

Network Working Group
Request for Comments: 2433
Category: Informational

G. Zorn
S. Cobb
Microsoft Corporation
October 1998

Microsoft PPP CHAP Extensions

Status of this Memo

This memo provides information for the Internet community. It does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

Copyright Notice

Copyright (C) The Internet Society (1998). All Rights Reserved.

IESG Note

The protocol described here has significant vulnerabilities. People planning on implementing or using this protocol should read section 12, "Security Considerations".

1. Abstract

The Point-to-Point Protocol (PPP) [1] provides a standard method for transporting multi-protocol datagrams over point-to-point links. PPP defines an extensible Link Control Protocol and a family of Network Control Protocols (NCPs) for establishing and configuring different network-layer protocols.

This document describes Microsoft's PPP CHAP dialect (MS-CHAP), which extends the user authentication functionality provided on Windows networks to remote workstations. MS-CHAP is closely derived from the PPP Challenge Handshake Authentication Protocol described in RFC 1994 [2], which the reader should have at hand.

The algorithms used in the generation of various MS-CHAP protocol fields are described in an appendix.

2. Introduction

Microsoft created MS-CHAP to authenticate remote Windows workstations, providing the functionality to which LAN-based users are accustomed while integrating the encryption and hashing algorithms used on Windows networks.

Where possible, MS-CHAP is consistent with standard CHAP. Briefly, the differences between MS-CHAP and standard CHAP are:

- * MS-CHAP is enabled by negotiating CHAP Algorithm 0x80 in LCP option 3, Authentication Protocol.
- * The MS-CHAP Response packet is in a format designed for compatibility with Microsoft's Windows NT 3.5, 3.51 and 4.0, and Windows95 networking products. The MS-CHAP format does not require the authenticator to store a clear-text or reversibly encrypted password.
- * MS-CHAP provides authenticator-controlled authentication retry and password changing mechanisms.
- * MS-CHAP defines a set of reason-for-failure codes returned in the Failure packet Message field.

3. Specification of Requirements

In this document, the key words "MAY", "MUST", "MUST NOT", "optional", "recommended", "SHOULD", and "SHOULD NOT" are to be interpreted as described in [2].

4. LCP Configuration

The LCP configuration for MS-CHAP is identical to that for standard CHAP, except that the Algorithm field has value 0x80, rather than the MD5 value 0x05. PPP implementations which do not support MS-CHAP, but correctly implement LCP Config-Rej, should have no problem dealing with this non-standard option.

5. Challenge Packet

The MS-CHAP Challenge packet is identical in format to the standard CHAP Challenge packet.

MS-CHAP authenticators send an 8-octet challenge Value field. Peers need not duplicate Microsoft's algorithm for selecting the 8-octet value, but the standard guidelines on randomness [1,2,7] SHOULD be observed.

Microsoft authenticators do not currently provide information in the Name field. This may change in the future.

6. Response Packet

The MS-CHAP Response packet is identical in format to the standard CHAP Response packet. However, the Value field is sub-formatted differently as follows:

- 24 octets: LAN Manager compatible challenge response
- 24 octets: Windows NT compatible challenge response
- 1 octet : "Use Windows NT compatible challenge response" flag

The LAN Manager compatible challenge response is an encoded function of the password and the received challenge as output by the routine LmChallengeResponse() (see section A.1, below). LAN Manager passwords are limited to 14 case-insensitive OEM characters. Note that use of the LAN Manager compatible challenge response has been deprecated; peers SHOULD NOT generate it, and the sub-field SHOULD be zero-filled. The algorithm used in the generation of the LAN Manager compatible challenge response is described here for informational purposes only.

The Windows NT compatible challenge response is an encoded function of the password and the received challenge as output by the routine NTChallengeResponse() (see section A.5, below). The Windows NT password is a string of 0 to (theoretically) 256 case-sensitive Unicode [8] characters. Current versions of Windows NT limit passwords to 14 characters, mainly for compatibility reasons; this may change in the future.

