Hash Chain: a Scalable Content Provenance and Integrity Verifying Protocol for NDN

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August 26, 2020

Problem Definition

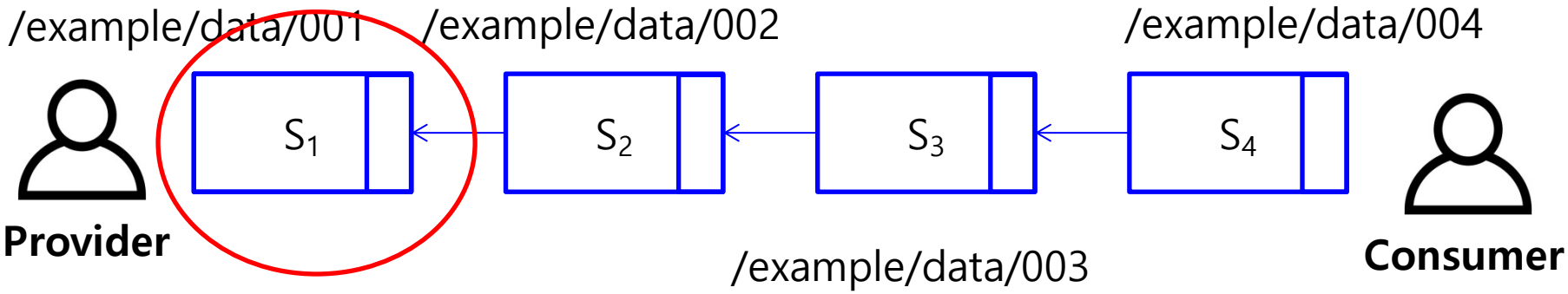
- The modern **server** usually has two **CPU** sockets on its motherboard. These **CPUs** usually start at 4 **cores** and go, as of 2015 for Intel Xeon, up to 18 **cores** per **CPU**. While 4-socket and larger **servers** exist, they are less common today. A two-socket **server** with 36 **cores** is an insane overkill for most applications as of 2015. – from Quora

- Hash Chain can only utilize one core which is could lead to poor performance even compared to RSA-with-SHA256.

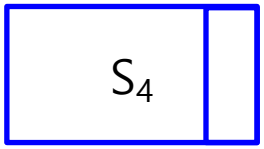
Hash Chain light-weight per-packet authentication

- Hash Chain (HC) has two mechanisms.
  - Batch Hash Chain: This is the default mode that guarantee the provenance upon receiving the packet. However, the provider needs to have the entire sequences before generating hash chain signatures.
  - Real-time Hash Chain: This is apt for real-time usage. However, this cannot guarantee the provenance until it receives the last packet. For example, traffic signal of vehicular networks, other real-time tactile IoT signals

