

Network Working Group
Internet-Draft
Intended status: Informational
Expires: November 19, 2016

C. Percival
Tarsnap
S. Josefsson
SJD AB
May 18, 2016

**The `script` Password-Based Key Derivation Function
draft-josefsson-script-kdf-05**

Abstract

This document specifies the password-based key derivation function `script`. The function derives one or more secret keys from a secret string. It is based on memory-hard functions which offer added protection against attacks using custom hardware. The document also provides an ASN.1 schema.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on November 19, 2016.

Copyright Notice

Copyright (c) 2016 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in [Section 4.e](#) of

the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

- [1. Introduction](#) [2](#)
- [2. Scrypt Parameters](#) [3](#)
- [3. The Salsa20/8 Core Function](#) [4](#)
- [4. The scryptBlockMix Algorithm](#) [4](#)
- [5. The scryptROMix Algorithm](#) [5](#)
- [6. The scrypt Algorithm](#) [6](#)
- [7. ASN.1 Syntax](#) [7](#)
 - [7.1. ASN.1 Module](#) [8](#)
- [8. Test Vectors for Salsa20/8 Core](#) [9](#)
- [9. Test Vectors for scryptBlockMix](#) [9](#)
- [10. Test Vectors for scryptROMix](#) [10](#)
- [11. Test Vectors for PBKDF2 with HMAC-SHA-256](#) [11](#)
- [12. Test Vectors for scrypt](#) [11](#)
- [13. Test Vectors for PKCS#8](#) [12](#)
- [14. Copying Conditions](#) [13](#)
- [15. Acknowledgements](#) [13](#)
- [16. IANA Considerations](#) [13](#)
- [17. Security Considerations](#) [13](#)
- [18. References](#) [14](#)
 - [18.1. Normative References](#) [14](#)
 - [18.2. Informative References](#) [14](#)
- Authors' Addresses [15](#)

1. Introduction

Password-based key derivation functions are used in cryptography and security protocols for deriving one or more secret keys from a secret value. Over the years, several password-based key derivation functions have been used, including the original DES-based UNIX Crypt-function, FreeBSD MD5 crypt, PKCS#5 PBKDF2 [[RFC2898](#)] (typically used with SHA-1), GNU SHA-256/512 crypt [[SHA2CRYPT](#)], Windows NT LAN Manager (NTLM) [[NTLM](#)] hash, and the Blowfish-based bcrypt [[BCRYPT](#)]. These algorithms are all based on a cryptographic primitive combined with salting and/or iteration. The iteration count is used to slow down the computation, and the salt is used to make pre-computation costlier.

All password-based key derivation functions mentioned above share the same weakness against powerful attackers. Providing that the number of iterations used is increased as computer systems get faster, this allows legitimate users to spend a constant amount of time on key derivation without losing ground to an attackers' ever-increasing computing power - as long as attackers are limited to the same

software implementations as legitimate users. While parallelized hardware implementations may not change the number of operations performed compared to software implementations, this does not prevent them from dramatically changing the asymptotic cost, since in many contexts - including the embarrassingly parallel task of performing a brute-force search for a passphrase - dollar-seconds are the most appropriate units for measuring the cost of a computation. As semiconductor technology develops, circuits do not merely become faster; they also become smaller, allowing for a larger amount of parallelism at the same cost.

Consequently, existing key derivation algorithms, even when the iteration count is increased so that the time taken to verify a password remains constant, the cost of finding a password by using a brute force attack implemented in hardware drops each year.

The scrypt function aims to reduce the advantage which attackers can gain by using custom-designed parallel circuits for breaking password-based key derivation functions.

This document do not introduce scrypt for the first time. The original scrypt paper [[SCRYPT](#)] was published as a peer-reviewed scientific paper, and contains further background and discussions.

The purpose of this document is to serve as a stable reference for IETF documents making use of scrypt. The rest of this document is divided into sections that each describe parameter choices and algorithm steps needed for the final "scrypt" algorithm.

