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PERFORMANCE EVALUATION OF A TELETEXT SYSTEM

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ABSTRACT

Four parameters are defined to measure the performance of a teletext system namely, the probability of delivering a message within specified time, the transmission efficiency, the average number of errors per page and the throughput. Each of them is derived and computational results are presented taking the UK teletext system as an example. These parameters have been compared in their ability to characterize the performance of the teletext system.

I. INTRODUCTION

In simple terms teletext can be described as a technique for broadcasting computerized information and entertainment to television sets. The service is distributed via the already existing broadcast network and can be received on television sets. For the above mentioned reasons the use of this information medium has grown enormously in the last years.

Teletext as we know it is primarily a British development, although the technique was being tested at the same time in a number of countries including North America and Japan. The UK standard has been adopted by many European countries, which have similar television standards. Teletext data is transmitted during the vertical blanking interval of the television broadcasting signal. During this interval the scanning beams at the camera and receiver move from the last row of the screen to the first row. That is why the television broadcasting signal does not contain any information during this interval. Thus teletext data can be transmitted without interfering with the normal television broadcast.

The teletext concept has been described in numerous papers and books, e.g. [1],[4] and [5]. This paper presents the performance evaluation of the UK teletext system in terms of the probability of delivering a message within specified time, the transmission efficiency, the average number of errors per page and the throughput.

The paper is organized as follows. Section II describes the UK teletext system. Section III defines and formulates the performance parameters. The computational results are presented in section IV. Section V contains the concluding remarks.

II. UK TELETEXT SYSTEM

The television channel has a video bandwidth of 5 MHz. The teletext data is coded in a not return to zero code. Therefore the theoretical maximum signalling speed (Nyquist theory) is equal to 10 Mbit/s. The theoretical maximum can not be used in practice because: the existing broadcast network is not based on transmitting constant amplitudes, the group velocity characteristic of the broadcasting network is not constant, and the broadcasting companies are not able to control the interference caused by ether, between the transmitting and receiving antenna. For practical reasons a bit rate of 6.9375 Mbit/s was chosen for the UK unified standard, which equals 444 line frequencies.

Although a vertical blanking interval (VBI) of the television broadcasting signal lasts 64 μs, the teletext data can only be transmitted during the last 54 μs because the first 12 μs is needed for line synchronization and color burst. The number of bits in a teletext line can be calculated by:

$$N_{bits} = INT[r_b t] \quad (1)$$

where INT[x] denotes the integer part of x, r_b is the bit rate and t is the actual data transmission duration. Using $r_b = 6.9375$ Mbits/s, $t=54$ μs and (1), N_{bits} equals to 360 bits. Therefore a teletext packet can contain 45 bytes. The first five bytes of every packet, which are also known as the prefix bytes, are used for synchronization and addressing purposes. Out of these five bytes the first two bytes are for bit synchronization, the third byte is for byte synchronization and the fourth and fifth bytes are used for magazine and row addressing. The remaining 40 bytes contain the character information.

Figure 1 shows the structure of a teletext page by UK standard. A teletext page consists of 24 visible teletext packets and 7 ghost packets which can be used for future applications like the use of high resolution graphics [2]. The first line of every page, the page header, does not have the same structure as the other lines on that page (Fig. 1). The first thirteen bytes of the page header are not information bytes. Out of these thirteen bytes the first five bytes are for synchronization and addressing, the sixth and seventh bytes contain the page

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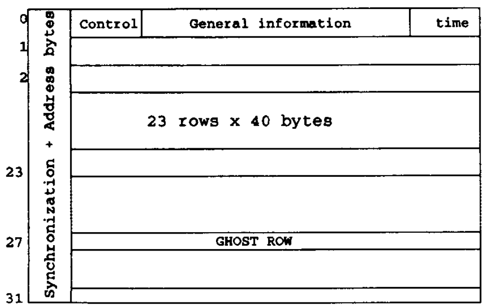

Fig. 1. The structure of a teletext page by the UK standard.

number, bytes eight to eleven give the time code and the twelfth and thirteenth bytes contain control information for the display of the teletext page.
From the above it can be seen that the header bytes and prefix bytes contain vital information, therefore they are protected by Hamming code. This code can detect and correct one bit error per byte.
The pages are grouped in magazines, each magazine can contain 100 pages. The teletext service contains 8 magazines.