The "use Windows NT compatible challenge response" flag, if 1, indicates that the Windows NT response is provided and should be used in preference to the LAN Manager response. The LAN Manager response will still be used if the account does not have a Windows NT password hash, e.g. if the password has not been changed since the account was uploaded from a LAN Manager 2.x account database. If the flag is 0, the Windows NT response is ignored and the LAN Manager response is used. Since the use of LAN Manager authentication has been deprecated, this flag SHOULD always be set (1) and the LAN Manager compatible challenge response field SHOULD be zero-filled.

The Name field identifies the peer's user account name. The Windows NT domain name may prefix the user's account name (e.g. "BIGCO\johndoe" where "BIGCO" is a Windows NT domain containing the user account "john-doe"). If a domain is not provided, the backslash should also be omitted, (e.g. "johndoe").

7. Success Packet

The Success packet is identical in format to the standard CHAP Success packet.

8. Failure Packet

The Failure packet is identical in format to the standard CHAP Failure packet. There is, however, formatted text stored in the Message field which, contrary to the standard CHAP rules, affects the protocol. The Message field format is:

```
"E=eeeeeeeeee R=r C=cccccccccccccccc V=vvvvvvvvvv"
```

where

The "eeeeeeeeee" is the decimal error code (need not be 10 digits) corresponding to one of those listed below, though implementations should deal with codes not on this list gracefully.

```
646 ERROR_RESTRICTED_LOGON_HOURS
647 ERROR_ACCT_DISABLED
648 ERROR_PASSWD_EXPIRED
649 ERROR_NO_DIALIN_PERMISSION
691 ERROR_AUTHENTICATION_FAILURE
709 ERROR_CHANGING_PASSWORD
```

The "r" is a flag set to "1" if a retry is allowed, and "0" if not. When the authenticator sets this flag to "1" it disables short timeouts, expecting the peer to prompt the user for new credentials and resubmit the response.

The "cccccccccccccccc" is 16 hexadecimal digits representing an ASCII representation of a new challenge value. This field is optional. If it is not sent, the authenticator expects the resubmitted response to be calculated based on the previous challenge value plus decimal 23 in the first octet, i.e. the one immediately following the Value Size field. Windows 95 authenticators may send this field. Windows NT authenticators do not, but may in the future. Both systems implement peer support of this field.

The "vvvvvvvvvv" is the decimal version code (need not be 10 digits) indicating the MS-CHAP protocol version supported on the server. Currently, this is interesting only in selecting a Change Password packet type. If the field is not present the version should be assumed to be 1; since use of the version 1

Change Password packet has been deprecated, this field SHOULD always contain a value greater than or equal to 2.

Implementations should accept but ignore additional text they do not recognize.

9. Change Password Packet (version 1)

The version 1 Change Password packet does not appear in standard CHAP. It allows the peer to change the password on the account specified in the previous Response packet. The version 1 Change Password packet should be sent only if the authenticator reports ERROR_PASSWD_EXPIRED (E=648) and V is either missing or equal to one in the Message field of the Failure packet.

The use of the Change Password Packet (version 1) has been deprecated; the format of the packet is described here for informational purposes, but peers SHOULD NOT transmit it.

The format of this packet is as follows:

- 1 octet : Code (=5)
- 1 octet : Identifier
- 2 octets: Length (=72)
- 16 octets: Encrypted LAN Manager Old password Hash
- 16 octets: Encrypted LAN Manager New Password Hash
- 16 octets: Encrypted Windows NT Old Password Hash
- 16 octets: Encrypted Windows NT New Password Hash
- 2 octets: Password Length
- 2 octets: Flags

Code
5

Identifier
The Identifier field is one octet and aids in matching requests and replies. The value is the Identifier of the received Failure packet to which this packet responds plus 1.

Length
72

Encrypted LAN Manager New Password Hash
Encrypted LAN Manager Old Password Hash
These fields contain the LAN Manager password hash of the new and old passwords encrypted with the last received challenge value, as output by the routine LmEncryptedPasswordHash() (see section A.8, below).

