A Modified 2D-Checksum Error Detecting Method for Data Transmission in Noisy Media

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ABSTRACT:

In data transmission a change in single bit in the received data may lead to miss understanding or a disaster. Each bit in the sent information has high priority especially with information such as the address of the receiver. The importance of error detection with each single change is a key issue in data transmission field.

The ordinary single parity detection method can detect odd number of errors efficiently, but fails with even number of errors. Other detection methods such as two-dimensional and checksum showed better results and failed to cope with the increasing number of errors.

Two novel methods were suggested to detect the binary bit change errors when transmitting data in a noisy media. Those methods were: 2D-Checksum method and Modified 2D-Checksum. In 2D-checksum method, summing process was done for 7×7 patterns in row direction and then in column direction to result 8×8 patterns. While in modified method, an additional parity diagonal vector was added to the pattern to be 8×9. By combining the benefits of using single parity (detecting odd number of error bits) and the benefits of checksum (reducing the effect of 4-bit errors) and combining them in 2D shape, the detection process was improved. By contaminating any sample of data with up to 33% of noise (change 0 to 1 and vice versa), the detecting process in first method was improved by approximately 50% compared to the ordinary traditional two dimensional-parity method and gives best detection results in second novel method.

Keywords: Checksum; one dimentional parity; 2Dimensional parity; Error Detecting.

طريقة تدقيق الجمع ثنائي الابعاد المعدلة في أكتشاف أخطاء نقل البيانات في الوسط الصاخب

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الخلاصة:

عند عملية نقل البيانات ، التغيير في وحدة المعلومات الثنائية (bit) في البيانات المستلمة قد يقود الى سوء فهم أو كارثة. كل bit من البيانات المرسلة لها أولوية عالية خصوصاً في المعلومات مثل عنوان المستلم. أهمية عملية أكتشاف الخطأ لكل تغير وحيد هي قضية رئيسية في أرسال البيانات.

الطريقة التقليدية الأحادية التعادلية في أكتشاف الأخطاء يمكن ان تكتشف الاعداد الفردية من الاخطاء بشكل كفوء، لكنها تفشل مع الاعداد الزوجية من الاخطاء. طرق أكتشاف الأخطاء الأخرى مثل ثنائية الابعاد و تدقيق الجمع أظهرت نتائج أفضل وفشلت في مواكبة الزيادة في أعداد الأخطاء.

تقنيتين جديدتين مقترحة لاكتشاف التغير الخاطيء في وحدات البيانات الثنائية (binary bits) عند ارسالها في وسط صاخب. هذه الطريقتين هي: طريقة تدقيق الجمع ثنائي الابعاد و طريقة تدقيق الجمع ثنائي الابعاد المعدلة. في الطريقة الأولى، تتم عملية جمع للمصفوفة ال 7×7 باتجاه أفقي ثم ياتجاه عمودي لتنتج مصفوفة 8×8. بينما في الطريقة المعدلة ، يضاف موجه تعادلي قطري للمصفوفة لتنتج 8×9. وبدمج الفوائد من استعمال تعادل أفقي (ايجاد أعداد فردية لوحدات البيانات الثنائية الخاطئة) وفوائد تدقيق الجمع (تقليل تأثير الاخطاء المتكونة من 4 - وحدات بيانات ثنائية خاطئة) ودمجهما معا بشكل ثنائي الابعاد ، تم تحسين عملية اكتشاف الاخطاء. فعند مزج أية عينة بيانات مع ضوضاء (noise) وبنسبة تصل حتى إلى 33% (وذلك بتبديل الصفر لواحد والعكس بالعكس) فأن عملية اكتشاف الاخطاء في الطريقة الأولى تحسنت بما يقارب 50% بالمقارنة مع الطريقة التقليدية لاكتشاف الاخطاء الثنائية الابعاد بينما أعطت الطريقة الثانية أفضل النتائج في اكتشاف الأخطاء .

كلمات البحث: تدقيق الجمع ، التعادلية أحادية البعد ، التعادلية ثنائية البعد، أكتشاف الاخطاء.

1. INTRODUCTION:

Error coding is used for fault tolerant computing in computer memory, magnetic and optical data storage media, satellite and deep space communications, network communications, cellular telephone networks, and almost any other form of digital data communication. Transmitting digital data are widely used in telecommunications; many applications require sending data from source to destination using different types of media (Muralidahara, 2011).

