

**Subject:** OFFICIAL COMMENT: Khichidi-1  
**From:** "prasanth" <prasanth@igcar.gov.in>  
**Date:** Thu, 8 Jan 2009 16:33:24 +0530  
**To:** <hash-function@nist.gov>  
**CC:** <hash-forum@nist.gov>

hi,

i have some cryptanalysis study for Khichidi. how i can (where) submit my paper .please helpme.

Regards,  
PRasanth Thandra.

**Subject:** OFFICIAL COMMENT: Khichidi-1

**From:** Prasanth Thandra <prasanth\_thandra@yahoo.co.in>

**Date:** Fri, 9 Jan 2009 09:31:59 +0530 (IST)

**To:** "hash-function@nist.gov" <hash-function@nist.gov>

**CC:** "hash-forum@nist.gov" <hash-forum@nist.gov>

Sir,

our finding of 2ndpreimages and collisions of Khichidi-1 is attached. Please find the same.  
Thanking you.

Regards,

Prasanth KuamarThandra

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# Huge 2ndpreimages and collisions of khichidi-1

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## Abstract

Khichidi-1[1] is a contestant of Sha-3[2]. A collision attack on khichidi is proposed in [3]. In this paper we exploited a weakness in the design of the algorithm. This allowed us to propose two kind of attacks 1) 2ndpreimage attack[4], 2) Collision attack[4]. Our attacks are applicable to all the versions 224, 256, 384 and 512 and it is potentially strong.

**Key words:** khichidi-1, Hash function, 2ndpreimage resistance, Collision resistance,.

**Introduction:** Khichidi-1 [1] is a contestant of Sha-3 program. The algorithm uses a sequential combination of shuffling of bits, T-function, and LFSR in its compression function, C. For further details of the algorithm, please see [1]. collision attacks are proposed on khichidi-1 in [3]. Our observation showed that the algorithm has potential flaws in the design. In this paper, we proved that a khichidi-1 is vulnerable to 2ndpreimage attacks as well as collision attacks. With our attack, both 2ndpreimage and collisions can be found for almost all messages of practical purpose. Our attack require a pre-computed table,  $tablexC$ , with  $(2*2^{32})$  words of 32-bit length. Once the table is computed, finding a 2ndpreimage for a given message requires only calling of Round1 for the given message and its 2ndpreimage. Finding a collision also requires the same. Hence, the complexity of attacks requires the call of compression function for (N-1) times for finding a first collision/2ndpreimage, where N is the total number of blocks for compression in both message and its 2ndpreimage/collision. Our attack allows constructing huge number of collisions with same hash value, similarly 2ndpreimages.

In khichidi, the compression function C used recursively to compress padded messages of lengths multiple of 448, 512, 768 and 1024 in respective versions in CBC-mode [5]. The compression function, C, comprises a shuffling function(S) followed by a T-function (T) followed by a LFSR(L). These three functions act on 32-bit words. The most interesting thing is that our attack is independent of the details of these functions. A modification in any of these functions does not make khichidi as secured against our attack except that the computation of  $tablexC$  changes. Hash computation for a message using khichidi involves mainly two parts one is compression of the message, “Round1”, second is final hash computation. This second part involves in total 5 rounds, “Round 2 to 6”. The padded message is divided in to blocks of respective lengths and these blocks are compressed to a fixed length through a recursive operation of function C in CBC-mode. Hence, the output of Round1 has a fixed length depending on the version of Khichidi-1.

This fixed length output is fed to “Round2” followed by “Round3”, “Round4”, “Round5” and “Round6”. The output of “Round6” is the hash value of the message.

Our attack concentrates on the compressed output of Round1. Using our attack for a given message, we can find huge number of messages, which generates the same output as that of given message after Round1. Hence, irrespective of the details of “Round2-6” the strategy of our attack works. In finding collision/2ndpreimage it dose not even required to compute these last five rounds.