Forward Chain Signature Generation Example



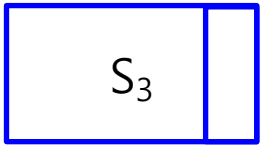
/example/data/004



$K_4 = H(name_4 \| data_4 \| 0x0000)$

$Null\_hash = H(0x00000000000000000000)$

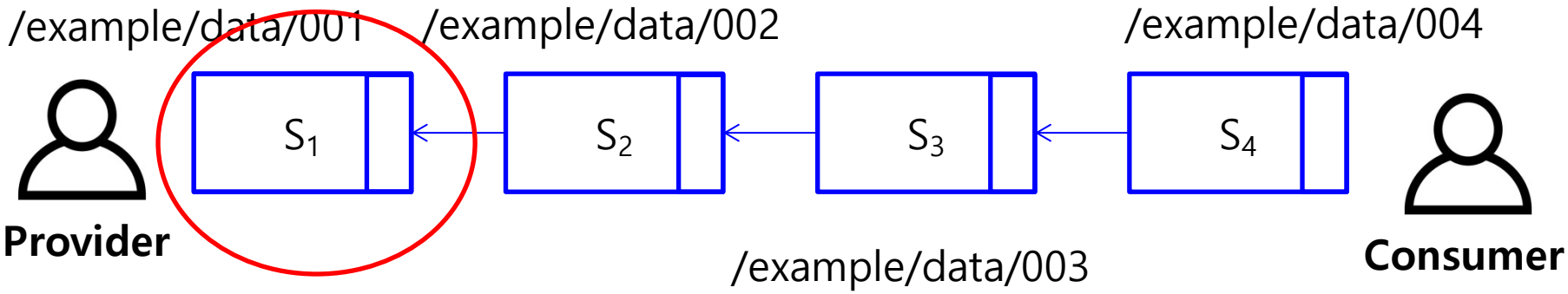
/example/data/003



$K_3 = H(name_3 \| data_3 \| k_4)$

$k_4 = 0x66970e0d57360fdd4835c80$

Forward Chain Signature Generation Example



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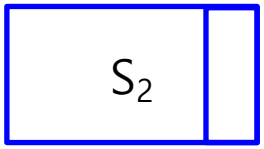
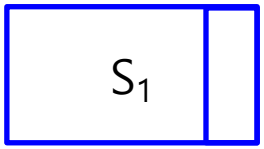