III. PERFORMANCE PARAMETERS

The performance of a teletext system can be measured by the following performance parameters: probability of delivering a message within specified time, transmission efficiency, average number of errors per page, and throughput.
A transmitted page is received if the header is received correctly. In other words every hamming coded header byte should have less than two bit errors. The received page is correct if every packet is received without bit errors. A received packet is correct when the data bytes do not contain any bit errors.
The probability of a hamming coded header or prefix byte being received correctly, P_{hb}, is given by:

$$P_{hb} = q^8 + 8pq^7 \tag{2}$$

where p is the binary error probability (BEP), and q is defined as:

$$q \triangleq 1-p \ . \tag{3}$$

A transmitted page is not lost if the following header bytes are received correctly: 1 framecode byte, 2 magazine and row address bytes, 2 page address bytes, 4 time code bytes and 1 control byte. The bit-synchronization bytes, also known as the Clock Run in bytes, have not been mentioned in this list because it has been assumed that bit synchronization is achieved between transmitter and receiver. Therefore a transmitted page is lost if the ten header bytes are not received correctly. Hence the probability of losing a page P_{lp}, which equals the probability of errors occurring in the header, is given by:

$$P_{lp} = 1 - (q^8 + 8pq^7)^{10} \ . \tag{4}$$

A packet is received when the address bytes and frame code are received correctly, thus the probability of receiving a packet P_{prefix} is determined by:

$$P_{prefix} = (q^8 + 8pq^7)^3 \ . \tag{5}$$

Since there are 320 data bits in a packet and assuming they have a parity check, the probability of receiving a correct packet P_{pack} equals :

$$P_{pack} = (q^8 + 8pq^7)^3 \, q^{320} \ . \tag{6}$$

A. MESSAGE DELIVERY WITHIN SPECIFIED TIME

In the majority of cases it is very important to know whether the required information will be received within a reasonable time or not [3]. By repeating the message, the number of errors can be reduced. The maximum number of repetitions is limited by the specified time. Thus the performance of the teletext system could be measured by calculating, $P_D(t \le t_s)$, the probability of successfully delivering a message within a specified time t_s.

A message consisting of M bits has to be delivered within t_s seconds. The minimum number of teletext pages, n_{min} needed to transmit the message is given by:

$$n_{min} = \mathrm{Ceil}\,[\,M/B\,] \ . \tag{7}$$

Here ceil[.] represents the upperbound integer operator which yields the maximum value of n_{min} and B is the number of data bits in a teletext page.
The maximum number of pages that can be transmitted in t_s seconds are:

$$n_{max} = \mathrm{Int}\,[\,t_s r_b / N_t\,] \tag{8}$$

where N_t is the total number of bits in a page and r_b is the bit rate.
The total number of recyclings possible, c, within t_s seconds can be derived using (7) and (8):

$$c = \mathrm{Int}\,[\,(n_{max} - n_{min})/n_{min}\,] \ . \tag{9}$$

The probability of i pages with errors, $P_{er}(i)$, is given by a binomial distribution:

$$P_{er}(i) = \binom{n_{min}}{i} P_{er}^{\,i} \, (1-P_{er})^{(n_{min}-i)} \tag{10}$$

where P_{er} is the probability of a page with errors.

Assuming that only one page is corrected per repeated cycle then $P_D(t \le t_s)$ is given by:

$$P_D(t \le t_s) = \sum_{i=0}^{c} \binom{n_{min}}{i} P_{er}^{i} (1-P_{er})^{(n_{min}-i)}. \qquad (11)$$

If we assume that errors only occur in the header bytes of a page, then P_{er} can be replaced by P_{lp} (4) and equation (11) becomes equation (11) of [2]. The errors in the header bytes are not the only cause of an unsuccessful message reception. When the errors in the data block as well as the errors in the header are considered, the expression for P_{er} in equation (11) becomes:

$$P_{er} = P_{lp} + (1 - P_{lp}) P_{dbl} \qquad (12)$$

where P_{dbl} is the probability of errors occurring in the data block.
The data block of a UK teletext page contains 23 packets, therefore P_{dbl} is given by:

$$P_{dbl} = 1 - P_{pack}^{23} . \qquad (13)$$

The assumption that only one page is corrected per repeated cycle is the worst case condition. Thus $P_D(t \le t_s)$ is the lowest value of the probability of successfully delivering a message within t_s seconds.

Equation (11) is based on the assumption that one page is corrected per repeated cycle. By redefining $P_D(t \le t_s)$, the results for more than one corrected page per cycle can be calculated.
Equation (9) gives the number of recyclings possible within t_s seconds. Thus the probability of a lost page within t_s seconds, i.e., after c recyclings equals:

$$P_{er}(c) = P_{er}^{c+1}. \qquad (14)$$

Thus the probability of receiving a correct page after t_s seconds, P_{cp}, equals:

$$P_{cp} = 1 - P_{er}^{c+1}. \qquad (15)$$

The number of pages needed to transmit a message of M bits have been calculated in equation (7). Therefore using equation (7) and (15) $P_D(t \le t_s)$ for more than one corrected page per cycle is given by:

$$P_D(t \le t_s) = [1 - (P_{er})^{c+1}]^{n_{min}}. \qquad (16)$$

B. TRANSMISSION EFFICIENCY

The data transmission rate used to calculate $P_D(t \le t_s)$ is actually a burst rate, meaning that when data are being transmitted, they go at that speed, but because there are also moments when no data are being transmitted, the effective data rate is considerably less. Depending on the number of teletext lines that are transmitted during the VBI, the time needed to transmit a magazine of 100 pages varies between 4 and 32 seconds for 16 and 2 transmitted teletext lines per VBI, respectively. Thus the teletext viewer will have to wait a long time to receive the required page when the magazine is repeated to reduce the errors. This would make the teletext service far less appealing. The waiting time can be reduced by only repeating a selection of pages. For example an error in the sports page is not as serious as a fault in exchange rates of the financial page.
The performance of a teletext service with selectively repeated pages can be measured by calculating the transmission efficiency. The transmission efficiency is defined as the ratio of the average number of correctly received information bytes and the total number of transmitted bytes:

$$TE_{he} = \frac{B\, [n_t P_c + n(P_{cr} - P_c)]}{(n_t + n)\, N_t} \qquad (17)$$

where B represents the total number of information bytes in a teletext page, n_t represents the total number of pages, n is the number of repeated pages, N_t represents the total number of bytes in a teletext page, P_c represents the probability of receiving an information byte without errors and P_{cr} represents the probability of receiving an information byte without errors when the page has been repeated.
The derivation of TE_{he} has been based on bytes instead of bits because a byte represents a character in a teletext page, hence losing more than one bit of the same byte has the same effect on the screen as losing the first bit of the byte.
A byte is received correctly when the header is received correctly, the packet prefix is received correctly and the 8 bits of the byte are correct.
Using (2) the probability of receiving an information byte correctly is given by:

$$P_c = q^8 (q^8 + 8pq^7)^{13} . \qquad (18)$$

The probability of receiving a byte correctly is the complement of the probability of an incorrect byte . An information byte is not correct after repeated transmission if either (i) the page is lost both times, or (ii) the packet is lost during the normal transmission and the page is lost in the repetition, or (iii) the page is lost during the normal transmission and the packet is lost in the repetition, or (iv) the packet is lost both times.
Therefore P_{cr} is given by:

$$P_{cr} = 1 - \{ P_{lp}^2 + 2P_{lp}(1-P_{lp})P_{lpack} + (1-P_{lp})^2 P^2_{lpack} \} \qquad (19)$$

where

$$P_{lpack} = 1 - q^8 (q^8 + 8pq^7)^3 . \quad (20)$$

Equations (19) and (20) can be simplified by ignoring the errors in the header:

$$P_{cr} = 1 - \{(1-P_{prefix})^2 + 2P_{prefix}(1-P_{prefix})(1-q^8) + P^2_{prefix}(1 - q^8)^2\} \quad (21)$$

and

$$P_c = q^8(q^8 + 8pq^7)^3 . \quad (22)$$

The transmission efficiency without consideration of header errors, TE, is calculated by using (21) and (22) in (17).

C. AVERAGE NUMBER OF ERRORS PER PAGE

Another parameter to measure the performance is the average number of byte errors per page (ANEP). The Average number of errors per page is given by:

$$ANEP = B(1 - q^8(q^8 + 8pq^7)^3) . \quad (23)$$

In (23) it has been assumed that the header is received correctly.
When a limited number of pages is repeated, the ANEP is given by:

$$ANEP = \frac{B\ [n_t(1-P_c + n(P_c - P_{cr})]}{n_t} . \quad (24)$$

D. THROUGHPUT

The throughput is defined as the ratio of the number of information bytes multiplied by the probability of receiving a page and the number of total bytes. In [2] the throughput is calculated by:

$$S = \frac{Bn_t(1-P_{lh})}{N_t n_t} = \frac{M\ (1 - P_{lh})}{N_{tot}} . \quad (25)$$

In (25) the possibility that the data in the received page might be incorrect has not been considered. If errors in the data block are considered, (25) becomes the same as the transmission efficiency for n=0:

$$S = \frac{M\ P_c}{N_{tot}} . \quad (26)$$

IV. COMPUTATIONAL RESULTS

Figure 2 shows the probability of delivering a message within specified time for various values of the binary error probability. It shows that at least two recyclings (3.3 s) are necessary to get a P_D that is almost equal to 1, when BEP=10^{-7}. These results are not very encouraging but we should remember that equation (11) is derived under the assumption that only one page is corrected per repeated cycle. Another reason for these results is that all the pages have to be received without a single bit error. In practical situations this is not necessary.
Figure 3 compares P_D calculated by equation (11) and (16). It shows that the results are better when it is considered that more than one page can be

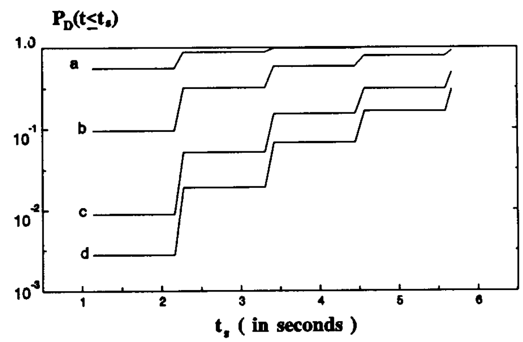

Fig. 2. The probability of successfully delivering a message consisting of 736 kbytes within a specified time for a binary error probability of (a) p=10^{-7}, (b) p=4.10^{-7}, (c) p=8.10^{-7}, (d) p=10^{-6}. It is assumed that errors occur in the header and data block.