In network transmission, the digital information may be affected by noisy signals which differ from network media to other. Some network media such as air is considered the worst type of distorted media. Networks must be able to transfer data from one device to another with acceptable accuracy (Forouzan, 2007), and (Kourse and Ross, 2010).

A single bit change in message frame format is consider unacceptable in data transmission, because this bit error may lies in important field of the frame such as the address field.

Error detecting for these error bits is an important issue to ensure that the information is transferred intact from its source to its destination. Error coding uses mathematical formulas to encode data bits at the source into longer bit words for transmission (Muralidahara, 2011), (Forouzan, 2007).

2. TYPES OF ERRORS IN TRANSMISSION

In network, at the sender side the data link layer performs calculations on the message and appends the resulted check bits within the message. While the data link layer at the receiver side repeats the same calculations in the received message and compares the results with the appended check bits (Forouzan, 2007).

If the two results were equals then the message was sent successful and the message delivered to the upper layer in the OSI layers, but when the results were not equal, this means that there was an error in the sent message and the data link layer should not accept the message and the message thrown away (Forouzan, 2007).

There was no need to correct the error since correction error delayed the data link layer and the error correcting is the responsibility of above layers specifically the Transport layer.

According to the number of error bits there were two types of error bits (Forouzan, 2007), and (Stallings, 2011):

2.1 Single-bit Error

The term single-bit error means that only one bit of given data unit (such as a byte, character, or data unit) is changed from 1 to 0 or from 0 to 1 as shown in **Fig. 1**.

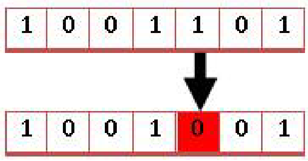

Figure 1. Single-bit error

2.2 Burst Error

The term burst error means that two or more bits in the data unit have changed from 0 to 1 or vice-versa. Burst error doesn't necessary mean that error occurs in consecutive bits. Burst errors shown in **Fig. 2** are mostly to happen in serial transmission. The duration of the noise is normally longer than the duration of a single bit, which means that the noise affects a set of data.

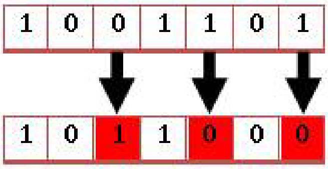

Figure 2. Burst error

3. SOME TYPES OF ERROR DETECTING METHODS

3.1 Single Parity Check

The most common and least expensive mechanism for error- detection is the single parity check. In this technique, a redundant bit called parity bit, is appended to every data unit so that the number of 1s in the unit (including the parity becomes even and called even parity) (Forouzan, 2007).

1	0	0	1	1	0	1	1

Figure 3. Single parity check

3.2 Two-Dimensional Parity Check

Performance can be improved by using two-dimensional parity check, which organizes the block of bits in the form of a table. Parity check bits are calculated for each row, which is equivalent to a single parity check bit. Parity check bits are also calculated for all columns then both are sent along with the data. This is illustrated in **Fig. 4** (Forouzan, 2007), (Rao and Chun, 2009), (Suri and Deora, 2011), (Zhang *et al.*, 2010), (Danial *et. al.*, 2011), and (Anne et. al, 2004).

1	1	0	0	0	1	0	1
0	1	1	1	0	0	1	0
1	0	1	0	0	0	1	1
0	0	1	1	1	0	1	0
1	1	0	0	1	1	0	0
1	0	0	0	1	0	1	1
0	0	1	1	0	1	0	1
0	1	0	1	1	1	0	0

Figure 4. Two-Dimensional Parity Check

3.3 Checksum

In checksum error detection scheme, the segments are summed arithmetically in the sender's end. The checksum result carry bits are wrapped to the sum and added with it (Forouzan, 2007). The result is sent along with the data segments as shown in **Fig. 5**. At the receiver's end, the process is repeated and the results are compared with the sent checksum. If the subtraction result is zero, the received data is accepted; otherwise discarded.

Figure 5. Checksum

4. NOVEL MODIFIED CHECKSUM

In this work two novel 2D-checksum techniques named (**2D-Checksum** and **Modified 2D-checksum**) were introduced and compared to the one dimensional single parity check and 2D-Parity check techniques results.

The suggested **2D-Checksum** method was done in three steps:

1- Summing the seven words of the 7 × 7 pattern vertically using traditional checksum method shown in **Fig.5**, and then the resulted word was stored in the CCS (Column Checksum) word, which was added as the 8th row of the pattern **Fig. 6**.