$K_2 = H(name_2 \| data_2 \| k_3)$

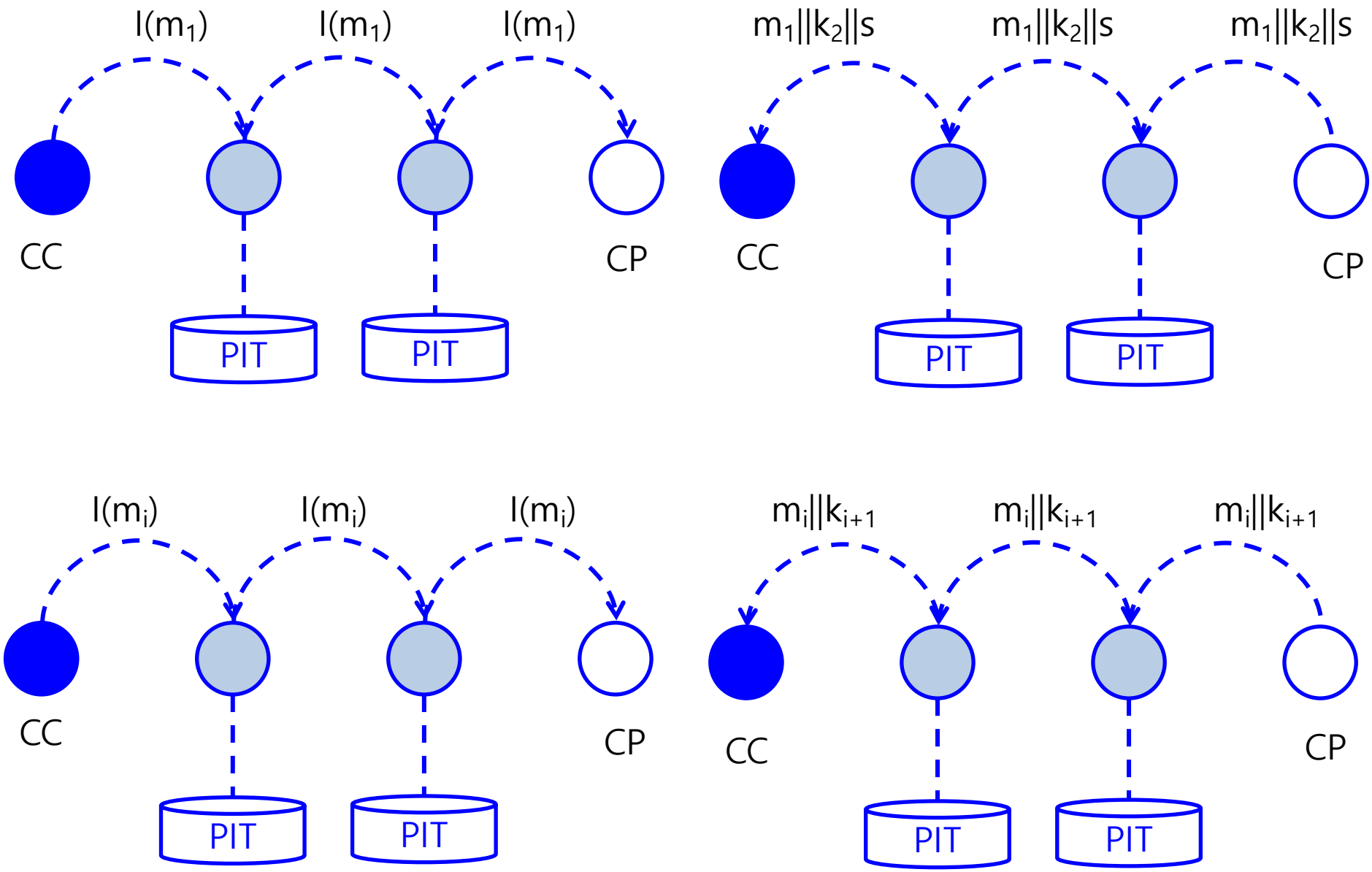
/example/data/001



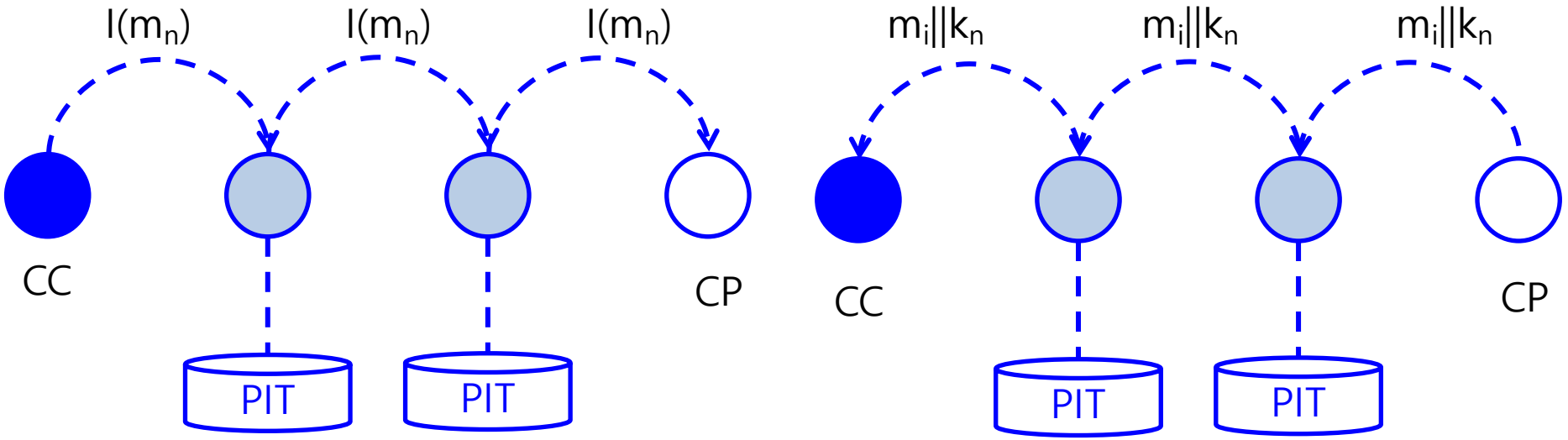
$K_1 = H(name_1 \| data_1 \| k_2)$

Forward Chain Signature Generation Example

- 0-step $m_1 = name_1 + data_1$
- (BC-1) $k_n = H(m_n \,||\, null\_hash)$
- (BC-2) $k_i = H(m_i \,||\, k_{i+1})$, all $n > i > 1$
- (BC-3) $k_1 = H(m_1 \,||\, k_2)$
- (BC-4) $RSA\_SIGN(PR_{CP,} K_1)$
- (BC-5) $S = E(PR_{CP}, K_{1,} K_n)$