2. Scrypt Parameters

The scrypt function takes several parameters. The passphrase P is typically a human-chosen password. The salt is normally uniquely and randomly generated [[RFC4086](#)]. The parameter r ("blockSize") specify the block size. The CPU/Memory cost parameter N ("costParameter") must be larger than 1, a power of 2 and less than $2^{(128 * r / 8)}$. The parallelization parameter p ("parallelizationParameter"), a positive integer less than or equal to $((2^{32}-1) * 32) / (128 * r)$. The intended output length $dkLen$ in octets of the derived key ("keyLength"); a positive integer less than or equal to $(2^{32} - 1) * 32$.

Users of scrypt can tune the parameters N , r , and p according to the amount of memory and computing power available, the latency-bandwidth product of the memory subsystem, and the amount of parallelism desired. At the current time, taking $r=8$ and $p=1$ appears to yield good results, but as memory latency and CPU parallelism increase it is likely that the optimum values for both r and p will increase.

Note also that since the computations of SMix are independent, a large value of p can be used to increase the computational cost of scrypt without increasing the memory usage; so we can expect scrypt to remain useful even if the growth rates of CPU power and memory capacity diverge.

3. The Salsa20/8 Core Function

Salsa20/8 Core is a round-reduced variant of the Salsa20 Core. It is a hash function from 64-octet strings to 64-octet strings. Note that Salsa20/8 Core is not a cryptographic hash function since it is not collision-resistant. See section 8 of [[SALSA20SPEC](#)] for its specification, and [[SALSA20CORE](#)] for more information. The algorithm description, in C language, is included below as a stable reference, without endianness conversion and alignment.

```
#define R(a,b) (((a) << (b)) | ((a) >> (32 - (b))))
void salsa20_word_specification(uint32 out[16],uint32 in[16])
{
    int i;
    uint32 x[16];
    for (i = 0;i < 16;++i) x[i] = in[i];
    for (i = 8;i > 0;i -= 2) {
        x[ 4] ^= R(x[ 0]+x[12], 7);  x[ 8] ^= R(x[ 4]+x[ 0], 9);
        x[12] ^= R(x[ 8]+x[ 4],13);  x[ 0] ^= R(x[12]+x[ 8],18);
        x[ 9] ^= R(x[ 5]+x[ 1], 7);  x[13] ^= R(x[ 9]+x[ 5], 9);
        x[ 1] ^= R(x[13]+x[ 9],13);  x[ 5] ^= R(x[ 1]+x[13],18);
        x[14] ^= R(x[10]+x[ 6], 7);  x[ 2] ^= R(x[14]+x[10], 9);
        x[ 6] ^= R(x[ 2]+x[14],13);  x[10] ^= R(x[ 6]+x[ 2],18);
        x[ 3] ^= R(x[15]+x[11], 7);  x[ 7] ^= R(x[ 3]+x[15], 9);
        x[11] ^= R(x[ 7]+x[ 3],13);  x[15] ^= R(x[11]+x[ 7],18);
        x[ 1] ^= R(x[ 0]+x[ 3], 7);  x[ 2] ^= R(x[ 1]+x[ 0], 9);
        x[ 3] ^= R(x[ 2]+x[ 1],13);  x[ 0] ^= R(x[ 3]+x[ 2],18);
        x[ 6] ^= R(x[ 5]+x[ 4], 7);  x[ 7] ^= R(x[ 6]+x[ 5], 9);
        x[ 4] ^= R(x[ 7]+x[ 6],13);  x[ 5] ^= R(x[ 4]+x[ 7],18);
        x[11] ^= R(x[10]+x[ 9], 7);  x[ 8] ^= R(x[11]+x[10], 9);
        x[ 9] ^= R(x[ 8]+x[11],13);  x[10] ^= R(x[ 9]+x[ 8],18);
        x[12] ^= R(x[15]+x[14], 7);  x[13] ^= R(x[12]+x[15], 9);
        x[14] ^= R(x[13]+x[12],13);  x[15] ^= R(x[14]+x[13],18);
    }
    for (i = 0;i < 16;++i) out[i] = x[i] + in[i];
}
```

4. The scryptBlockMix Algorithm

The scryptBlockMix algorithm is the same as the BlockMix algorithm described in [[SCRYPT](#)] but with Salsa20/8 Core used as the hash

function H. Below, Salsa(T) corresponds to the Salsa20/8 Core function applied to the octet vector T.

Algorithm scryptBlockMix

Parameters:

r Block size parameter.