2- The same process was done to the columns of the 7×7 pattern , i.e. summing words horizontally with checksum technique and the result was added as the 8th column as RCS (Row Checksum).

3- The remaining P- bit in the south-east corner of the 8×8 pattern (shown in **Fig.6**) was computed as the even single parity of both two words (RCS and CCS).

At the receiver side the 2D-Checksum process was recalculated to the 7×7 portion of the received pattern. The resulted RCS and CCS were compared to those of the received 8×8 pattern.

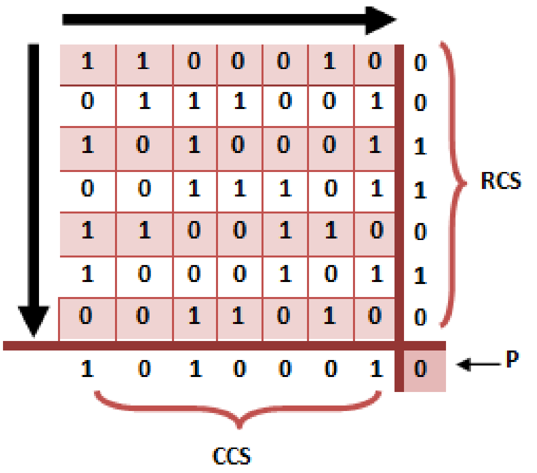

Figure 6. Two-Dimensional Checksum

In the second method (**Modified 2D-checksum**) the technique of detection was done in five steps:

1- Calculating CCS as shown previously in 2D-Checksum in **Fig.6**.

2- Calculating RCS as shown previously in 2D-Checksum in **Fig.6**.

3- Calculating P-bit as shown previously in 2D-Checksum in **Fig.6**.

4- Calculating new vector by adding single parity bit to each diagonal of the 7×7 pattern as shown in **Fig.7**. Each diagonal consist of 7-bits as shown with the bubbled numbers in **Fig.7**. The process yields in 7-bit vector named DPV (Diagonal Parity Vector). This vector was added as the 9th vector of the resulted 8×8 pattern.

5- Additional Parity bit of the DPV was calculated as the single parity bit of the DPV to complete the 7-bit DPV vector to become 8-bit vector and to add more check parameter. The resulted pattern will be 8×9 pattern as illustrated in **Fig. 7**.

The receiver side will receive the 8×9 pattern and will recalculate all five added parameters again to the 7×7 portion and compare results to detect the errors caused by noisy media.

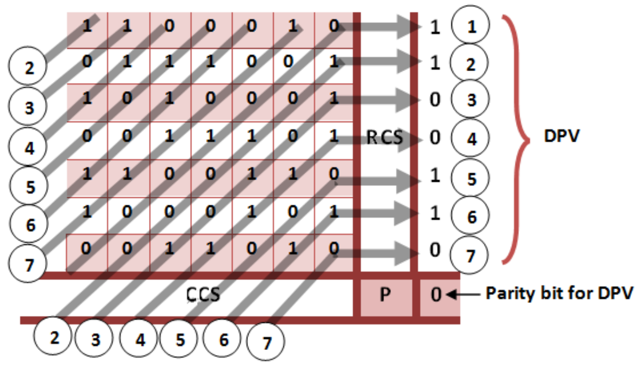

Figure 7. Modified Two-Dimensional Checksum

5. RESULTS AND DISCUSSIONS

The traditional and novel techniques were tested on 10,000 samples and each sample was contaminated with single bit error, then two bit errors …etc, till 33% changes in the real 7×7 pattern data. The results of error detection are shown in **Table 1** and **Fig. 8**. The number at each column represents the number of failed in detection of the errors. **Table 2** shows the ratio of additional overhead added to the real data for each type of error detection schemes.

TABLE I. **RESULTS OF EACH DETECTING SCHEME FOR 10,000 CONTAMINATED WITH ERROR PATTERNS.**

No. of error bits in pattern	No. of Non Detected Error patterns			
	1D-parity check vector [a]	*2D- parity check*	*2D-checksum*	*Modified 2D-checksum*
1	0	0	0	0
2	1266	0	0	0
3	0	0	0	0
4	462	15	2	0
5	0	0	1	0
6	246	3	1	0
7	0	0	2	0
8	203	3	1	0
9	0	0	0	0
10	171	2	1	0
11	0	0	0	0

No. of error bits in pattern	No. of Non Detected Error patterns			
	1D-parity check vector [a]	*2D- parity check*	*2D-checksum*	*Modified 2D-checksum*
12	158	6	1	0
13	0	0	0	0
14	158	1	0	0
15	0	0	1	0
16	144	6	1	0

a. Each pattern has single parity bit, all seven bits called parity vector.

