the queue must not exceed $N \cdot e - 2$. Therefore,

$\lambda_j = \lambda \cdot P(\text{no type j packet}) \cdot P(q < \tau)$

$$\begin{cases} \lambda_j = \lambda \cdot (\frac{N \cdot r - j}{N \cdot r}) \cdot (1 - \frac{j+1}{N \cdot e}) & j <= N \cdot e - 2 \\ \lambda_j = 0 & j > N \cdot e - 2 \end{cases} \tag{10}$$

$$\mu_j = \mu = \mu_0 \cdot e \ ; \qquad j = 1,2,\ldots(N \cdot e - 2) \tag{11}$$

Hence, we get that

$$\begin{cases} P(n) = P(0) \cdot (\frac{\rho}{N \cdot r})^n \cdot (1 - \frac{n+1}{N \cdot e})^n \cdot \frac{(N \cdot r)!}{(N \cdot r - n)!} & n <= N \cdot e - 2 \\ P(n) = 0 & n > N \cdot e - 2 \end{cases} \tag{12}$$

Since $\sum_{n=0}^{N \cdot e - 2} P(n) = 1$

We get $$P(0) = \left[\sum_{n=0}^{N \cdot e - 2} (\frac{\rho}{N \cdot r})^n \cdot (1 - \frac{n+1}{N \cdot e})^n \cdot \frac{(N \cdot r)!}{(N \cdot r - n)!}\right]^{-1} \tag{13}$$

The queuing time for the packet will be $(n+1)/\mu_e$ if the packet is allowed to enter the queue. If the packet is discarded, the refresh delay would rely on the next transmission of the page containing this packet which is equal to τ and k/μ_e if the packet is already in the queue at position k.

Therefore, the mean queuing time for this packet is

$$q_i = \sum_{n=0}^{N \cdot e-2} \left[\frac{n+1}{\mu_e} \cdot P(enter) + \frac{1}{N} \sum_{\tau=\frac{1}{u}}^{\frac{N}{u}} \tau \cdot P(discard) + \sum_{k=1}^{n} \frac{k}{\mu_e} \cdot \frac{1}{n} \cdot P(replace) \right] \tag{14}$$

Assume that all packets have the same probability of changing. This is appropriate if a long time frame is considered. The mean update delay over all message types is

$$q = \sum_{i=1}^{N} P_i \times q_i = q_i \tag{15}$$

Substitute (15),(16), (17) and (18) into (24), we get

$$q = \sum_{n=0}^{N \cdot e-2} P(n) \cdot \left\{ \frac{n+1}{2\mu e N r} \left[2(N \cdot r - n)(1 - \frac{n+1}{N \cdot e}) + \frac{(N+1)(N \cdot r - n)}{N} + n \right] \right\} \tag{16}$$

A quantity of interest in this system is the probability of a packet being discarded. This happens when a packet arrives at the ghost row queue and finds that it is not already in the queue and the queue time is longer than or equal to the time required in the main queue. The update of this packet will rely on the next transmission of the page containing this packet and therefore would not get any benefit from this system. From (17), we find this is given by

$$P(discard) = \sum_{n=0}^{N \cdot e-2} P(n) \cdot \frac{N \cdot r - n}{N \cdot r} \cdot (\frac{n+1}{u \cdot e}) \tag{17}$$

The discard probability is shown as a function of the load, ρ , for several values of e in Fig. 4. As expected, the discarding probability increases with increases in load and decreases as the number of ghost rows increases.

The worst case is when the arrival rate far exceeds the transmission rate (i.e., $\lambda \rightarrow \infty$). The maximum queue length is $N \cdot e - 2$ and the discard probability is as follows :

$$\lim_{\lambda \to \infty} P(discard) = \frac{N(r-e)+2}{N \cdot r} \cdot \frac{N \cdot e - 1}{N \cdot e} \tag{18}$$

which is approaching one because $(r >> e)$ but never equal to one. Therefore, even in the absolute worst case, some benefits are still maintained. Also, this worst case does not happen in teletext as the system is designed for human reception.

