Introduction to SMB 3.1

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The SMB3.1 preview document is available online
Agenda

1. Extensible Negotiation
2. Preauthentication Integrity
3. Encryption Improvements
4. Cluster Dialect Fencing
5. Cluster Client Failover (CCF) v2
6. Questions
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Overview

- Very few reserved bits remain in the negotiate request / response messages.
  - How to negotiate complex connection capabilities?
- SMB 3.1 Extensible Negotiation
  - Extend negotiate request/response via negotiate contexts (same idea as existing create contexts).
  - Repurpose reserved fields in negotiate request / response as NegotiateContextOffset and NegotiateContextCount fields.
  - Add list of negotiate contexts to end of existing negotiate request / response messages.
## Negotiate Contexts

### SMB2 Negotiate Request / Response

- **NegotiateContextOffset**
- **NegotiateContextCount**

<table>
<thead>
<tr>
<th>Byte 0</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>DataLength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data (DataLength) …</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data payload is determined by ID.

Padding (if necessary) to 8-byte-align negotiate contexts.
Key Points

- Server processes negotiate contexts if the request’s `Dialects` array indicates support for SMB 3.1.
- Server responds with negotiate contexts only if the response’s `DialectRevision` is SMB 3.1.
- Receiver must ignore negotiate contexts it doesn’t understand.
- SMB 2/3 server implementations MUST be willing to accept negotiate requests that are larger than the `SMB2_HEADER + SMB2_REQ_NEGOTIATE + Dialects` array.
  - Client does not know whether a server supports SMB 3.1. Must assume that it does and send negotiate contexts.
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Overview

- Preauthentication messages (negotiate and session setup) are vulnerable to tampering.
- SMB 3.0x Negotiate Validation doesn’t protect negotiate contexts or session setup.
- How to provide end-to-end protection in a way that accommodates future protocol revisions?
- SMB 3.1 Preauthentication Integrity
  - Input hash of the preauthentication message exchanges to KDF when deriving a session’s secret keys.
  - Message signature validation/decryption will fail in case of preauthentication message tampering.
Selecting a Hash Function

- SMB 3.1 client and server exchange mandatory negotiate contexts for each connection.
- Client’s negotiate context specifies a set of supported hash functions.
- Server’s negotiate context specifies the selected hash function.
- SHA-512 is currently the only supported hash function.
- Preimage attack resistance is provided by a salt value that the client and server generate via a secure PRNG per request/response.

SMB2_PREAMUTH_INTEGRITY_CAPABILITIES
(Negotiate Context ID: 0x0001)

<table>
<thead>
<tr>
<th>Byte 0</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>HashAlgorithmCount</td>
<td>SaltLength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HashAlgorithms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Computing the Hash Value

- N = 00…0
- N = H(H(N || Request) || Response)
  - S = N
  - S = H(S || Request)
  - S = H(S || Response)
  - ... S = H(S || Request)
- S = H(S || Request) || Response)
- Derive signing, crypto, app keys using S (next slide) and verify signature.

H(x): hash value of bit string x using the negotiated hash function
A || B: concatenation of bit strings A and B

Client

Server

Negotiate request
- N = H(N || Request)
  - N = H(N || Response)
  - S = N
  - S = H(S || Request)
  - S = H(S || Response)
  - ... S = H(S || Request)

Session setup request
- S = H(S || Request)
  - S = H(S || Response)
  - ... S = H(S || Request)

Derive signing, crypto, app keys using S (next slide)
Deriving Secret Keys from the Hash Value

\[ \text{DerivedKey} = \text{KDF}^1(\text{SessionKey}, \text{Label}^2, \text{Context}) \]

<table>
<thead>
<tr>
<th>Derived Key</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Key</td>
<td>“SMBAppKey”</td>
</tr>
<tr>
<td>Signing Key</td>
<td>“SMBSigningKey”</td>
</tr>
<tr>
<td>Client to server cipher key</td>
<td>“SMBC2SCipherKey”</td>
</tr>
<tr>
<td>Server to client cipher key</td>
<td>“SMBS2CCipherKey”</td>
</tr>
</tbody>
</table>

Session’s final preauthentication integrity hash value (S)

1. KDF is SP108-800-CTR-HMAC-SHA256 (same as SMB 3.0x)
2. Note that KDF labels have changed since SMB 3.0x
Security Analysis

Result of an attacker tampering with the exchange of negotiate and/or session setup messages between an SMB 3.1 client and an SMB 3.1 server based on the resulting connection’s SMB dialect.

