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DATA-DEPENDENT SEARCH FOR MAXIMUM TIME INTERVAL ERROR

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Abstract – In the paper the data-dependent search for the Maximum Time Interval Error (MTIE) is described. In the first section the authors introduce the problem of time effective MTIE assessment. Then the data-independent method of MTIE assessment based on the estimator formula is described. In the next section the time effective data-dependent process of MTIE search is described. The results of the calculation experiment proved the time effectiveness of the proposed method.

Keywords: MTIE, estimation, data-dependent

1. INTRODUCTION

The quality of timing signals is essential for information transmission through telecommunication networks. Maximum Time Interval Error (MTIE), Allan deviation (ADEV), and time deviation (TDEV) are the parameters which give the information about the timing signal quality. Maximum Time Interval Error can be used for dimensioning the memories (FIFOs) located at the boundaries of different time scale areas in the telecommunication network circuitry. The quotient of the MTIE and the observation interval for which the MTIE has been found gives us the upper limit of the relative frequency inaccuracy within this interval. ADEV and TDEV give the information about noises affecting the timing signal. The limit values of MTIE and TDEV for the particular types of clocks are defined and recommended in the telecommunication standards and requirements [1, 2, 3]. Computation of the parameter's estimates and comparing them with the limits is an essential activity in the service and maintenance of the telecommunication network so the obvious goal is to make the computation short in time.

In the paper the data-dependent approach to MTIE estimation is studied. The methods being implementations of this approach are presented and its dependence upon the data type is considered. The results of computation experiment are discussed.

2. MAXIMUM TIME INTERVAL ERROR

The basic characteristic of timing (synchronization) signal gained directly from measurement is time error (TE). Time error is a difference between the time function of a clock (evaluated timing signal) and the time function of a reference clock (measurement reference timing signal). MTIE estimate is calculated using a series of equally spaced time error samples (TE time series).

The maximum time interval error is defined in international standards as the maximum peak-to-peak time error variation of a given timing signal, with respect to an ideal timing signal within a particular time period [1, 2, 3]. If the results of time error function measurements $x(t)$ take the form of N equally spaced samples $\{x_i\}$, MTIE can be estimated from the formula

$$M\hat{T}IE(n\tau_0) = \max_{1\le k\le N-n}\left(\max_{k\le i\le k+n} x_i - \min_{k\le i\le k+n} x_i\right) \qquad (1)$$

where $\{x_i\}$ is a sequence of N samples of time error function $x(t)$ taken with sampling interval τ_0, $\tau=n\tau_0$ is an observation interval, and n=1, 2, ..., N–1.

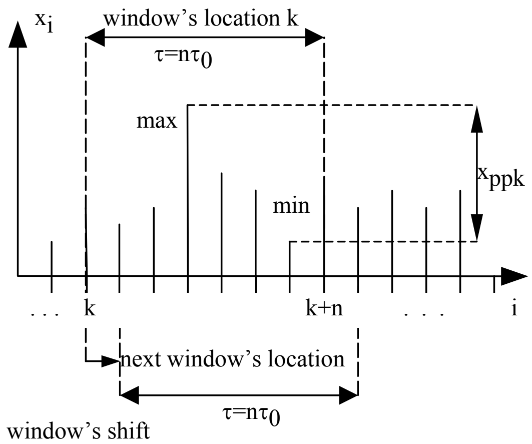

Fig. 1. The idea of direct search for MTIE

There are two approaches to the computation of MTIE for a given TE series: non data-dependent and data-dependent. Plain computation directly following the estimator formula belongs to the first category. Another implementation of this approach, based on the binary decomposition of time error sequence, was suggested by Bregni and Maccabruni [4]. The authors of this paper has proposed some method of MTIE computation being an implementation of the data-dependent approach called extreme fix method (EF) [5, 6] and its developed version called extreme fix method with sequential data reducing (EFSDR) [7].