Input:

B[0] || B[1] || ... || B[2 * r - 1]
Input octet string (of size 128 * r octets),
treated as 2 * r 64-octet blocks,
where each element in B is a 64-octet block.

Output:

B'[0] || B'[1] || ... || B'[2 * r - 1]
Output octet string.

Steps:

1. X = B[2 * r - 1]
2. for i = 0 to 2 * r - 1 do
 T = X xor B[i]
 X = Salsa (T)
 Y[i] = X
end for
3. B' = (Y[0], Y[2], ..., Y[2 * r - 2],
 Y[1], Y[3], ..., Y[2 * r - 1])

5. The scryptROMix Algorithm

The scryptROMix algorithm is the same as the ROMix algorithm described in [[SCRYPT](#)] but with scryptBlockMix used as the hash function H and the Integerify function explained inline.

Algorithm scryptROMix

Input:

r Block size parameter.
B Input octet vector of length $128 * r$ octets.
N CPU/Memory cost parameter, must be larger than 1,
 a power of 2 and less than $2^{(128 * r / 8)}$.

Output:

B' Output octet vector of length $128 * r$ octets.

Steps:

1. $X = B$
2. for $i = 0$ to $N - 1$ do
 $V[i] = X$
 $X = \text{scryptBlockMix}(X)$
 end for
3. for $i = 0$ to $N - 1$ do
 $j = \text{Integerify}(X) \bmod N$
 where $\text{Integerify}(B[0] \dots B[2 * r - 1])$ is defined
 as the result of interpreting $B[2 * r - 1]$ as a
 little-endian integer.
 $T = X \text{ xor } V[j]$
 $X = \text{scryptBlockMix}(T)$
 end for
4. $B' = X$

6. The scrypt Algorithm

The PBKDF2-HMAC-SHA-256 function used below denote the PBKDF2 algorithm [[RFC2898](#)] used with HMAC-SHA-256 [[RFC6234](#)] as the PRF. The HMAC-SHA-256 function generates 32 octet outputs.

Algorithm scrypt

Input:

P Passphrase, an octet string.
 S Salt, an octet string.
 N CPU/Memory cost parameter, must be larger than 1,
 a power of 2 and less than $2^{(128 * r / 8)}$.
 r Block size parameter.
 p Parallelization parameter, a positive integer
 less than or equal to $((2^{32}-1) * hLen) / MLen$
 where hLen is 32 and MLen is $128 * r$.
 dkLen Intended output length in octets of the derived
 key; a positive integer less than or equal to
 $(2^{32} - 1) * hLen$ where hLen is 32.

Output:

DK Derived key, of length dkLen octets.

Steps:

1. Initialize an array B consisting of p blocks of $128 * r$ octets each:
 $B[0] || B[1] || \dots || B[p - 1] =$
 $\text{PBKDF2-HMAC-SHA256}(P, S, 1, p * 128 * r)$
2. for i = 0 to p - 1 do
 $B[i] = \text{scryptROMix}(r, B[i], N)$
 end for
3. $DK = \text{PBKDF2-HMAC-SHA256}(P, B[0] || B[1] || \dots || B[p - 1],$
 $1, dkLen)$

7. ASN.1 Syntax

This section defines ASN.1 syntax for the scrypt key derivation function. This is intended to operate on the same abstraction level as PKCS#5's PBKDF2. The OID id-scrypt below can be used where id-PBKDF2 is used, with scrypt-params corresponding to PBKDF2-params. The intended application of these definitions includes PKCS #8 and other syntax for key management.

The object identifier id-scrypt identifies the scrypt key derivation function.

id-scrypt OBJECT IDENTIFIER ::= {1 3 6 1 4 1 11591 4 11}

The parameters field associated with this OID in an AlgorithmIdentifier shall have type scrypt-params:


```
scrypt-params ::= SEQUENCE {  
    salt OCTET STRING,  
    costParameter INTEGER (1..MAX),  
    blockSize INTEGER (1..MAX),  
    parallelizationParameter INTEGER (1..MAX),  
    keyLength INTEGER (1..MAX) OPTIONAL }
```

The fields of type scrypt-params have the following meanings:

- salt specifies the salt value. It shall be an octet string.
- costParameter specifies the CPU/Memory cost parameter N.
- blockSize specifies the block size parameter r.
- parallelizationParameter specifies the parallelization parameter.
- keyLength, an optional field, is the length in octets of the derived key. The maximum key length allowed depends on the implementation; it is expected that implementation profiles may further constrain the bounds. This field only provides convenience; the key length is not cryptographically protected.