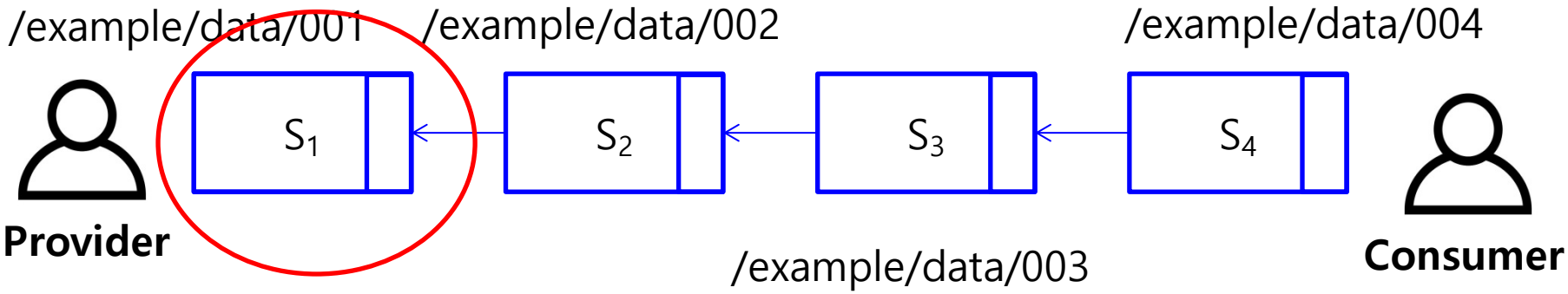


Propagation of Interest and Data packets for the Forward Hash Chain



Propagation of Interest and Data packets for the Forward Hash Chain

Forward Chain Signature Verification Example



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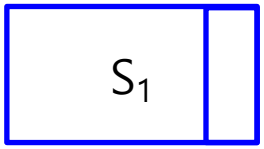
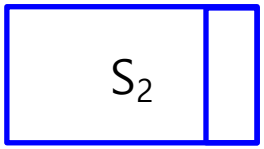


$K_{4,}\ K_1 = \text{Decrypt}(PUB_{CP,}\ S)$

$K_1 = H(name_1 \parallel data_1 \parallel k_2)$

If $K_1 == K_1'$: pass

/example/data/002

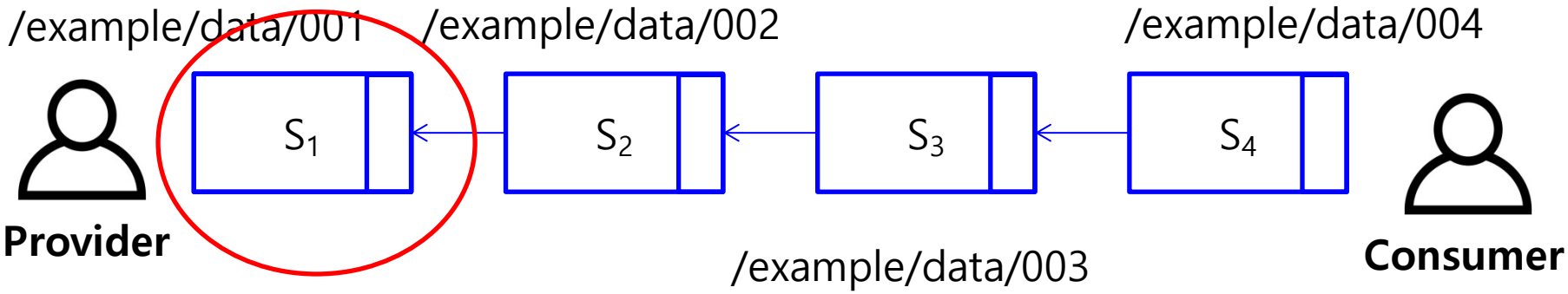


$K_2 = H(name_2 \parallel data_2 \parallel k_3)$

If $K_2 == K_2'$: pass

※ K_1' prime means calculated

Forward Chain Signature Verification Example



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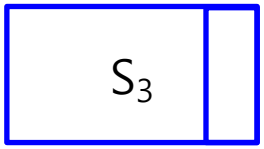
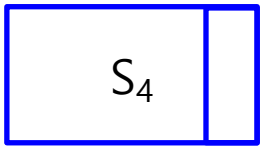


