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SPAKE2, a PAKE
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Abstract

This Internet-Draft describes SPAKE2, a secure, efficient password authentication protocol.
based key exchange protocol.
1. Introduction

This document describes a means for two parties that share a password to derive a shared key. This method is compatible with any group, is computationally efficient, and has a strong security proof.

2. Definition of SPAKE2

Let $G$ be a group in which the Diffie-Hellman problem is hard of order $ph$, with $p$ a big prime and $h$ a cofactor. We denote the operations in the group additively. Let $H$ be a hash function from arbitrary strings to bit strings of a fixed length. Common choices for $H$ are SHA256 or SHA512. We assume there is a representation of elements of $G$ as byte strings: common choices would be SEC1 uncompressed for elliptic curve groups or big endian integers of a particular length for prime field DH.

$||$ denotes concatenation of strings. We also let $\text{len}(S)$ denote the length of a string in bytes, represented as an eight-byte big-endian number.

We fix two elements $M$ and $N$ as defined in the table in this document for common groups, as well as a generator $G$ of the group. $G$ is specified in the document defining the group, and so we do not recall it here.

Let $A$ and $B$ be two parties. We will assume that $A$ and $B$ are also representations of the parties such as MAC addresses or other names (hostnames, usernames, etc). We assume they share an integer $w$. Typically $w$ will be the hash of a user-supplied password, truncated and taken mod $p$. Protocols using this protocol must define the method used to compute $w$: it may be necessary to carry out normalization.

$A$ picks $x$ randomly and uniformly from the integers in $[0,ph)$ divisible by $h$, and calculates $X=xG$ and $T=wM+X$, then transmits $T$ to $B$.

$B$ selects $y$ randomly and uniformly from the integers in $[0,ph)$,
divisible by h and calculates \( Y = yG \), \( S = wN + Y \), then transmits \( S \) to \( A \).

Both \( A \) and \( B \) calculate a group element \( K \). \( A \) calculates it as \( x(S - wN) \), while \( B \) calculates it as \( y(T - wM) \). \( A \) knows \( S \) because it has received it, and likewise \( B \) knows \( T \).

This \( K \) is a shared secret, but the scheme as described is not secure. It is essential to combine \( K \) with the values transmitted and received via a hash function to have a secure protocol. If higher-level protocols prescribe a method for doing so, that SHOULD be used. Otherwise we can compute \( K' \) as \( H(\text{len}(A) || A || \text{len}(B) || B || \text{len}(S) || S || \text{len}(T) || T || \text{len}(K) || K) \) and use \( K' \) as the key.

Note that the calculation of \( S = wN + yG \) may be performed more efficiently then by two separate scalar multiplications via Strauss’s algorithm.

3. Table of points for common groups

Every curve presented in the table below has an OID from [OID]. We construct a string using the OID and the needed constant, for instance "1.3.132.0.35 point generation seed (M)" for P-512. This string is turned into an infinite sequence of bytes by hashing with SHA256, and hashing that output again to generate the next 32 bytes, and so on.

The initial segment of bytes is taken, and the first byte has all bits but the low-order one cleared, and the second-order bit set. This string of bytes is then interpreted as a SEC1 compressed point. If this is impossible, then the next non-overlapping segment of sufficient length is taken.

For P256:

\[
\begin{align*}
M &= 02886e2f97ace46e55ba9dd7242579f2993b64e16ef3dcab95afd497333d8fa12f \\
N &= 03d8bbd6c639c62937b04d997f38c3770719c629d7014d49a24b4f98baa1292b49
\end{align*}
\]

For P384:

\[
\begin{align*}
M &= 030ff0895ae5ebf6187080a82d82b42e2765e3b2f8749c7e05eba366434b363d3dc36f15314739074d2eb8613fceeec2853 \\
N &= 02c72cf2e390853a1c1c4ad816a62fd15824f56078918f43f922ca21518f9c543bb
\end{align*}
\]
For P521:

\[ M = 02003f06f38131b2ba2600791e82488e8d20ab889af753a41806c5db18d37d85608cfae06b82e4a72cd744c719193562a653ea1f119eef9356907edc9b56979962d7aa \]

\[ N = 0200c7924b9ec017f3094562894336a53c50167ba8c5963876880542bc669e494b2532d76c5b53dfb349fdf69154b9e0048c58a42e8ed04cef052a3bc349d95575cd25 \]

4. Security Considerations

A security proof for prime order groups is found in [REF]. Note that
the choice of M and N is critical for the security proof. The points
in the table of points were generated via the use of a hash function
to mitigate this risk.

There is no key-confirmation as this is a one round protocol. It is
expected that a protocol using this key exchange mechanism provides
key confirmation separately if desired.

Elements should be checked for group membership: failure to properly
validate group elements can lead to attacks. In particular it is
essential to verify that received points are valid compressions of
points on an elliptic curve when using elliptic curves. It is not
necessary to validate membership in the prime order subgroup: the
multiplication by cofactors eliminates this issue.

The choices of random numbers should be uniformly at random. Note
that to pick a random multiple of h in \([0, ph)\) one can pick a random
integer in \([0, p)\) and multiply by h.

This PAKE does not support augmentation. As a result, the server has
to store a password equivalent. This is considered a significant
drawback.

As specified the shared secret K is not suitable for use as a shared
key. It should be passed to a hash function along with the public
values used to derive it and the party identities to avoid attacks.
In protocols which do not perform this separately, the value denoted
K' should be used instead. This is critical for security.

5. IANA Considerations

No IANA action is required.
6. Acknowledgments

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7. References


Author Addresses
Watson Ladd
watsonbladd@gmail.com
Berkeley, CA