To be usable in PKCS#8 [[RFC5208](#)] and Asymmetric Key Packages [[RFC5958](#)] the following extension of the PBES2-KDFs type is needed.

```
PBES2-KDFs ALGORITHM-IDENTIFIER ::=  
    { {scrypt-params IDENTIFIED BY id-scrypt}, ... }
```

7.1. ASN.1 Module

For reference purposes, the ASN.1 syntax is presented as an ASN.1 module here.


```
-- scrypt ASN.1 Module

scrypt-0 {1 3 6 1 4 1 11591 4 10}

DEFINITIONS ::= BEGIN

id-scrypt OBJECT IDENTIFIER ::= {1 3 6 1 4 1 11591 4 11}

scrypt-params ::= SEQUENCE {
    salt OCTET STRING,
    costParameter INTEGER (1..MAX),
    blockSize INTEGER (1..MAX),
    parallelizationParameter INTEGER (1..MAX),
    keyLength INTEGER (1..MAX) OPTIONAL
}

PBES2-KDFs ALGORITHM-IDENTIFIER ::=
    { {scrypt-params IDENTIFIED BY id-scrypt}, ... }

END
```

8. Test Vectors for Salsa20/8 Core

Below is a sequence of octets to illustrate input and output values for the Salsa20/8 Core. The octets are hex encoded and whitespace is inserted for readability. The value corresponds to the first input and output pair generated by the first scrypt test vector below.

INPUT:

```
7e 87 9a 21 4f 3e c9 86 7c a9 40 e6 41 71 8f 26
ba ee 55 5b 8c 61 c1 b5 0d f8 46 11 6d cd 3b 1d
ee 24 f3 19 df 9b 3d 85 14 12 1e 4b 5a c5 aa 32
76 02 1d 29 09 c7 48 29 ed eb c6 8d b8 b8 c2 5e
```

OUTPUT:

```
a4 1f 85 9c 66 08 cc 99 3b 81 ca cb 02 0c ef 05
04 4b 21 81 a2 fd 33 7d fd 7b 1c 63 96 68 2f 29
b4 39 31 68 e3 c9 e6 bc fe 6b c5 b7 a0 6d 96 ba
e4 24 cc 10 2c 91 74 5c 24 ad 67 3d c7 61 8f 81
```

9. Test Vectors for scryptBlockMix

Below is a sequence of octets to illustrate input and output values for scryptBlockMix. The test vector uses an r value of 1. The octets are hex encoded and whitespace is inserted for readability. The value corresponds to the first input and output pair generated by the first scrypt test vector below.

INPUT

```
B[0] = f7 ce 0b 65 3d 2d 72 a4 10 8c f5 ab e9 12 ff dd
       77 76 16 db bb 27 a7 0e 82 04 f3 ae 2d 0f 6f ad
       89 f6 8f 48 11 d1 e8 7b cc 3b d7 40 0a 9f fd 29
       09 4f 01 84 63 95 74 f3 9a e5 a1 31 52 17 bc d7
```

```
B[1] = 89 49 91 44 72 13 bb 22 6c 25 b5 4d a8 63 70 fb
       cd 98 43 80 37 46 66 bb 8f fc b5 bf 40 c2 54 b0
       67 d2 7c 51 ce 4a d5 fe d8 29 c9 0b 50 5a 57 1b
       7f 4d 1c ad 6a 52 3c da 77 0e 67 bc ea af 7e 89
```

OUTPUT

```
B'[0] = a4 1f 85 9c 66 08 cc 99 3b 81 ca cb 02 0c ef 05
       04 4b 21 81 a2 fd 33 7d fd 7b 1c 63 96 68 2f 29
       b4 39 31 68 e3 c9 e6 bc fe 6b c5 b7 a0 6d 96 ba
       e4 24 cc 10 2c 91 74 5c 24 ad 67 3d c7 61 8f 81
```

```
B'[1] = 20 ed c9 75 32 38 81 a8 05 40 f6 4c 16 2d cd 3c
       21 07 7c fe 5f 8d 5f e2 b1 a4 16 8f 95 36 78 b7
       7d 3b 3d 80 3b 60 e4 ab 92 09 96 e5 9b 4d 53 b6
       5d 2a 22 58 77 d5 ed f5 84 2c b9 f1 4e ef e4 25
```