$K_1 = H(name_3 \| data_3 \| k_4)$

If $K_3 == K_3'$: pass

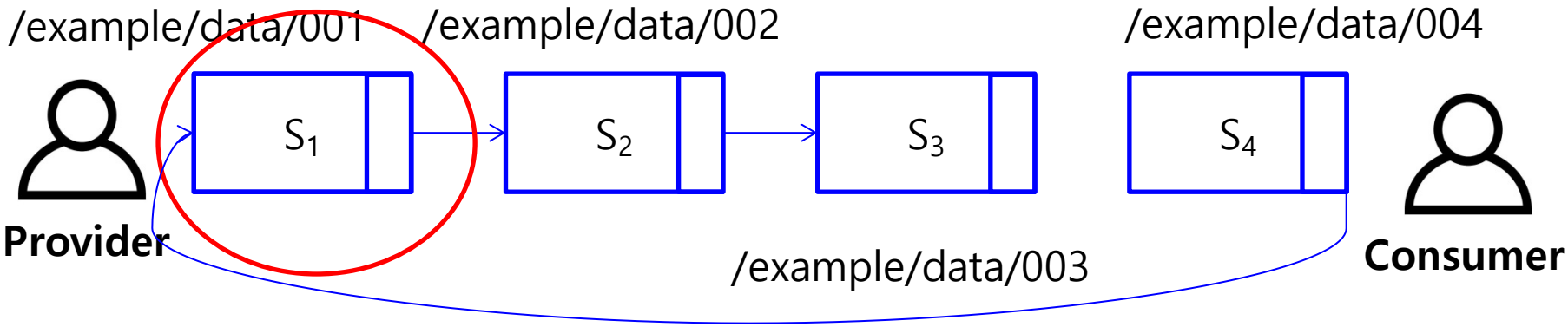
/example/data/004



$K_4 = H(name_4 \| data_4 \| null\_hash)$

If $K_4 == K_4'$: pass

Backward Chain Signature Generation Example



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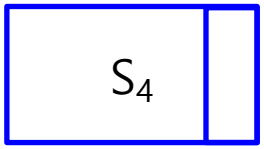

$K_4 = H(name_4 \| data_4 \| 0x0000)$

$Null\_hash = H(0x00000000000000000000)$

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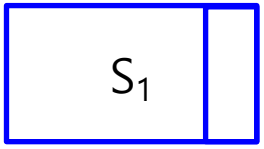
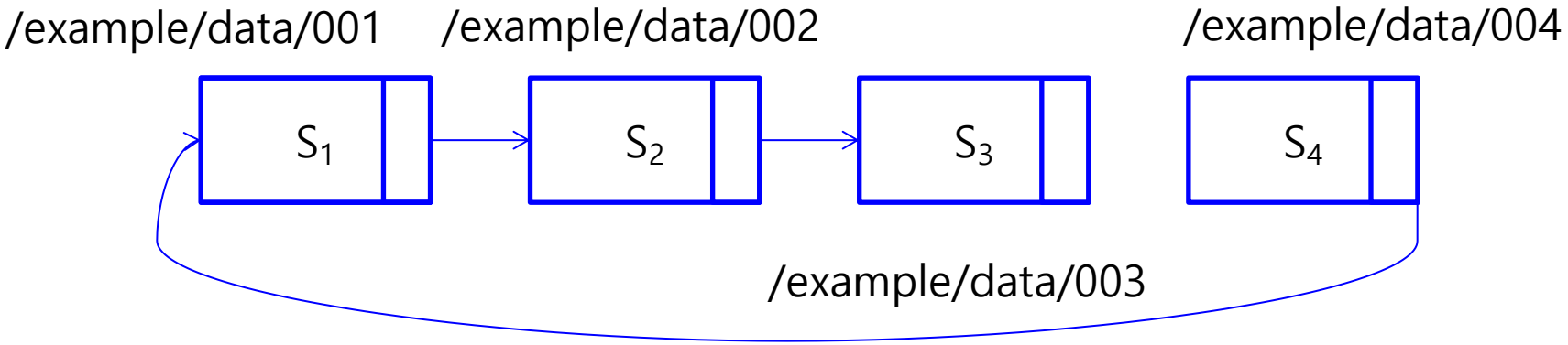