Encrypted Windows NT New Password Hash

Encrypted Windows NT Old Password Hash

These fields contain the Windows NT password hash of the new and old passwords encrypted with the last received challenge value, as output by the pseudo-code routine

NtEncryptedPasswordHash() (see section A.10, below).

Password Length

The length in octets of the LAN Manager compatible form of the new password. If this value is greater than or equal to zero and less than or equal to 14 it is assumed that the encrypted LAN Manager password hash fields are valid. Otherwise, it is assumed these fields are not valid, in which case the Windows NT compatible passwords MUST be provided.

Flags

This field is two octets in length. It is a bit field of option flags where 0 is the least significant bit of the 16-bit quantity:

Bit 0

If this bit is set (1), it indicates that the encrypted Windows NT hashed passwords are valid and should be used. If this bit is cleared (0), the Windows NT fields are not used and the LAN Manager fields must be provided.

Bits 1-15

Reserved, always clear (0).

10. Change Password Packet (version 2)

The version 2 Change Password packet does not appear in standard CHAP. It allows the peer to change the password on the account specified in the preceding Response packet. The version 2 Change Password packet should be sent only if the authenticator reports ERROR_PASSWD_EXPIRED (E=648) and a version of 2 or greater in the Message field of the Failure packet.

This packet type is supported by Windows NT 3.51, 4.0 and recent versions of Windows 95. It is not supported by Windows NT 3.5 or early versions of Windows 95.

The format of this packet is as follows:

1 octet	: Code
1 octet	: Identifier
2 octets	: Length
516 octets	: Password Encrypted with Old NT Hash

16 octets : Old NT Hash Encrypted with New NT Hash
516 octets : Password Encrypted with Old LM Hash
16 octets : Old LM Hash Encrypted With New NT Hash
24 octets : LAN Manager compatible challenge response
24 octets : Windows NT compatible challenge response
2-octet : Flags

Code

6

Identifier

The Identifier field is one octet and aids in matching requests and replies. The value is the Identifier of the received Failure packet to which this packet responds plus 1.

Length

1118

Password Encrypted with Old NT Hash

This field contains the PWBLOCK form of the new Windows NT password encrypted with the old Windows NT password hash, as output by the `NewPasswordEncryptedWithOldNtPasswordHash()` routine (see section A.11, below).

Old NT Hash Encrypted with New NT Hash

This field contains the old Windows NT password hash encrypted with the new Windows NT password hash, as output by the `OldNtPasswordHashEncryptedWithNewNtPasswordHash()` routine (see section A.14, below).

Password Encrypted with Old LM Hash

This field contains the PWBLOCK form of the new Windows NT password encrypted with the old LAN Manager password hash, as output by the `NewPasswordEncryptedWithOldLmPasswordHash()` routine described in section A.15, below. Note, however, that the use of this field has been deprecated: peers SHOULD NOT generate it, and this field SHOULD be zero-filled.

Old LM Hash Encrypted With New NT Hash

This field contains the old LAN Manager password hash encrypted with the new Windows NT password hash, as output by the `OldLmPasswordHashEncryptedWithNewNtPasswordHash()` routine (see section A.16, below). Note, however, that the use of this field has been deprecated: peers SHOULD NOT generate it, and this field SHOULD be zero-filled.

LAN Manager compatible challenge response

Windows NT compatible challenge response

The challenge response field (as described in the Response packet description), but calculated on the new password and the same challenge used in the last response. Note that use of the LAN Manager compatible challenge response has been deprecated; peers SHOULD NOT generate it, and the field SHOULD be zero-filled.

Flags

This field is two octets in length. It is a bit field of option flags where 0 is the least significant bit of the 16-bit quantity. The format of this field is illustrated in the following diagram:

```

          1
5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+---+---+---+---+---+---+---+---+---+
|                                     | |
+---+---+---+---+---+---+---+---+---+
```

Bit 0

The "use Windows NT compatible challenge response" flag as described in the Response packet.

Bit 1

Set (1) indicates that the "Password Encrypted with Old LM Hash" and "Old LM Hash Encrypted With New NT Hash" fields are valid and should be used. Clear (0) indicates these fields are not valid. This bit SHOULD always be clear (0).