10. Test Vectors for scryptROMix

Below is a sequence of octets to illustrate input and output values for scryptROMix. The test vector uses an r value of 1 and an N value of 16. The octets are hex encoded and whitespace is inserted for readability. The value corresponds to the first input and output pair generated by the first scrypt test vector below.

INPUT:

```
B = f7 ce 0b 65 3d 2d 72 a4 10 8c f5 ab e9 12 ff dd
    77 76 16 db bb 27 a7 0e 82 04 f3 ae 2d 0f 6f ad
    89 f6 8f 48 11 d1 e8 7b cc 3b d7 40 0a 9f fd 29
    09 4f 01 84 63 95 74 f3 9a e5 a1 31 52 17 bc d7
    89 49 91 44 72 13 bb 22 6c 25 b5 4d a8 63 70 fb
    cd 98 43 80 37 46 66 bb 8f fc b5 bf 40 c2 54 b0
    67 d2 7c 51 ce 4a d5 fe d8 29 c9 0b 50 5a 57 1b
    7f 4d 1c ad 6a 52 3c da 77 0e 67 bc ea af 7e 89
```

OUTPUT:

```
B = 79 cc c1 93 62 9d eb ca 04 7f 0b 70 60 4b f6 b6
    2c e3 dd 4a 96 26 e3 55 fa fc 61 98 e6 ea 2b 46
    d5 84 13 67 3b 99 b0 29 d6 65 c3 57 60 1f b4 26
    a0 b2 f4 bb a2 00 ee 9f 0a 43 d1 9b 57 1a 9c 71
    ef 11 42 e6 5d 5a 26 6f dd ca 83 2c e5 9f aa 7c
    ac 0b 9c f1 be 2b ff ca 30 0d 01 ee 38 76 19 c4
    ae 12 fd 44 38 f2 03 a0 e4 e1 c4 7e c3 14 86 1f
    4e 90 87 cb 33 39 6a 68 73 e8 f9 d2 53 9a 4b 8e
```

11. Test Vectors for PBKDF2 with HMAC-SHA-256

Below is a sequence of octets illustrating input and output values for PBKDF2-HMAC-SHA-256. The octets are hex encoded and whitespace is inserted for readability. The test vectors below can be used to verify the PBKDF2-HMAC-SHA-256 [RFC2898] function. The password and salt strings are passed as sequences of ASCII [RFC0020] octets.

```
PBKDF2-HMAC-SHA-256 (P="passwd", S="salt",
                    c=1, dkLen=64) =
55 ac 04 6e 56 e3 08 9f ec 16 91 c2 25 44 b6 05
f9 41 85 21 6d de 04 65 e6 8b 9d 57 c2 0d ac bc
49 ca 9c cc f1 79 b6 45 99 16 64 b3 9d 77 ef 31
7c 71 b8 45 b1 e3 0b d5 09 11 20 41 d3 a1 97 83
```

```
PBKDF2-HMAC-SHA-256 (P="Password", S="NaCl",
                    c=80000, dkLen=64) =
4d dc d8 f6 0b 98 be 21 83 0c ee 5e f2 27 01 f9
64 1a 44 18 d0 4c 04 14 ae ff 08 87 6b 34 ab 56
a1 d4 25 a1 22 58 33 54 9a db 84 1b 51 c9 b3 17
6a 27 2b de bb a1 d0 78 47 8f 62 b3 97 f3 3c 8d
```

12. Test Vectors for scrypt

For reference purposes, we provide the following test vectors for scrypt, where the password and salt strings are passed as sequences of ASCII [RFC0020] octets.