<table>
<thead>
<tr>
<th>Connection Dialect</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Attack is detected when client fails to validate the signature of the final session setup response.</td>
</tr>
<tr>
<td>3.0x or 2.x</td>
<td>Attack is detected by SMB 3.0x Negotiate Validation upon first tree connect.</td>
</tr>
<tr>
<td>1.x</td>
<td>Attack succeeds! SMB 1.x has no MITM attack mitigations</td>
</tr>
</tbody>
</table>

Note that SMB 3.1 Preauthentication Integrity cannot protect anonymous or guest sessions. The client and server can’t sign messages without an authenticated context.
Key Points

- Preauthentication Integrity is mandatory for SMB 3.1.
- Session setup hashes are only calculated for master and binding session setup exchanges, not reauthentication.
- Preauthentication Integrity supersedes SMB 3.0x Negotiate Validation for SMB 3.1 connections.
- Preauthentication Integrity protects all future protocol revisions since hashing is message agnostic.
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Overview

- SMB 3.0x mandates the AES-128-CCM cipher
  - What if a different cipher is required for performance, regulatory requirements, etc?
- In SMB 3.1 ciphers are negotiated per-connection
  - Easily retire old ciphers and add new ciphers
- SMB 3.1 adds support for AES-128-GCM
  - More efficient encryption/decryption = higher IOPS/bandwidth
- SMB 3.1 clients can require a session to be encrypted even if server does not require encryption.
Selecting a Cipher

- SMB 3.1 client and server exchange negotiate contexts for each connection if they support encryption.

- Client’s negotiate context specifies a set of supported ciphers in order from most to least preferred.

- Server’s negotiate context specifies the selected cipher.
  - Selection policy is server’s choice: client-preferred, server-preferred, etc.
  - Reserved cipher ID 0x0000 indicates that the client and server have no common cipher.
  - No SMB2_ENCRYPTION_CAPABILITIES context in server response indicates that the server does not support encryption.

- Encryption capabilities flag is never set in an SMB 3.1 Negotiate Response.
### SMB2_TRANSFORM_HEADER Changes

<table>
<thead>
<tr>
<th>Byte 0</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProtocolId</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
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<td>...</td>
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<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonce</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OriginalMessageSize</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td>Flags</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SessionId</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nonce size determined by cipher:

<table>
<thead>
<tr>
<th>Cipher</th>
<th>Nonce Size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES-128-CCM</td>
<td>11</td>
</tr>
<tr>
<td>AES-128-GCM</td>
<td>12</td>
</tr>
</tbody>
</table>

EncryptionAlgorithm field renamed to Flags:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0001</td>
<td>Payload is encrypted using cipher negotiated for the connection</td>
</tr>
</tbody>
</table>
AES-GCM Performance

- 2.0x faster than AES-128-CCM encryption.
- 1.6x faster than AES-CMAC signing!

**Test configuration (client and server)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>2x Intel Xeon E5-2660 @ 2.2 GHz</td>
</tr>
<tr>
<td>Network</td>
<td>1x Intel Ethernet Server Adapter X520 @ 10 Gbps</td>
</tr>
<tr>
<td>Storage</td>
<td>SSD</td>
</tr>
<tr>
<td>Storage Workload</td>
<td>File copy (1 thread doing 8 async 1 MiB writes)</td>
</tr>
</tbody>
</table>
Client-mandated Encryption

- New security capability for security-hardened clients.
- Client sets the SMB2_SESSION_FLAG_ENCRYPT_DATA flag in its session setup request.
- Server acknowledges the encryption request by setting the SMB2_SESSION_FLAG_ENCRYPT_DATA flag in the session setup response.
- Server rejects all unencrypted requests for the session just as if the server had required encryption for the session.
Key Points

- AES-CCM required for SMB 3.0x crypto compatibility.
- AES-GCM provides significant performance gains.
- A session cannot be bound across channels that negotiated different ciphers.
  - Multichannel code has to be updated
- Client-mandated encryption depends on Preauthentication Integrity to guarantee secure connection.
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- All nodes in a cluster must support the same SMB dialects to allow a client to failover transparently between cluster nodes.
- How to allow clusters with nodes that support different maximum SMB dialects?
- SMB 3.1 Cluster Dialect Fencing
  - Define a cluster maximum SMB dialect
  - Fence access to cluster shares based on dialect.
  - Fenced clients instructed to reconnect at a cluster-supported dialect.
Fencing Clustered Tree Connects

An SMB 3.1 client accesses a clustered file share on an SMB 3.1 server that is a member of a cluster whose maximum clustered SMB dialect is 3.02.

1. Client negotiates 3.1, authenticates then issues tree connect.
2. Server determines that client is accessing a cluster share at an invalid dialect.
3. Server fails tree connect request with an extended error (status = 0xC05D0001) whose data payload indicates the maximum cluster-supported dialect (3.02).
4. Client disconnects, reconnects with new Client GUID, negotiates 3.02, authenticates, then reissues tree connect.
SMB2_TREE_CONNECT Request Changes

Once a client has successfully connected to a clustered share it must set the CLUSTER_RECONNECT (0x0001) flag on all subsequent clustered tree connect requests to the same server.

- Addresses a race condition when the cluster’s maximum SMB dialect is being raised.

### Reserved field renamed to Flags:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0001</td>
<td>Client has already successfully connected to a clustered file share on this server at the current SMB dialect.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Byte 0</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure Size</td>
<td>Flags</td>
<td>PathOffset</td>
<td>PathLength</td>
</tr>
<tr>
<td>Buffer</td>
<td>...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Key Points

- Dialect fencing only affects clustered share access.
  - Clients can still access non-clustered shares using SMB 3.1 even if the maximum cluster dialect is < 3.1.
  - Can’t mix clustered and non-clustered access on same connection.

- Client implementation should protect against infinite loop of tree connect failure, disconnect, reconnect, tree connect failure, …
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