**Attack:** The only pre-requirement for finding collisions or 2ndpreimage is that tablex $C$  involves  $x$ ,  $C(x)$ , for all the values of  $x$ , where  $x$  is a 32-bit number. Single table computed once is sufficient for finding collisions or 2ndpreimages for any message for all the versions of khichidi.

Procedure of the attack is explained for 224 version with a general example. The procedure is same for finding a 2ndpreimages or collisions. We are going to find a collision/2ndpreimage for a (448-32) bit message,  $M$ . Length of the message can be expressed as, (448(p)-32)-bits where  $p=1, 2, 3, 4\dots$ etc.  $M^i$  is the  $i^{\text{th}}$  block of message  $M$  and  $M_j^i$  is the  $j^{\text{th}}$  word, 32-bit, of  $M^i$ . When  $M$  is padded with  $L^1$ (which is  $M_6^2=0X800001A0$  in this case) padded-message length becomes 448 bits. The 2ndpreimage/collision for padded-message  $M$  is the message of length (448(p + q)-32) where  $q=1, 2, 3\dots$  etc. One restriction on the lengths of unpadded-messages  $M$ ,  $m$  is that the padding process should be restricted to 32 bits. That is the length of  $m$  should be such that its binary form can be expressed using not more than 31-bits. For present case let  $q$  is also 1. So, the length of unpadded-message  $m$  is 864 bits, and the padding word is  $L^2$ , which is  $m_6^4=0X80000360$ . Hence, the padded-message  $m$  has length of 896 bits. Now the “Round1” of  $M$  is shown in Fig. 1(a). The output of “Round1” for padded-message  $M$  is shown in Fig. 1(a). The 4 blocks and corresponding words of the padded-message  $m$  and their compression is as shown in Fig. 1(b). The output of Round1 of this “padded-message  $m$ ” should be equal to the output of Round1 of “padded- message  $M$ ”. If this can happen the result is either a collision or a 2ndpreimage. The only word fixed in “padded-message  $m$ ” is  $L^2$ . The requirements of message  $m$  to become a 2ndpreimage/collision of  $M$  and achieving these requirements are given below systematically.

- 1) The first requirement is  $D_6^2$  should be equal to  $C(L^2 \oplus D_5^2 \oplus d_6^3)$ . To make it happen, find  $x$  from tablex $C$  mentioned earlier such that  $D_6^2 = C(x)$ . Now, chose  $d_6^3 = (L^2 \oplus D_5^2 \oplus x)$ . This makes  $D_6^2 = C(L^2 \oplus D_5^2 \oplus d_6^3)$ .
- 2) But,  $d_6^3 = C(d_6^2 \oplus m_6^3 \oplus d_5^3)$ . Now from tablex $C$  find  $y$  such that  $d_6^3 = C(y)$ . Hence,  $m_6^3$  should be equal to  $(d_6^2 \oplus y \oplus d_5^3)$ .  $m_6^3 = (d_6^2 \oplus y \oplus d_5^3)$ . Now, Chose words from  $m_0^1$  to  $m_5^3$  randomly and calculated the values of  $d_j^i$ s upto  $d_5^3$ . As  $d_5^3$ ,  $d_6^2$  and  $y$  are known and hence  $m_6^3$ .