Bits 2-15

Reserved, always clear (0).

11. Security Considerations

As an implementation detail, the authenticator SHOULD limit the number of password retries allowed to make brute-force password guessing attacks more difficult.

Because the challenge value is encrypted using the password hash to form the response and the challenge is transmitted in clear-text form, both passive known-plaintext and active chosen-plaintext attacks against the password hash are possible. Suitable precautions (i.e., frequent password changes) SHOULD be taken in environments where eavesdropping is likely.

The Change Password (version 1) packet is vulnerable to a passive eavesdropping attack which can easily reveal the new password hash. For this reason, it MUST NOT be sent if eavesdropping is possible.

12. References

- [1] Simpson, W., "The Point-to-Point Protocol (PPP)", STD 51, RFC 1661, July 1994.
- [2] Simpson, W., "PPP Challenge Handshake Authentication Protocol (CHAP)", RFC 1994, August 1996.
- [3] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [4] "Data Encryption Standard (DES)", Federal Information Processing Standard Publication 46-2, National Institute of Standards and Technology, December 1993.
- [5] Rivest, R., "MD4 Message Digest Algorithm", RFC 1320, April 1992.
- [6] RC4 is a proprietary encryption algorithm available under license from RSA Data Security Inc. For licensing information, contact:
RSA Data Security, Inc.
100 Marine Parkway
Redwood City, CA 94065-1031
- [7] Eastlake, D., Crocker, S., and J. Schiller, "Randomness Recommendations for Security", RFC 1750, December 1994.
- [8] "The Unicode Standard, Version 2.0", The Unicode Consortium, Addison-Wesley, 1996. ISBN 0-201-48345-9.
- [9] "DES Modes of Operation", Federal Information Processing Standards Publication 81, National Institute of Standards and Technology, December 1980

13. Acknowledgements

Thanks (in no particular order) to Jeff Haag (Jeff_Haag@3com.com), Bill Palter (palter@network-alchemy.com), Bruce Johnson (bjohnson@microsoft.com), Tony Bell (tonybe@microsoft.com), Benoit Martin (ehlija@vircom.com), and Joe Davies (josephd@microsoft.com) for useful suggestions and feedback.

14. Chair's Address

The PPP Extensions Working Group can be contacted via the current chair:

Karl Fox
Ascend Communications
3518 Riverside Drive
Suite 101
Columbus, OH 43221

Phone: +1 614 326 6841
EMail: karl@ascend.com

15. Authors' Addresses

Questions about this memo can also be directed to:

Glen Zorn
Microsoft Corporation
One Microsoft Way
Redmond, Washington 98052

Phone: +1 425 703 1559
Fax: +1 425 936 7329
EMail: glennz@microsoft.com

Steve Cobb
Microsoft Corporation
One Microsoft Way
Redmond, Washington 98052

EMail: stevec@microsoft.com

Appendix A - Pseudocode

The routines mentioned in the text are described in pseudocode below.

A.1 LmChallengeResponse()

```
LmChallengeResponse(
  IN  8-octet      Challenge,
  IN  0-to-14-oem-char Password,
  OUT 24-octet      Response )
{
  LmPasswordHash( Password, giving PasswordHash )
  ChallengeResponse( Challenge, PasswordHash, giving Response )
}
```

A.2 LmPasswordHash()

```
LmPasswordHash(
  IN  0-to-14-oem-char Password,
  OUT 16-octet      PasswordHash )
{
  Set UcasePassword to the uppercased Password
  Zero pad UcasePassword to 14 characters

  DesHash( 1st 7-octets of UcasePassword,
            giving 1st 8-octets of PasswordHash )

  DesHash( 2nd 7-octets of UcasePassword,
            giving 2nd 8-octets of PasswordHash )
}
```

A.3 DesHash()

```
DesHash(
  IN  7-octet Clear,
  OUT 8-octet Cypher )
{
  /*
   * Make Cypher an irreversibly encrypted form of Clear by
   * encrypting known text using Clear as the secret key.
   * The known text consists of the string
   *
   *          KGS!@#$$%
   */

  Set StdText to "KGS!@#$$%"
}
```

```
    DesEncrypt( StdText, Clear, giving Cypher )
}
```