$K_1 = H(name_1 \| data_1 \| k_4)$

$k_4 = 0x66970e0d57360fdd4835c80$

Backward Chain Signature Generation Example



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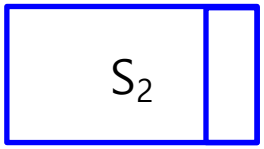
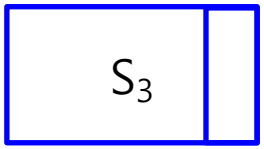


$K_2 = H(name_2 \| data_2 \| k_1)$

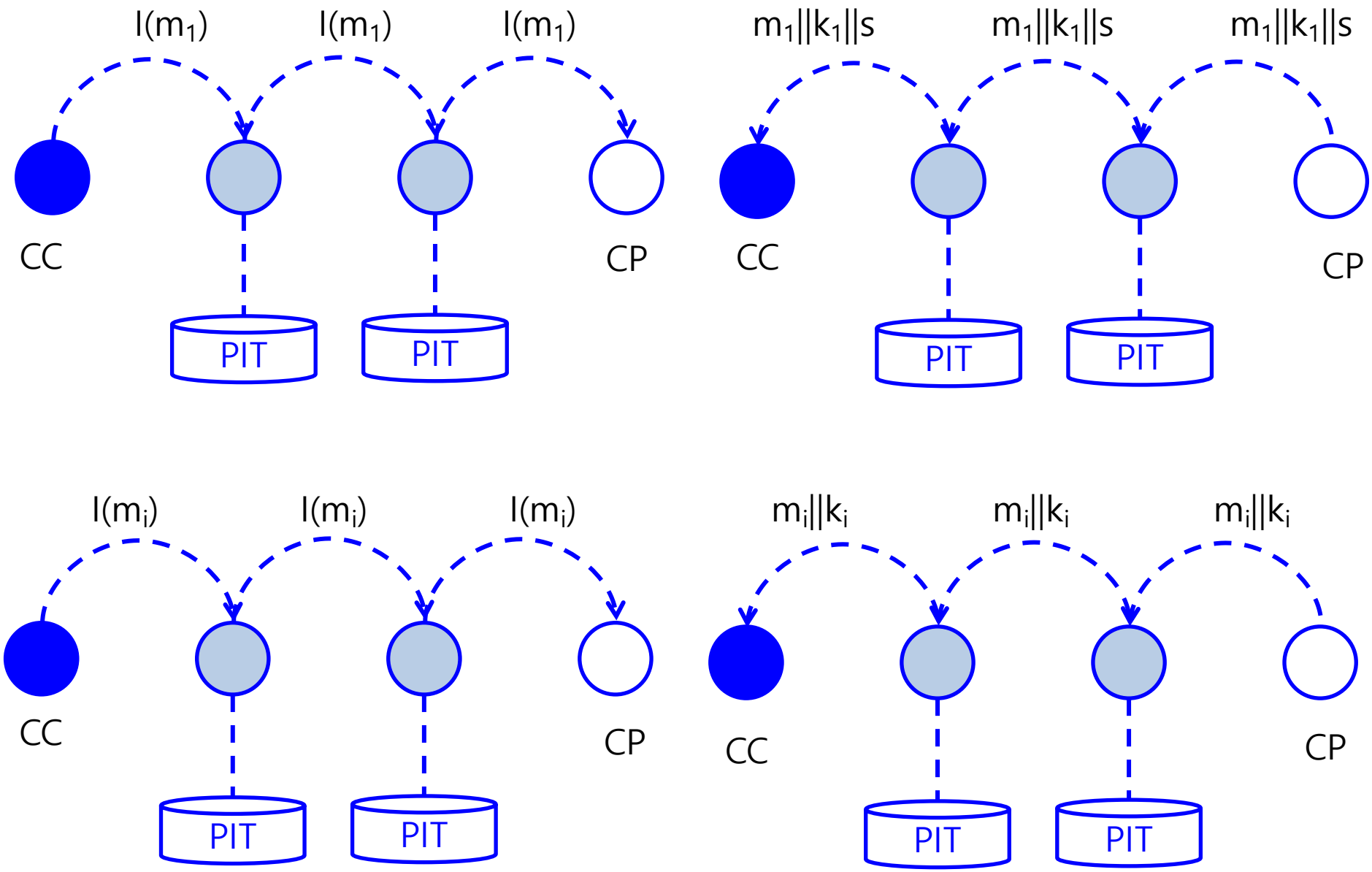
/example/data/003



$K_3 = H(name_3 \| data_3 \| k_2)$