Following the formula (1) directly in order to find the estimate of MTIE for the observation interval τ, all intervals having the width of τ, existing in the sequence of N time error samples must be reviewed. The window having the width of $\tau=n\tau_0$ and including n+1 samples is set at the beginning of data sequence $\{x_i\}$ and then it is shifted with the step of τ_0 to the end of the sequence. For each window's location the peak-to-peak value of time error in the window is found. The maximum peak-to-peak value found for all existing locations of the window is the value of MTIE(τ) estimate. The process of window reviewing does not depend on the data value. The complexity of calculation grows with n and therefore the direct method is really time-consuming.

3. DATA-DEPENDENT SEARCH FOR MTIE

In the data-dependent search for MTIE using EF method, some window's locations are excluded from inspection if the peak-to-peak value for these locations is not greater than the value found until now, or if this value may be found for the next window's locations. The EF method is based on fixing the positions of minimum and maximum samples for a given window's location. After finding the positions of the extremes the window's shift to the position of the first extreme (denoted as $p1$) is performed (Fig. 2). There are no extreme values in the distance between the starting position of the previous window's location and the $p1$ position. After the shift the peak-to-peak value for the window's location $p1$ should be found. Because the samples between the position $p1$ and the last sample in the previous window's location (k+n) were reviewed and the extreme values are known, they are excluded from inspection. The one-sample window's shift is performed when the first sample in the window is the extreme sample. What will be done next depends on the values at the boundaries of the window: the sample $p1$, which has just left the window, and the new sample $p1$+n+1, which has just came into the window. The comparison of these values may result or not in the review process of the window's location $p1$+1.

An example of window's shifts during the MTIE search using EF methods is presented in Fig. 3. At the top of Fig. 3 the sequence of 25 time error samples' values and their positions are given. The window considered spans 6 sample positions. The starting location of the window begins in the position 1 and ends in the position 6. After the window's review process the extreme samples are found: 2 in the position 4 (minimum) and 7 in the position 6 (maximum; white and black stars denote the interval minimum and maximum values, respectively). The peak-to-peak value for this window's location is 6. The window's shift to the first extreme (minimum in the position 4) is performed. The new samples covered by the window are analyzed and the extremes for the new window's location are found. Because the extreme samples do not change after the window's shift (lack of the star within a window marks no change in extreme), the one-sample shift is performed next. The new sample entering the window is 8 in the position 10 (new maximum for this location). The minimum value (4 in the position 7) should be found through the process of window's review. Then the successive window's shifts are performed until the end of the time error sequence. The maximum peak-to-peak value found for each window's location is the MTIE value for the observation interval considered.