A.4 DesEncrypt()

```
DesEncrypt(
  IN  8-octet Clear,
  IN  7-octet Key,
  OUT 8-octet Cypher )
{
  /*
   * Use the DES encryption algorithm [4] in ECB mode [9]
   * to encrypt Clear into Cypher such that Cypher can
   * only be decrypted back to Clear by providing Key.
   * Note that the DES algorithm takes as input a 64-bit
   * stream where the 8th, 16th, 24th, etc. bits are
   * parity bits ignored by the encrypting algorithm.
   * Unless you write your own DES to accept 56-bit input
   * without parity, you will need to insert the parity bits
   * yourself.
   */
}
```

A.5 NtChallengeResponse()

```
NtChallengeResponse(
  IN  8-octet          Challenge,
  IN  0-to-256-unicode-char Password,
  OUT 24-octet         Response )
{
  NtPasswordHash( Password, giving PasswordHash )
  ChallengeResponse( Challenge, PasswordHash, giving Response )
}
```

A.6 NtPasswordHash()

```
NtPasswordHash(
  IN  0-to-256-unicode-char Password,
  OUT 16-octet          PasswordHash )
{
  /*
   * Use the MD4 algorithm [5] to irreversibly hash Password
   * into PasswordHash. Only the password is hashed without
   * including any terminating 0.
   */
}
```

```
}
```

A.7 ChallengeResponse()

```
ChallengeResponse(  
  IN  8-octet  Challenge,  
  IN  16-octet PasswordHash,  
  OUT 24-octet Response )  
{  
  Set ZPasswordHash to PasswordHash zero-padded to 21 octets  
  
  DesEncrypt( Challenge,  
              1st 7-octets of ZPasswordHash,  
              giving 1st 8-octets of Response )  
  
  DesEncrypt( Challenge,  
              2nd 7-octets of ZPasswordHash,  
              giving 2nd 8-octets of Response )  
  
  DesEncrypt( Challenge,  
              3rd 7-octets of ZPasswordHash,  
              giving 3rd 8-octets of Response )  
}
```

A.8 LmEncryptedPasswordHash()

```
LmEncryptedPasswordHash(  
  IN  0-to-14-oem-char Password,  
  IN  8-octet          KeyValue,  
  OUT 16-octet          Cypher )  
{  
  LmPasswordHash( Password, giving PasswordHash )  
  
  PasswordHashEncryptedWithBlock( PasswordHash,  
                                   KeyValue,  
                                   giving Cypher )  
}
```

A.9 PasswordHashEncryptedWithBlock()

```
PasswordHashEncryptedWithBlock(  
  IN  16-octet PasswordHash,  
  IN  8-octet  Block,  
  OUT 16-octet Cypher )  
{
```

```

    DesEncrypt( 1st 8-octets PasswordHash,
                1st 7-octets Block,
                giving 1st 8-octets Cypher )

    DesEncrypt( 2nd 8-octets PasswordHash,
                1st 7-octets Block,
                giving 2nd 8-octets Cypher )
}

```

A.10 NtEncryptedPasswordHash()

```

NtEncryptedPasswordHash( IN 0-to-14-oem-char Password IN 8-octet
Challenge OUT 16-octet Cypher ) {
    NtPasswordHash( Password, giving PasswordHash )

    PasswordHashEncryptedWithBlock( PasswordHash,
                                    Challenge,
                                    giving Cypher )
}

```

A.11 NewPasswordEncryptedWithOldNtPasswordHash()

```

datatype-PWBLOCK
{
    256-unicode-char Password
    4-octets PasswordLength
}

NewPasswordEncryptedWithOldNtPasswordHash(
IN 0-to-256-unicode-char NewPassword,
IN 0-to-256-unicode-char OldPassword,
OUT datatype-PWBLOCK EncryptedPwBlock )
{
    NtPasswordHash( OldPassword, giving PasswordHash )

    EncryptPwBlockWithPasswordHash( NewPassword,
                                    PasswordHash,
                                    giving EncryptedPwBlock )
}