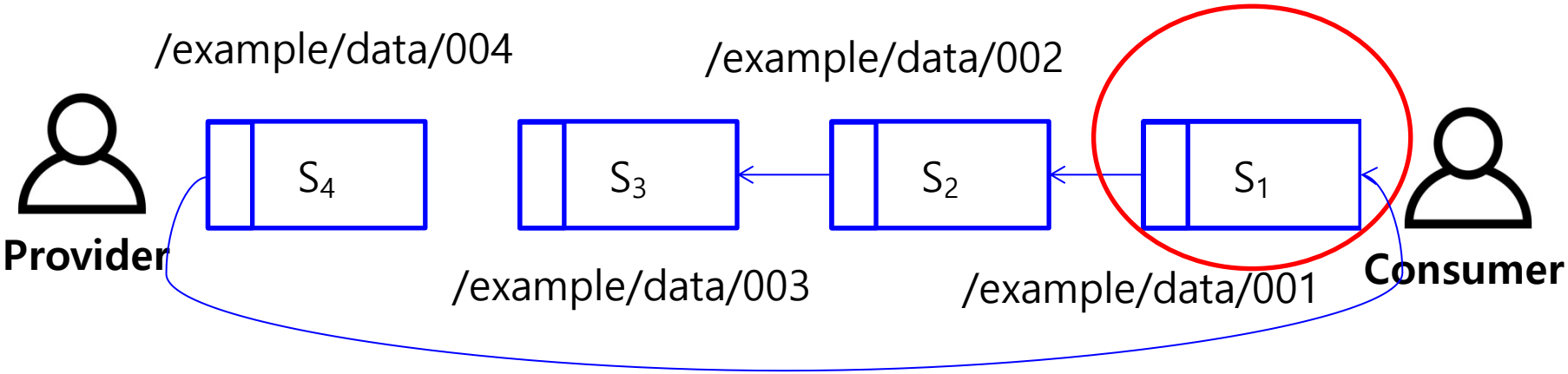
Backward Chain Signature Generation Example

- 0-step $m_1 = name_1 + data_1$
- (BC-1) $k_n = H(m_n \| null\_hash)$
- (BC-2) $k_1 = H(m_1 \| k_n)$
- (BC-3) $RSA\_SIGN(PR_{CP,} K_1)$ -> maybe required to hash one more time
- (BC-4) $k_i = H(m_i \| k_{i-1})$, all $n > i > 1$
- (BC-5) $S = E(PR_{CP}, K_{n,} K_{n-1})$