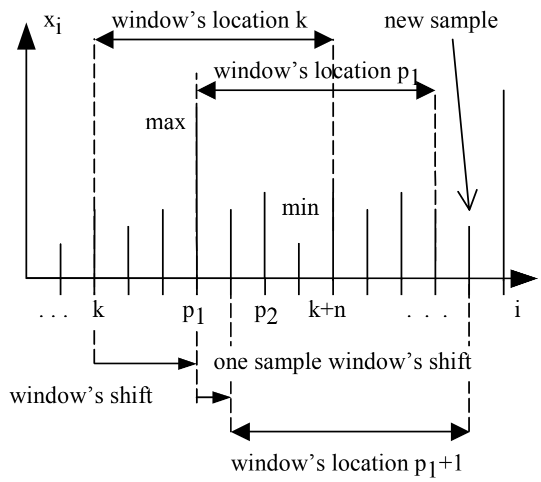

Fig. 2. The window's shift in the extreme fix method

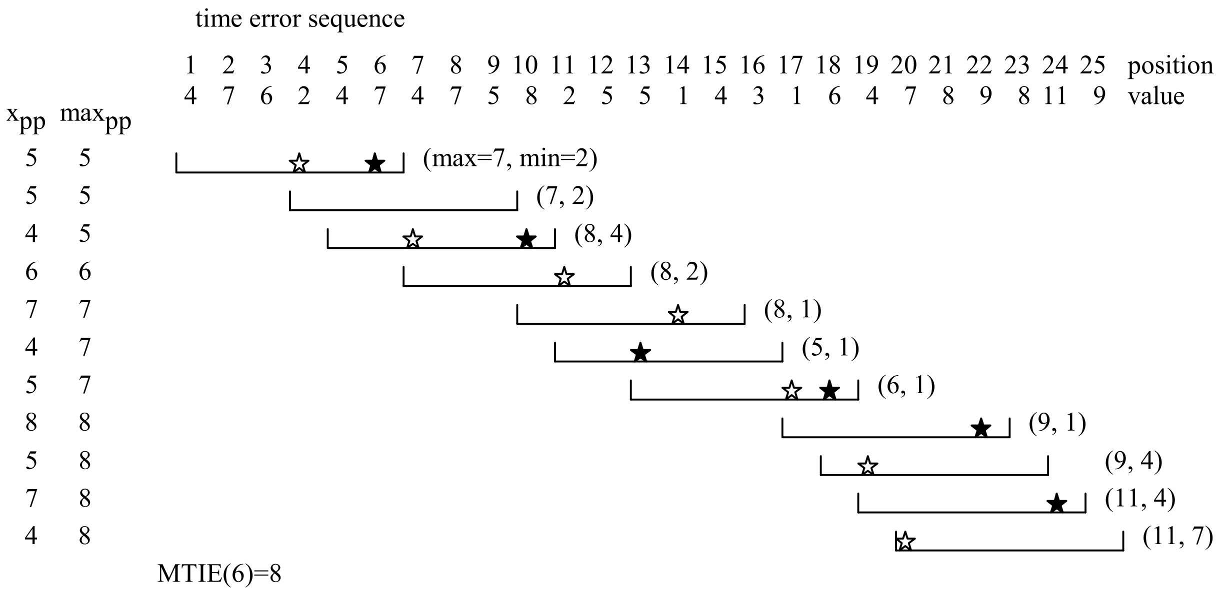

Fig. 3. The shifts of the 6 samples window for the time error sequence with 25 samples

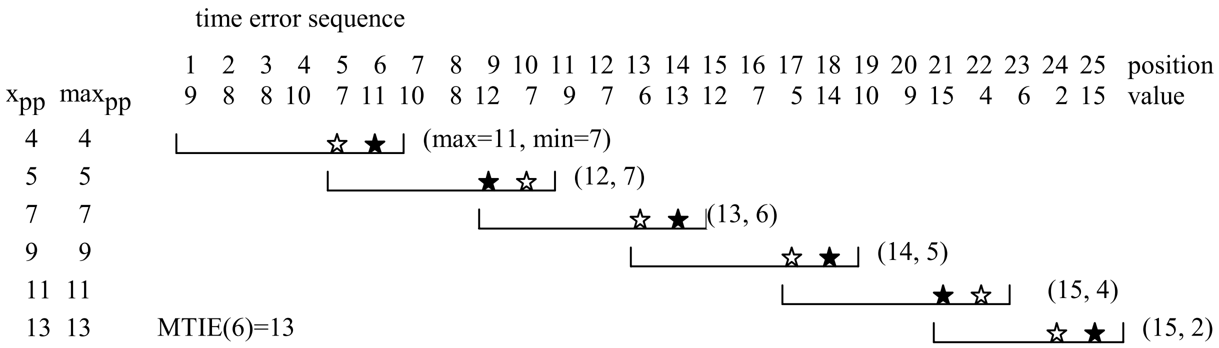

Fig. 4. The shifts of the 6 samples window for the TE sequence giving the best effectiveness of the computation (extreme samples are located at the end of the window's locations)