```

A.12 EncryptPwBlockWithPasswordHash()

```

EncryptPwBlockWithPasswordHash(
IN 0-to-256-unicode-char Password,
IN 16-octet PasswordHash,

```

```

OUT datatype-PWBLOCK      PwBlock )
{
    Fill ClearPwBlock with random octet values
    PwSize = lstrlenW( Password ) * sizeof( unicode-char )
    PwOffset = sizeof( ClearPwBlock.Password ) - PwSize
    Move PwSize octets to (ClearPwBlock.Password + PwOffset ) from Passwor
d
    ClearPwBlock.PasswordLength = PwSize
    Rc4Encrypt( ClearPwBlock,
                sizeof( ClearPwBlock ),
                PasswordHash,
                sizeof( PasswordHash ),
                giving PwBlock )
}

```

A.13 Rc4Encrypt()

```

Rc4Encrypt(
IN  x-octet Clear,
IN  integer ClearLength,
IN  y-octet Key,
IN  integer KeyLength,
OUT x-octet Cypher )
{
    /*
    * Use the RC4 encryption algorithm [6] to encrypt Clear of
    * length ClearLength octets into a Cypher of the same length
    * such that the Cypher can only be decrypted back to Clear
    * by providing a Key of length KeyLength octets.
    */
}

```

A.14 OldNtPasswordHashEncryptedWithNewNtPasswordHash()

```

OldNtPasswordHashEncryptedWithNewNtPasswordHash(
IN  0-to-256-unicode-char NewPassword,
IN  0-to-256-unicode-char OldPassword,
OUT 16-octet               EncryptedPasswordHash )
{
    NtPasswordHash( OldPassword, giving OldPasswordHash )
    NtPasswordHash( NewPassword, giving NewPasswordHash )
    NtPasswordHashEncryptedWithBlock( OldPasswordHash,
                                      NewPasswordHash,
                                      giving EncryptedPasswordHash )
}

```

A.15 NewPasswordEncryptedWithOldLmPasswordHash()

```
NewPasswordEncryptedWithOldLmPasswordHash(
  IN  0-to-256-unicode-char NewPassword,
  IN  0-to-256-unicode-char OldPassword,
  OUT datatype-PWBLOCK      EncryptedPwBlock )
{
  LmPasswordHash( OldPassword, giving PasswordHash )

  EncryptPwBlockWithPasswordHash( NewPassword, PasswordHash,
                                   giving EncryptedPwBlock )
}
```

A.16 OldLmPasswordHashEncryptedWithNewNtPasswordHash()

```
OldLmPasswordHashEncryptedWithNewNtPasswordHash(
  IN  0-to-256-unicode-char NewPassword,
  IN  0-to-256-unicode-char OldPassword,
  OUT 16-octet              EncryptedPasswordHash )
{
  LmPasswordHash( OldPassword, giving OldPasswordHash )

  NtPasswordHash( NewPassword, giving NewPasswordHash )

  NtPasswordHashEncryptedWithBlock( OldPasswordHash, NewPasswordHash,
                                     giving EncryptedPasswordHash )
}
```

A.17 NtPasswordHashEncryptedWithBlock()

```
NtPasswordHashEncryptedWithBlock(
  IN  16-octet PasswordHash,
  IN  16-octet Block,
  OUT 16-octet Cypher )
{
  DesEncrypt( 1st 8-octets PasswordHash,
              1st 7-octets Block,
              giving 1st 8-octets Cypher )

  DesEncrypt( 2nd 8-octets PasswordHash,
              2nd 7-octets Block,
              giving 2nd 8-octets Cypher )
}
```


Appendix B - Examples

B.1 Negotiation Examples

Here are some examples of typical negotiations. The peer is on the left and the authenticator is on the right.

The packet sequence ID is incremented on each authentication retry Response and on the change password response. All cases where the packet sequence ID is updated are noted below.