## Collision and 2nd Preimage of Khichidi-1

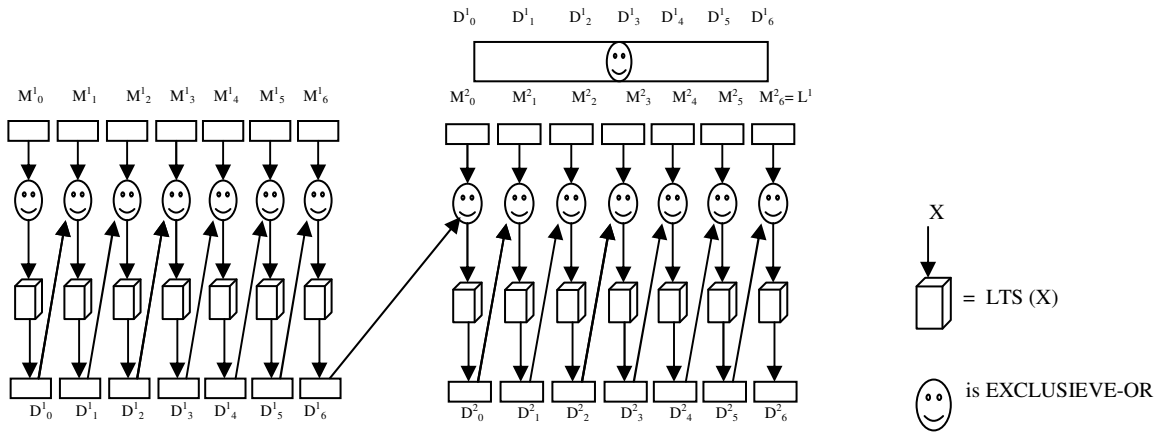


Fig. 1(a) Round1 of padded message M of length 448 bits

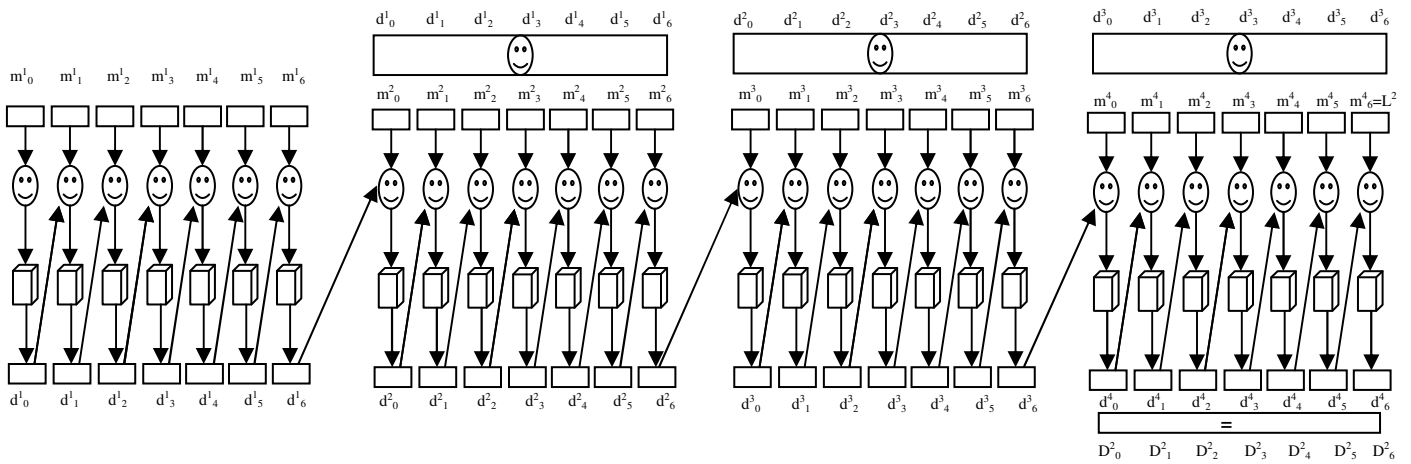


Fig. 1(b) Round1 of padded message m of length 896 bits

- 3) The next requirement, from Fig. 1(b), to have a collision/attack is  $D^2_0$  should be equal to  $C(m^4_0 \odot d^3_6 \odot d^3_0)$ . As,  $d^3_0$  and  $d^3_6$  are known already, using table C  $m^4_0$  is found.
- 4) The next requirement, from Fig. 1(b), to have a collision/attack is  $D^2_1$  should be equal to  $C(m^4_1 \odot D^2_0 \odot d^3_1)$ . As  $d^3_1$  and  $D^2_0$  are already known, using table C  $m^4_1$  is found.