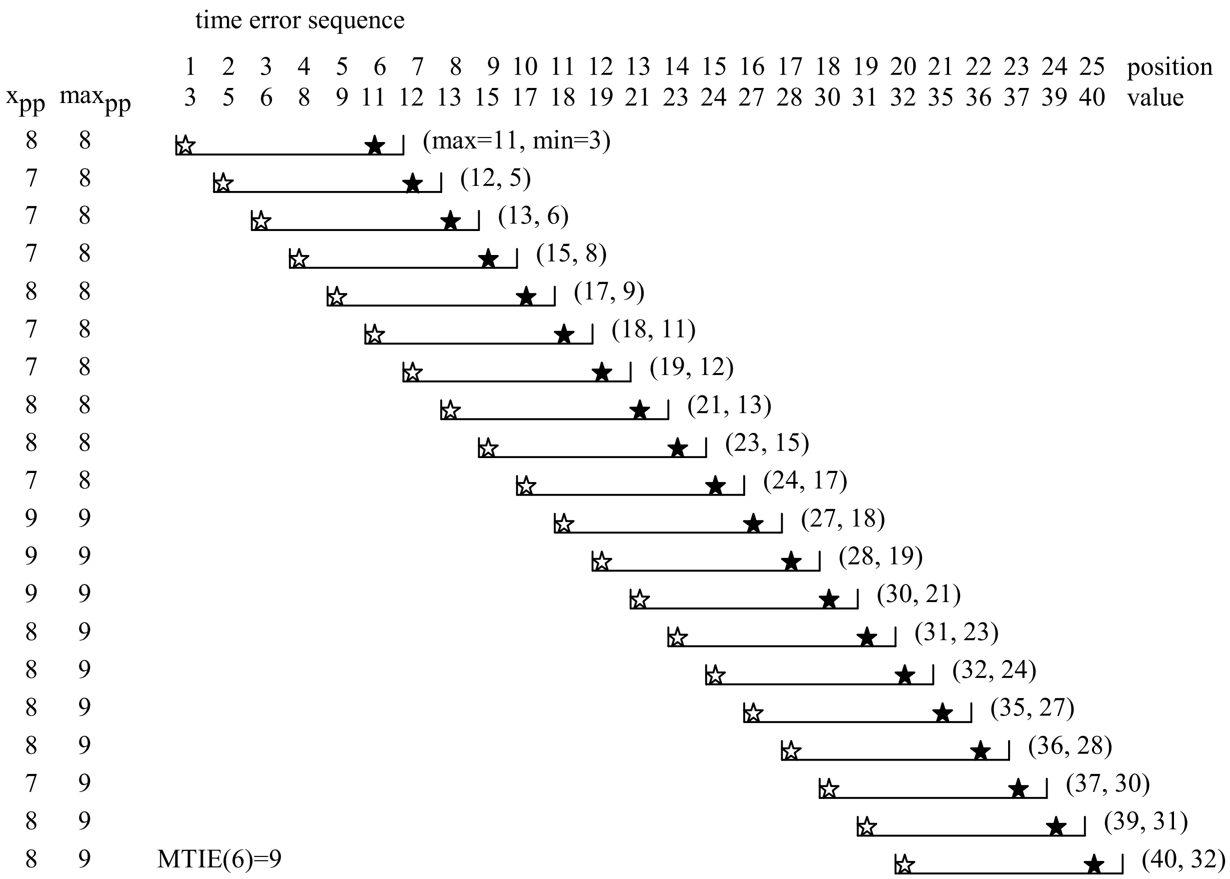

Fig. 5. The shifts of the 6 samples window for the monotonic TE sequence giving the worst effectiveness of the computation (extreme samples are located at the opposite boundaries of the window's locations)

The MTIE search using this method is very effective when the extreme samples are located close to the end of the window's location. The window's shift to the first extreme in the window's location is comparable with the window size. As the result the overall number of analyzed window's locations for the TE sequence is small and the calculation is performed quickly. An example of this case is presented in Fig. 4. The extreme samples are located at the last two positions of each window's location (including six samples) and the four-sample window's shift for each location is performed. Therefore only 6 window's locations are considered in comparison with 11 in the example in Fig. 3.

The window's review process after the one-sample shift of the window makes the calculation slow. The process is performed when the new sample in the window's location (after the one-sample shift) is not "more extreme" than the leaving sample and it is a need to find a new extreme. One can imagine the situation that for every window's location the leaving sample is an extreme of the same sort and the window's review process is necessary. An example of window's shifts over the monotonic time error sequence is presented in Fig. 5. The extreme samples are located at the opposite boundaries of the window's locations: the maximum at the right side and the minimum at the left side. Therefore the one-sample shift for each location should be performed. Because the leaving sample is minimum and the new sample is maximum, the search for the new minimum must be done using the window's review procedure. As the result great number of analyzed window's locations and the search for the extreme samples make the computation slow. The number of analyzed window's locations in the example in Fig. 5 is 20 in comparison with 11 (Fig. 3) and 6 (Fig. 4) in the previous examples.