The parameters to the scrypt function below are, in order, the password P (octet string), the salt S (octet string), the CPU/Memory cost parameter N, the block size parameter r, and the parallelization parameter p, and the output size dkLen. The output is hex encoded and whitespace is inserted for readability.

```
scrypt (P="", S="",
        N=16, r=1, p=1, dklen=64) =
77 d6 57 62 38 65 7b 20 3b 19 ca 42 c1 8a 04 97
f1 6b 48 44 e3 07 4a e8 df df fa 3f ed e2 14 42
fc d0 06 9d ed 09 48 f8 32 6a 75 3a 0f c8 1f 17
e8 d3 e0 fb 2e 0d 36 28 cf 35 e2 0c 38 d1 89 06
```

```
scrypt (P="password", S="NaCl",
        N=1024, r=8, p=16, dkLen=64) =
fd ba be 1c 9d 34 72 00 78 56 e7 19 0d 01 e9 fe
7c 6a d7 cb c8 23 78 30 e7 73 76 63 4b 37 31 62
2e af 30 d9 2e 22 a3 88 6f f1 09 27 9d 98 30 da
c7 27 af b9 4a 83 ee 6d 83 60 cb df a2 cc 06 40
```

```
scrypt (P="pleaseletmein", S="SodiumChloride",
        N=16384, r=8, p=1, dkLen=64) =
70 23 bd cb 3a fd 73 48 46 1c 06 cd 81 fd 38 eb
fd a8 fb ba 90 4f 8e 3e a9 b5 43 f6 54 5d a1 f2
d5 43 29 55 61 3f 0f cf 62 d4 97 05 24 2a 9a f9
e6 1e 85 dc 0d 65 1e 40 df cf 01 7b 45 57 58 87
```

```
scrypt (P="pleaseletmein", S="SodiumChloride",
        N=1048576, r=8, p=1, dkLen=64) =
21 01 cb 9b 6a 51 1a ae ad db be 09 cf 70 f8 81
ec 56 8d 57 4a 2f fd 4d ab e5 ee 98 20 ad aa 47
8e 56 fd 8f 4b a5 d0 9f fa 1c 6d 92 7c 40 f4 c3
37 30 40 49 e8 a9 52 fb cb f4 5c 6f a7 7a 41 a4
```

13. Test Vectors for PKCS#8

PKCS#8 [[RFC5208](#)] and Asymmetric Key Packages [[RFC5958](#)] encode encrypted private-keys. Using PBES2 with scrypt as the KDF, the following illustrates an example of a PKCS#8 encoded private-key. The password is "Rabbit" (without the quotes) with N=1048576, r=8 and p=1. The salt is "Mouse" and the encryption algorithm used is aes256-CBC. The derived key is: E2 77 EA 2C AC B2 3E DA-FC 03 9D 22 9B 79 DC 13 EC ED B6 01 D9 9B 18 2A-9F ED BA 1E 2B FB 4F 58.


```
-----BEGIN ENCRYPTED PRIVATE KEY-----
MIHiME0GCSqGSIB3DQEFDTBAMB8GCSsGAQQB2kcECzASBAVNb3VzZQIDEAAAAGEI
AgEBMB0GCWCGSAFlAwQBKqQQyYmguHMs0wzGMPoyObk/JgSBkJb47Ewd5iAqJllyy
+ni5ftd6gZgOPaLQCll7mEZc2KQay0VhjZm/7MbBUNbqOAXNM60GebXxVp6sHUAL
iBGY/Dls7B1TsWeG0bE0sS1MXEpuREuloZjcsNVcNXWPLldZtkSH6uwWzR0PyG/Z
+ZXfNodZtd/voKlvL0w5B3opGIFaLkbtLZQwMiGtl42AS89lZg==
-----END ENCRYPTED PRIVATE KEY-----
```

14. Copying Conditions

The authors agree to grant third parties the irrevocable right to copy, use and distribute this entire document or any portion of it, with or without modification, in any medium, without royalty, provided that, unless separate permission is granted, redistributed modified works do not contain misleading author, version, name of work, or endorsement information.

15. Acknowledgements

Text in this document was borrowed from [[SCRYPT](#)] and [[RFC2898](#)]. The PKCS#8 test vector was provided by Stephen N. Henson.

Feedback on this document were received from Dmitry Chestnykh, Alexander Klink, Rob Kendrick, Royce Williams Ted Rolle, Jr., Eitan Adler, Stephen Farrel, Nikos Mavrogiannopoulos, and Paul Kyzivat.