TABLE II. **RESULTS OF EACH DETECTING SCHEME FOR 10,000 CONTAMINATED WITH ERROR PATTERNS.**

Error detection method	Overhead for error detection methods			
	Real data 7×7 pattern (no. of bits)	*Added bits to the 7×7 pattern*	*Percentage of added bits*	*Sum of none detected patterns* [a]
1D- parity check vector	49	7	14.3%	2808
2D-parity check	49	15	30.6%	36
2D- checksum	49	15	30.6%	11
Modified 2D-checksum	49	23	46.9%	0

a. Summation of the fields in Table 1.

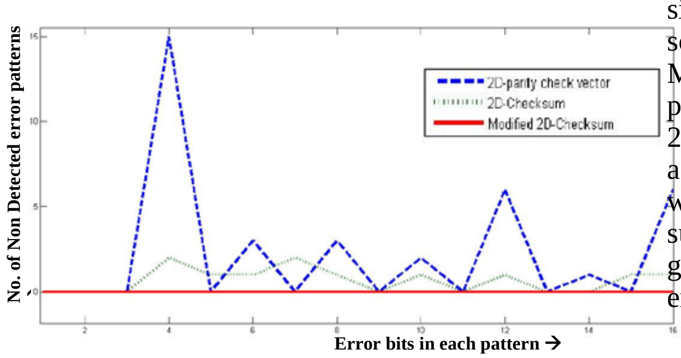

Figure 8. Novel methods compared with 2D-parity check.

One dimensional parity vector check detection method finds all odd number of changes in the same vector, but it fails in even number of changes since a change in state of one bit neglects the effect of the other change see **Fig. 9.a, 9.b and 9.c**. the single error in **Fig.9.c** can be easily detected by parity bit for the row. The two changes in single row cannot be detected by single parity bit since the change in one bit neglects the effect of the other error bit, but still the 2D-parity check can detect such errors from the column parity bits. 2D-parity check method finds all odd number of errors and many even number of errors as the case shown in **Fig. 9.c** but it fails in many cases as shown in **Fig. 9.d**. When 4 bits located as a square shape in the two dimensional map of the data, each pair of error bits will neglect the effect of the other pair.

Fig. 10 and **Fig. 11** showed two samples of 7×7 patterns contaminated with 4 bits noise to first sample and 10 bits in the second sample. Each of which was tested with ordinary parity check (single and 2D parity check) and with novel methods (2D-checksum and Modified 2D-checksum).

In **Fig. 10**, the ordinary methods failed in detecting the error bits. The parity check row and column of the transmitted data were the same as the recalculated parity check of the received noisy pattern. Although the 2D-checksum method also fails in detecting error, the 2D-Modified checksum detected the error effectively.

In **Fig. 11**, in spite of large number of error bits (10 bits) the ordinary methods still couldn't detect any of the error bits because in even number of error bits each pair neglects the effect of the other. Both the 2D-checksum method and the 2D-Modified checksum detected the error effectively.

New 2D-checksum method gave encouraged results compared to 1D- and 2D- parity check since it accumulates the error bits, but it failed in some patterns when error sum neglects each other. Modified 2D-checksum detects almost any possibility of errors, since it takes the advantage of 2D-checksum and 1D-parity check vector. The added 1D-parity vector was selected in diagonal way because the parity vector is somehow like the summation (without carry), as shown in **Fig. 7**, to guarantee the detection of every possible chance of error bit.