IV. Numerical examples and discussions

Consider a teletext system with a 100 pages and the transmission rate u_0 is 1. (u_0 varies from 1 if one TV line in the VBI is used to around 17 if all TV lines from 6 to 22 of each field are used [2]). The original number of packets per page r =24 as in most teletext systems [2]. The average access time and update delay without using any background memory is 50.5. Fig. 3 shows the update delay versus ρ with different number of e . It shows that significant improvement on the access time and update delay can be achieved using this method. As expected, the improvement reduces with increasing ρ, because as ρ increases, the probability of discard increases as shown in Fig. 4. As discussed above, ρ is normally small because the data change rate is not too fast.

For users using older terminals without the capability of decoding the ghost rows, using (2), the average access time and update delay with $e = 1$ is only increased by 4% which is hardly noticeable. We can conclude that the new system is also downward compatible to the older equipment.

V. Conclusions

Both the access time and the update delay are important factors contributing to the quality of services of the real time financial data systems. We have analyzed the performance of using VBI teletext for broadcasting. The results of using ghost rows and modern receivers with storage capabilities to shorten these delays showed that satisfactory results obtained. Both the access time and the update delay are significantly improved. In addition, older equipment may still be used in this new system.

VI. References

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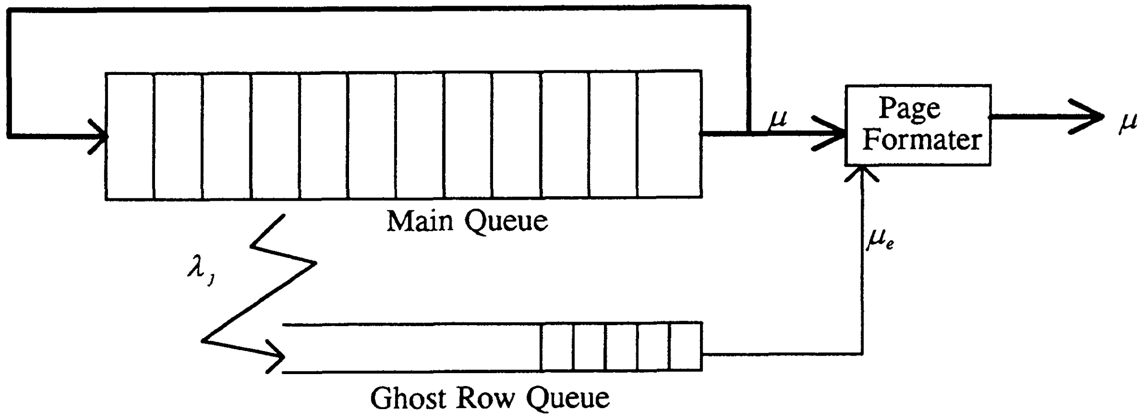

Fig. 1 System Model

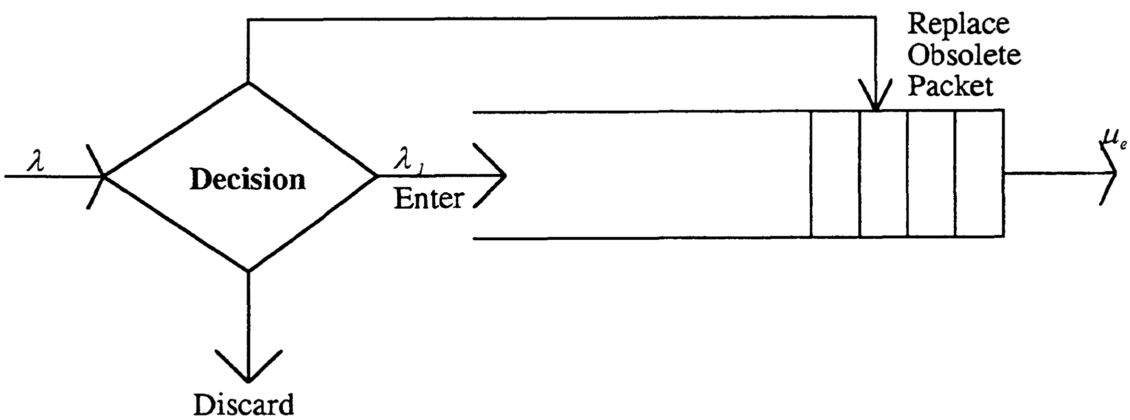

Fig. 2 Ghost Row Queue Model