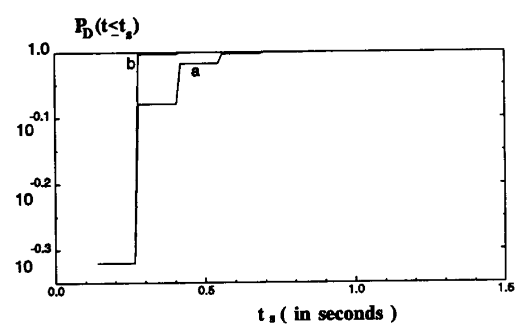

Fig. 3. The probability of successfully delivering a message consisting of 92 kbytes within specified time, calculated by (a) equation (11) and (b) equation (16). Header and data byte errors have been considered for a binary error probability of 10^{-4}.

TABLE I

The transmission efficiency calculated under the assumption that there are header errors (TE_{he}) and by ignoring the header errors (TE); BEP = 10^{-3}, n_t = 800, B = 920 bytes, N_t = 1080 bytes and n is the number of repeated pages.

n	TE_{he}(%)	TE (%)
0	84.49	84.47
20	82.43	82.43
40	80.49	80.49
60	78.63	78.63
80	76.86	76.86
100	75.17	75.17
200	67.72	67.72
300	61.63	61.63
400	56.55	56.54
500	52.26	52.25
600	48.57	48.56
700	45.38	45.37
800	42.59	42.58

TABLE II

Transmission efficiency (TE) and average number of errors per page (ANEP) for BEP=10^{-3} and n_t=100.

n	TE (%)	ANEP
0	84.50	7.733
10	76.87	6.966
20	70.53	6.199
30	65.16	5.432
40	60.55	4.665
50	56.56	3.898
60	53.07	3.131
70	49.99	2.363
80	47.24	1.597
90	44.79	0.829
100	42.59	0.062

corrected per repeated cycle.

The computational results of the transmission efficiency shown in Table I justify the simplification of the transmission efficiency by ignoring the errors in the header. The transmission efficiency for n=0 is not 100% because data and pages can be lost. The transmission efficiency and the average number of errors are calculated for various numbers of repeated pages in Table II. The transmission efficiency is still acceptable when 10% of the pages is repeated. Thus the system efficiency does not deteriorate much if important pages are repeated to improve their reception. In Table III the computational results of the throughput and probability of message delivery within specified time are compared. Table IV gives the throughput for various values of information bytes B for a BEP=10^{-5}.

TABLE III

Comparison between message delivery probability ($P_D(t \leq t_s)$) and throughput (S).

M (kbyte)	BEP	$P_D(t \leq t_s)$ t_s=2.2s	S (%)
92	10^{-6}	1.0000	85.19
	10^{-5}	0.9999	85.19
	10^{-4}	0.9997	85.18
	10^{-3}	0.9727	85.16
	10^{-2}	0.0769	82.92
736	10^{-6}	1.0000	85.19
	10^{-5}	0.9999	85.19
	10^{-4}	0.9977	85.18
	10^{-3}	0.8003	85.16
	10^{-2}	4.5×10^{-10}	82.92

TABLE IV

Throughput (S) for various numbers of information bytes (B) per page; BEP = 10^{-5}.

B (bytes)	S (%)
1080	100.00
966	89.44
943	87.31
920	85.19
875	81.02

V. CONCLUSIONS

The performance of the UK teletext system is analyzed and evaluated. The same technique can be used for evaluating the performance of any other teletext system.

Computational results show that when data errors are considered, at least two recyclings are needed for an acceptable value of P_D. The above mentioned outcome is a worst case result. When we assume that more than one page can be corrected per cycle, the result is considerably improved.

The transmission efficiency for $n_r = 0$ is not 100% because data and pages can be lost. If we want to obtain a transmission efficiency of more than 75%, the number of repeated pages must be less than 10% of the total number of pages. The transmission efficiency and the average number of errors per page decrease with increasing number of repeated pages.

The comparison between throughput and message delivery probability shows that the throughput has an acceptable value even when the probability of message delivery is almost zero. Thus the throughput gives a misleading view of the system performance.

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