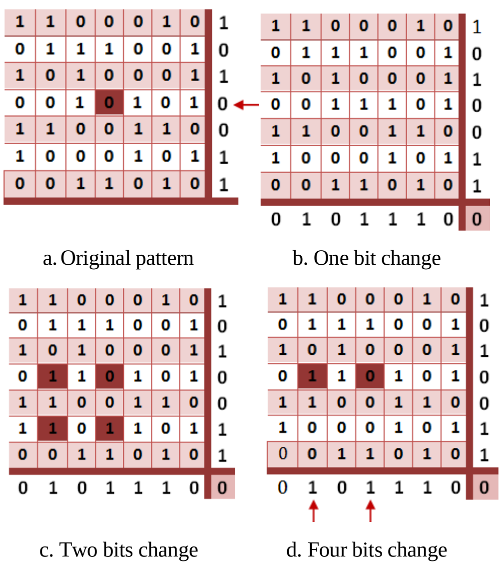

Figure 9. Effect of Error bits in received patterns.

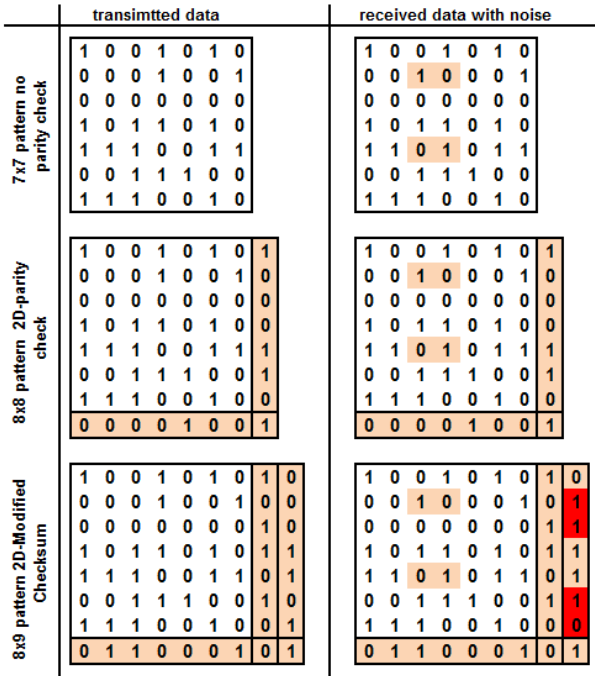

Figure 10. Ordinary and novel error detection methods for pattern contaminated with noise (4 error bits sample).

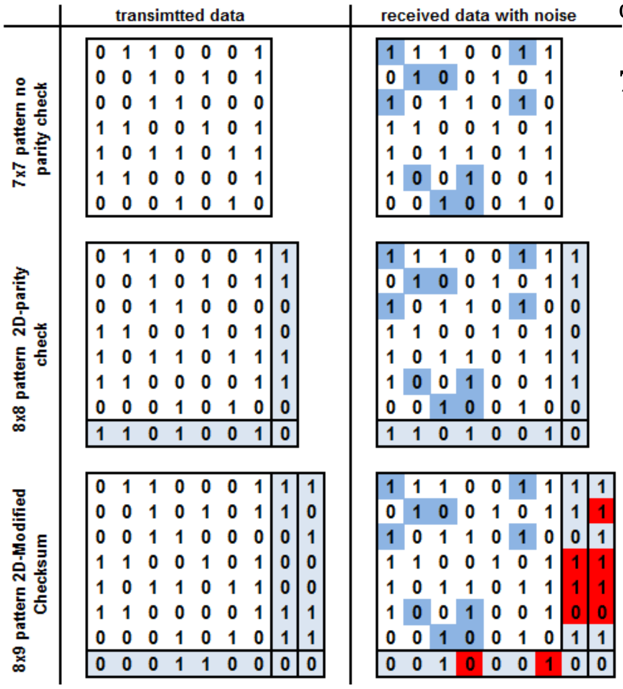

Figure 11. Ordinary and novel error detection methods for pattern contaminated with noise (10 error bits sample).

6. CONCLUTIONS

In spite of small overhead error detection bits and its simple implementation, Single bit error detecting method shows bad results in burst errors (even number of error bits).

While 2D-parity check method detects all odd numbers of error bits and many even number of error bits since the error-bits can be detected by the other dimensional parity checker. However this method fails in some cases. This method was easy to implement, and has more overhead to the actual data, but it gives reasonable results than the ordinary single parity checker.

Novel 2D-Checksum gives better results than all the previous methods, it adds moderated over head bits (equals to 2D-parity check overhead), and its implementation harder than the others. But its reasonable results improve the error detection process with 50% greater than 2D-parity check.

The modified 2D-checksum method gives the best results in error detection with an error bits up to 33% of transmitted data, more over head bits were added to accomplish this improvement in results, and it implementation is little bit harder than the others.

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