The EFSDR method can be used if we want to calculate the MTIE estimate values for some number of observation intervals τ within the range from τ_{min} till τ_{max}. In this case the MTIE estimate for the observation interval τ_{min} is computed first together with indication of local extreme samples found during the MTIE search. Then the EF search for MTIE for the observation intervals longer than τ_{min} is done using the reduced data being the series of extremes previously found. The EFSDR method carries the data-dependence features of the EF method described above and the realization of the procedure for several data types is similar.

From the very idea of the methods presented their dependence upon the data type is quite obvious. The data-dependent search is time effective if the TE time series is characterized with random behavior. TE series gained from real world measurements possesses this feature. But still it is important to gain some deeper insight into the influence of the data type; therefore a computation experiment was performed.

4. RESULTS OF THE EXPERIMENT

In the experiment the MTIE estimate was searched for several time error sequences using the extreme fix (EF) method. The calculations were performed for 21 observation intervals (5 intervals per decade) changing from τ_{min}=0.1 s to τ_{max}=1000 s. In the experiment the computing time of MTIE values was taken into consideration. We look at the computing time for the single observation intervals at the boundaries of the decades (for 0.1 s, 1 s, 10 s, 100 s, 1000 s), the computing time for the observation intervals within the decades, and the computing time of the whole range of 21 MTIE values.

The efficiency of the data-dependent method was tested using four different time error sequences. The first time error sequence represents one of the typical noises for the timing signals – white phase modulation (WPM, Fig. 6). The second time error sequence represents another of the typical noises – random walk frequency modulation (RWFM, Fig. 7). The other two sequences were obtained from the measurement of the real timing signals. One sequence (denoted as MSG, Fig. 8) was obtained from the comparison of two independent internal oscillators of some measurement systems. Another sequence was obtained from the comparison of two different GPS disciplined oscillators (Fig. 9). The time error samples were taken with the sampling interval τ_0=1/30 s during the period of 4000 s. The length of the time error sequences is 120001 samples. The results of MTIE calculation for the time error sequences considered are presented in Fig. 10-13. The calculations were performed using PC computer with Pentium II 450 MHz processor.

In Table I the time of MTIE calculation for the whole range of observation intervals and for the observation intervals within the decades is presented. In Table II the time of MTIE calculation for some selected observation intervals is presented.