16. IANA Considerations

None.

17. Security Considerations

This document specifies a cryptographic algorithm, and there is always a risk that someone will find a weakness in it. By following the cryptographic research area you may learn of publications relevant to scrypt.

ROMix has been proven sequential memory-hard under the Random Oracle model for the hash function. The security of scrypt relies on the assumption that BlockMix with Salsa20/8 Core does not exhibit any "shortcuts" which would allow it to be iterated more easily than a random oracle. For other claims about the security properties see [[SCRYPT](#)].

Passwords and other sensitive data, such as intermediate values, may continue to be stored in memory, core dumps, swap areas, etc, for a long time after the implementation has processed them. This makes attacks on the implementation easier. Thus, implementation should

consider storing sensitive data in protected memory areas. How to achieve this is system dependent.

By nature and depending on parameters, running the scrypt algorithm may require large amounts of memory. Systems should protect against a denial of service attack resulting from attackers presenting unreasonably large parameters.

Poor parameter choices can be harmful for security; for example, if you tune the parameters so that memory use is reduced to small amounts that will affect the properties of the algorithm.

18. References

18.1. Normative References

- [RFC2898] Kaliski, B., "PKCS #5: Password-Based Cryptography Specification Version 2.0", [RFC 2898](#), DOI 10.17487/RFC2898, September 2000, <<http://www.rfc-editor.org/info/rfc2898>>.
- [RFC6234] Eastlake 3rd, D. and T. Hansen, "US Secure Hash Algorithms (SHA and SHA-based HMAC and HKDF)", [RFC 6234](#), DOI 10.17487/RFC6234, May 2011, <<http://www.rfc-editor.org/info/rfc6234>>.

18.2. Informative References

- [RFC0020] Cerf, V., "ASCII format for network interchange", STD 80, [RFC 20](#), DOI 10.17487/RFC0020, October 1969, <<http://www.rfc-editor.org/info/rfc20>>.
- [RFC5208] Kaliski, B., "Public-Key Cryptography Standards (PKCS) #8: Private-Key Information Syntax Specification Version 1.2", [RFC 5208](#), DOI 10.17487/RFC5208, May 2008, <<http://www.rfc-editor.org/info/rfc5208>>.
- [RFC5958] Turner, S., "Asymmetric Key Packages", [RFC 5958](#), DOI 10.17487/RFC5958, August 2010, <<http://www.rfc-editor.org/info/rfc5958>>.
- [RFC4086] Eastlake 3rd, D., Schiller, J., and S. Crocker, "Randomness Requirements for Security", [BCP 106](#), [RFC 4086](#), DOI 10.17487/RFC4086, June 2005, <<http://www.rfc-editor.org/info/rfc4086>>.

[SALSA20SPEC]

Bernstein, D., "Salsa20 specification",
WWW <http://cr.yp.to/snuffle/spec.pdf>, April 2005.

[SALSA20CORE]

Bernstein, D., "The Salsa20 Core",
WWW <http://cr.yp.to/salsa20.html>, March 2005.

[SCRYPT]

Percival, C., "Stronger key derivation via sequential
memory-hard functions",
BSDCan'09 <http://www.tarsnap.com/scrypt/scrypt.pdf>, May
2009.

[BCRYPT]

Provos, N. and D. Mazieres, "A Future-Adaptable Password
Scheme", USENIX 1999
[https://www.usenix.org/legacy/event/usenix99/provos/
provos.pdf](https://www.usenix.org/legacy/event/usenix99/provos/provos.pdf), June 1999.

[NTLM]

"[MS-NLMP]: NT LAN Manager (NTLM) Authentication
Protocol", Microsoft [https://msdn.microsoft.com/en-
us/library/cc236621.aspx](https://msdn.microsoft.com/en-us/library/cc236621.aspx), 2015.

[SHA2CRYPT]

Drepper, U., "Unix crypt using SHA-256 and SHA-512",
URL <http://www.akkadia.org/drepper/SHA-crypt.txt>, April
2008.

Authors' Addresses

Colin Percival
Tarsnap

Email: cperciva@tarsnap.com

Simon Josefsson
SJD AB

Email: simon@josefsson.org
URI: <http://josefsson.org/>