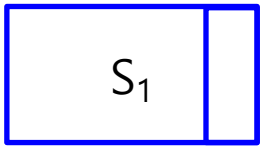


Propagation of Interest and Data packets for the Batch Hash Chain

Backward Chain Signature Verification Example



/example/data/001

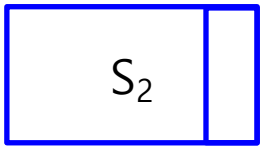


$K_4 = Decrypt(PUB_{CP}, S)$

$K_1 = H(name_1 \| data_1 \| k_4)$

If $K_1 == K_1'$: pass

/example/data/002

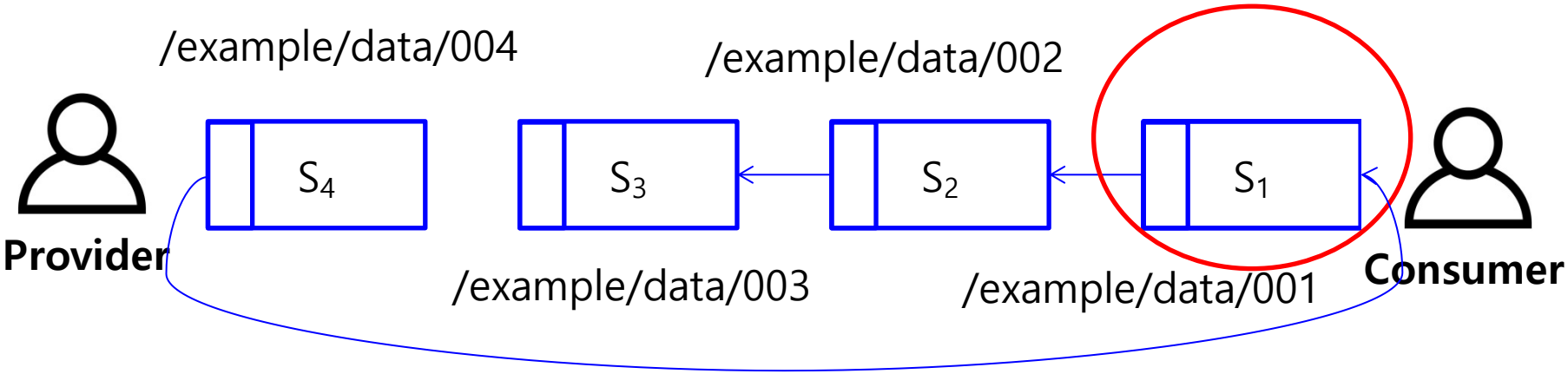


$K_2 = H(name_2 \| data_2 \| k_1)$

If $K_2 == K_2'$: delayed

※ K_1' prime means calculated

Backward Chain Signature Verification Example



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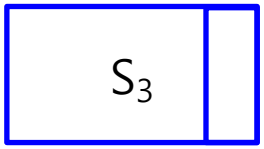
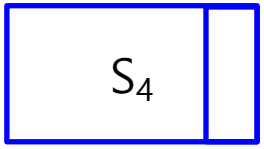


$K_1 = H(name_3 \| data_3 \| k_2)$

If $K_3 == K_3'$: pass

/example/data/004



$K_4 = H(name_4 \| data_4 \| null\_hash)$

If $K_4 == K_4'$: pass

Value	Reference	Description
0	DigestSha256	Integrity protection using SHA-256 digest
1	SignatureSha256WithRsa	Integrity and provenance protection using RSA signature over a SHA-256 digest
3	SignatureSha256WithEcdsa	Integrity and provenance protection using an ECDSA signature over a SHA-256 digest
4	SignatureHmacWithSha256	Integrity and provenance protection using SHA256 hash-based message authentication codes
5	SignatureSha256WithHashChain	Integrity and provenance protection using HashChain signature over a BLAKE3 digest
6	DigestBlake3	Integrity protection using Blake-3 digest
7	SignatureBlake3WithHashChain	Integrity and provenance protection using HashChain signature over a BLAKE3 digest
2,5-200		reserved for future assignments
>200		unassigned

BLAKE-3

- BLAKE-3 is compatible with SHA-256
  - https://github.com/BLAKE3-team/BLAKE3
  - https://github.com/BLAKE3-team/BLAKE3/tree/master/c
  - BLAKE3 is based on an optimized instance of the established hash function BLAKE2 and on the original Bao tree mode. The specifications and design rationale are available in the BLAKE3 paper. The default output size is 256 bits. The current version of Bao implements verified streaming with BLAKE3.

Implementation

- https://named-data.net/doc/NDN-packet-spec/current/signature.html
- Ndn-cxx HashChain
- ndn-cxx/ndn-cxx/security/
  - Along with signature-sha256-with-ecds
  - Digest-sha256
  - Digest-blake3
  - Signature-hash-chain-with-blake3
- Validation-policy and key-chain:
  - Make changes to validate hash chain
  - Make changes to validate Blake3

Conclusion

- Let's discuss!
- How to embed a Signature and keys
  - Signature in the data
  - (Data – size of signature)
  - Keys are placed as same as DigestSha256
  - https://named-data.net/doc/ndn-cxx/current/doxygen/d4/d08/sha256_8cpp_source.html