- 5) The next requirement, from Fig. 1(b), to have a collision/attack is  $D_2^2$  should be equal to  $C(m_2^4 \oplus D_1^2 \oplus d_2^3)$ . As  $d_2^3$  and  $D_1^2$  are already known, using table  $C$   $m_2^4$  is found.
- 6) The next requirement, from Fig. 1(b), to have a collision/attack is  $D_3^2$  should be equal to  $C(m_3^4 \oplus D_2^2 \oplus d_3^3)$ . As  $d_3^3$  and  $D_2^2$  are already known, using table  $C$   $m_3^4$  is found.
- 7) The next requirement, from Fig. 1(b), to have a collision/attack is  $D_4^2$  should be equal to  $C(m_4^4 \oplus D_3^2 \oplus d_4^3)$ . As  $d_4^3$  and  $D_3^2$  are already known, using table  $C$   $m_4^4$  is found.
- 8) The next requirement, from Fig. 1(b), to have a collision/attack is  $D_5^2$  should be equal to  $C(m_5^4 \oplus D_4^2 \oplus d_5^3)$ . As  $d_5^3$  and  $D_4^2$  are already known, using table  $C$   $m_5^4$  is found.
- 9) The last word  $m_6^4=L^2$  is the padding word to  $m$ .

Now the message  $m$  is completely known with random values from  $m_0^1$  to  $m_5^3$  and calculated values from  $m_6^3$  to  $m_5^4$  and the padding word  $L^2=m_6^4=0X80000360$ . This padded-message  $m$  generates same output in Round1 as that of message  $M$ . Hence, both  $M$ ,  $m$  generates the same hash value.

**More collisions/2ndpreimages:** Here, padded-message  $m$  has 2 blocks and its first collision  $M$  has 4 blocks and the compression function has been called for 5 (2+4 -1) times. Finding a second collision/2ndpreimage is much easier. For the padded-message  $M$  append (448-32) bits. Now the new padded-message  $\mathcal{M}$  is

$$M \parallel m_{j=0,1,2,3,4,5,6}^5 \parallel m_{j=0,1,2,3,4,5}^6 \parallel m_6^6 = L^3$$

Where, the last word  $m_6^6$  is the padding word. Now, as already explained above chose the values of  $m_{j=0,1,2,3,4,5}^5$  randomly and follow the steps mentioned above to obtain the values of  $m_{j=0,1,2,3,4,5}^6$  to make  $\mathcal{M}$  as a collision/2ndpreimage to both  $m$ ,  $M$ ,  $\mathcal{M}$ . In finding the second collision/2ndpreimage, the compression function  $C$  has been called only once. Proceeding further for more collisions by appending (448-32) bits as explained to the latest message requires a call to compression function only once. The above attack is applicable to all the versions of the algorithm khichidi-1. The procedure is same. But, as the number of words in each block increase with 256, 384 and 512 versions, corresponding changes are required in the procedure. As these changes are very straightforward we are not presenting those in this paper.

**Complexity:** From the above discussion, complexity of the attack can be summarized as follows. To find  $N$  collisions/2ndpreimages for a padded-message  $M$  with  $N$  number of

blocks requires  $3N$  calls of compression function. In addition to this, a pre-computation is required for table  $C$ .

**Similar attacks:** As above similar kind of construction of collisions/2ndpreimages for padded-message  $M$  is also possible where the collisions/2ndpreimages constructed are shorter than  $M$  by even number of blocks. Similar to the above attack where the collisions found to padded-message  $M$  are lengthier than  $M$  by even number of blocks. But, as the procedure is almost same we are not giving the complete details of this construction here.

**Conclusion:** In this paper, we presented a way constructing very huge number of 2ndpreimages to a given message and a way of finding collisions for khichidi-1. Our procedure complexity is very less with a pre-computed table. The procedure requires the number of calls to compression function linearly dependent on the total number of blocks of messages involved in finding a collision/2ndpreimage. The procedure is same for finding collisions/2ndpreimages for all the versions of khichidi. Our attack clearly exploited the weaknesses involved in the design of the algorithm.

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