Response retry is never allowed after Change Password. Change Password may occur after Response retry. The implied challenge form is shown in the examples, though all cases of "first challenge+23" should be replaced by the "C=cccccccccccccccc" challenge if authenticator supplies it in the Failure packet.

B.1.1 Successful authentication

```
<- Challenge
Response ->
<- Success
```

B.1.2 Failed authentication with no retry allowed

```
<- Challenge
Response ->
<- Failure (E=691 R=0)
```

B.1.3 Successful authentication after retry

```
<- Challenge
Response ->
<- Failure (E=691 R=1), disable short timeout
Response (++ID) to first challenge+23 ->
<- Success
```

B.1.4 Failed hack attack with 3 attempts allowed

```
<- Challenge
Response ->
<- Failure (E=691 R=1), disable short timeout
Response (++ID) to first challenge+23 ->
<- Failure (E=691 R=1), disable short timeout
Response (++ID) to first challenge+23+23 ->
```

```
<- Failure (E=691 R=0)
```

B.1.5 Successful authentication with password change

```
<- Challenge
Response ->
  <- Failure (E=648 R=0 V=2), disable short timeout
ChangePassword (++ID) to first challenge ->
  <- Success
```

B.1.6 Successful authentication with retry and password change

```
<- Challenge
Response ->
  <- Failure (E=691 R=1), disable short timeout
Response (++ID) to first challenge+23 ->
  <- Failure (E=648 R=0 V=2), disable short timeout
ChangePassword (++ID) to first challenge+23 ->
  <- Success
```

B.2 Hash Example

Intermediate values for password "MyPw".

8-octet Challenge:

10 2D B5 DF 08 5D 30 41

0-to-256-unicode-char NtPassword:

4D 00 79 00 50 00 77 00

16-octet NtPasswordHash:

FC 15 6A F7 ED CD 6C 0E DD E3 33 7D 42 7F 4E AC

24-octet NtChallengeResponse:

4E 9D 3C 8F 9C FD 38 5D 5B F4 D3 24 67 91 95 6C
A4 C3 51 AB 40 9A 3D 61

B.3 Example of DES Key Generation

DES uses 56-bit keys, expanded to 64 bits by the insertion of parity bits. After the parity of the key has been fixed, every eighth bit is a parity bit and the number of bits that are set (1) in each octet is odd; i.e., odd parity. Note that many DES engines do not check parity, however, simply stripping the parity bits. The following example illustrates the values resulting from the use of the 16-octet NTPasswordHash shown in Appendix B.2 to generate a pair of DES keys

(e.g., for use in the NtPasswordHashEncryptedWithBlock() described in Appendix A.17).

16-octet NtPasswordHash:

FC 15 6A F7 ED CD 6C 0E DD E3 33 7D 42 7F 4E AC

First "raw" DES key (initial 7 octets of password hash):

FC 15 6A F7 ED CD 6C

First parity-corrected DES key (eight octets):

FD 0B 5B 5E 7F 6E 34 D9

Second "raw" DES key (second 7 octets of password hash)

0E DD E3 33 7D 42 7F

Second parity-corrected DES key (eight octets):

0E 6E 79 67 37 EA 08 FE

Full Copyright Statement

Copyright (C) The Internet Society (1998). All Rights Reserved.

This document and translations of it may be copied and furnished to others, and derivative works that comment on or otherwise explain it or assist in its implementation may be prepared, copied, published and distributed, in whole or in part, without restriction of any kind, provided that the above copyright notice and this paragraph are included on all such copies and derivative works. However, this document itself may not be modified in any way, such as by removing the copyright notice or references to the Internet Society or other Internet organizations, except as needed for the purpose of developing Internet standards in which case the procedures for copyrights defined in the Internet Standards process must be followed, or as required to translate it into languages other than English.

The limited permissions granted above are perpetual and will not be revoked by the Internet Society or its successors or assigns.

This document and the information contained herein is provided on an "AS IS" basis and THE INTERNET SOCIETY AND THE INTERNET ENGINEERING TASK FORCE DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