Fig. 6. WPM time error sequence

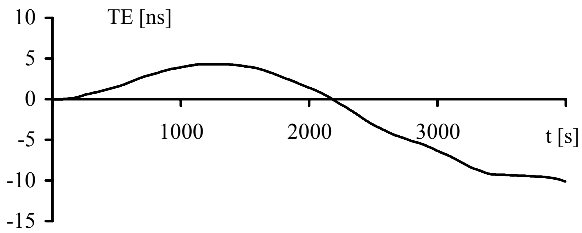

Fig. 7. RWFM time error sequence

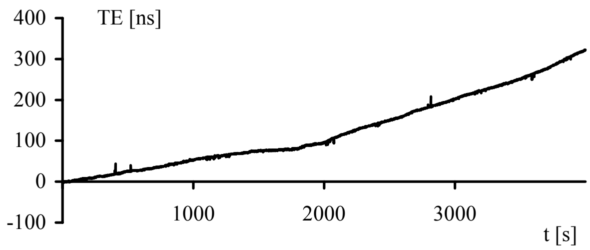

Fig. 8. MSG time error sequence

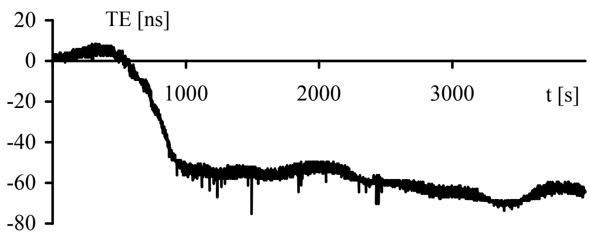

Fig. 9. GPS time error sequence

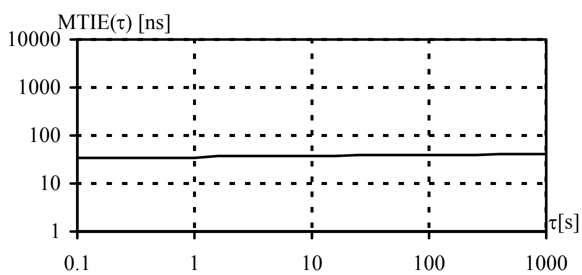

Fig. 10. MTIE for WPM time error sequence

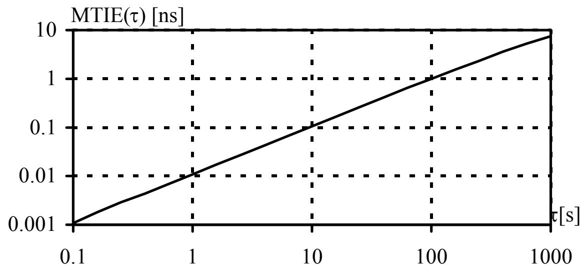

Fig. 11. MTIE for RWFM time error sequence

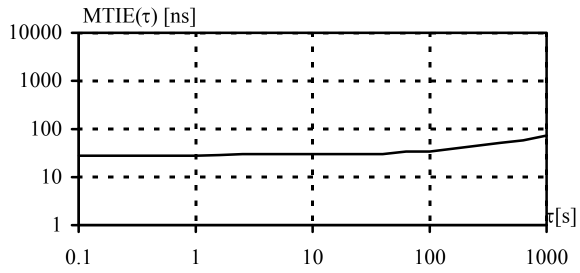

Fig. 12. MTIE for MSG time error sequence

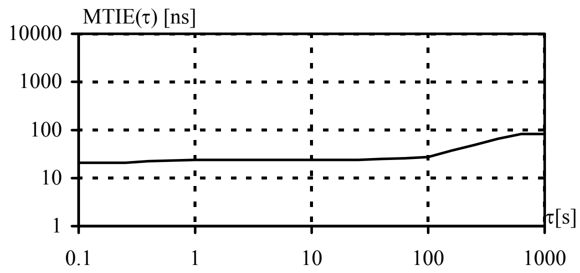

Fig. 13. MTIE for GPS time error sequence

TABLE I. Time of MTIE calculation for the ranges of observation intervals (in seconds)

TE	range of observation intervals [s]				
	[0.1-1000]	[0.1-1]	(1-10]	(10-100]	(100-1000]
WPM	79	34	17	15	13
RWFM	84130	178	1048	9545	72622
MSG	111	38	22	18	33
GPS	119	32	15	16	56

TABLE II. Time of MTIE calculation for some chosen observation intervals (in seconds)

TE	observation intervals [s]				
	0.1	1	10	100	1000
WPM	7.64	4.15	3.19	2.85	1.88
RWFM	16.21	53.11	415.46	3860.53	24699.14
MSG	6.80	6.36	2.66	5.03	8.40
GPS	6.45	4.60	2.65	4.42	10.41

Using the data-dependent method presented we obtained the shortest computing time for the time error sequences showing significant short-term random behavior (for example white phase modulation, WPM). For the sequence showing strong long-term effects (random walk frequency modulation, RWFM) the computing time using the EF method was longer than for other sequences. In this case we observed the monotonic changes of TE samples (as in the example in Fig. 5), which results in longer calculation. The speeding mechanism of the EF method does not operate, as well as the reduction mechanism of the EFSDR method. The time of MTIE calculation for the MSG and GPS sequences is close to the time of calculation for the WPM sequences. These sequences represent the mixture of long-term (frequency offset in MSG sequence) and short-term behavior. The presence of the short-term random effects causes that the data-dependent computation can be rather fast.

5. CONCLUSIONS

The methods realizing data-dependent search for MTIE are very often time effective. According to the authors' experience the time error series gained from the measurement of timing signals in telecommunication equipment allow on the effective application of the methods. One has to remember that it is possible to encounter the situations in which the monotonic changes dominate the random behavior of time error samples. In order to identify the noise type affecting the timing signal it is advisable to estimate ADEV or TDEV before the MTIE computation. In case the random behavior of the signal is week, one has to switch to the non data-dependent method of MTIE search.

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