# TLS Batch Signing

Fun with Merkle trees

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# TLS handshake costs

- Key derivations and other symmetric crypto
  - Comparatively cheap
- (EC)DH operation
  - Ephemeral key with fast EC curve
- Signature with long-lived key
  - May be expensive
  - Faster algorithms may be unavailable (customer-provided RSA key)
  - Long-lived secrets may have extra protections (RPC to remote key, HSM, etc)

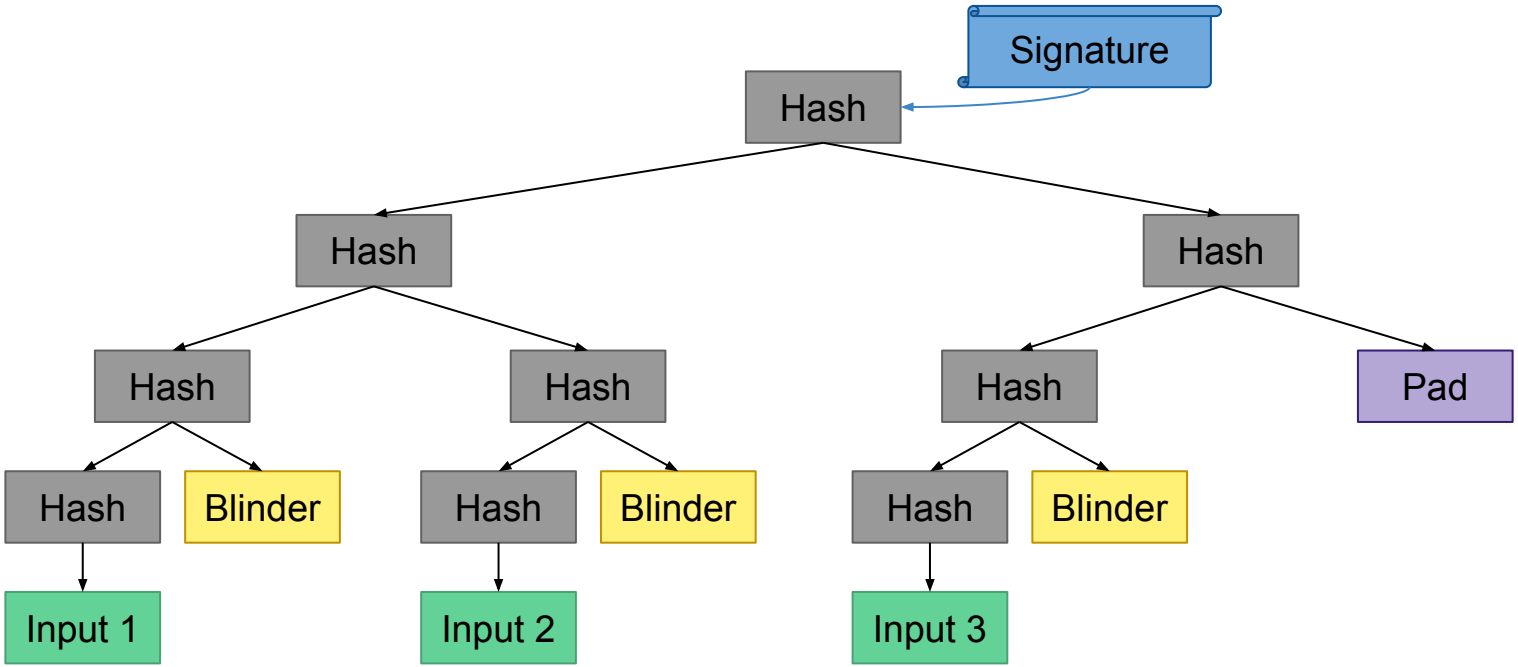
Can we lower the signature costs?

# Batch signatures

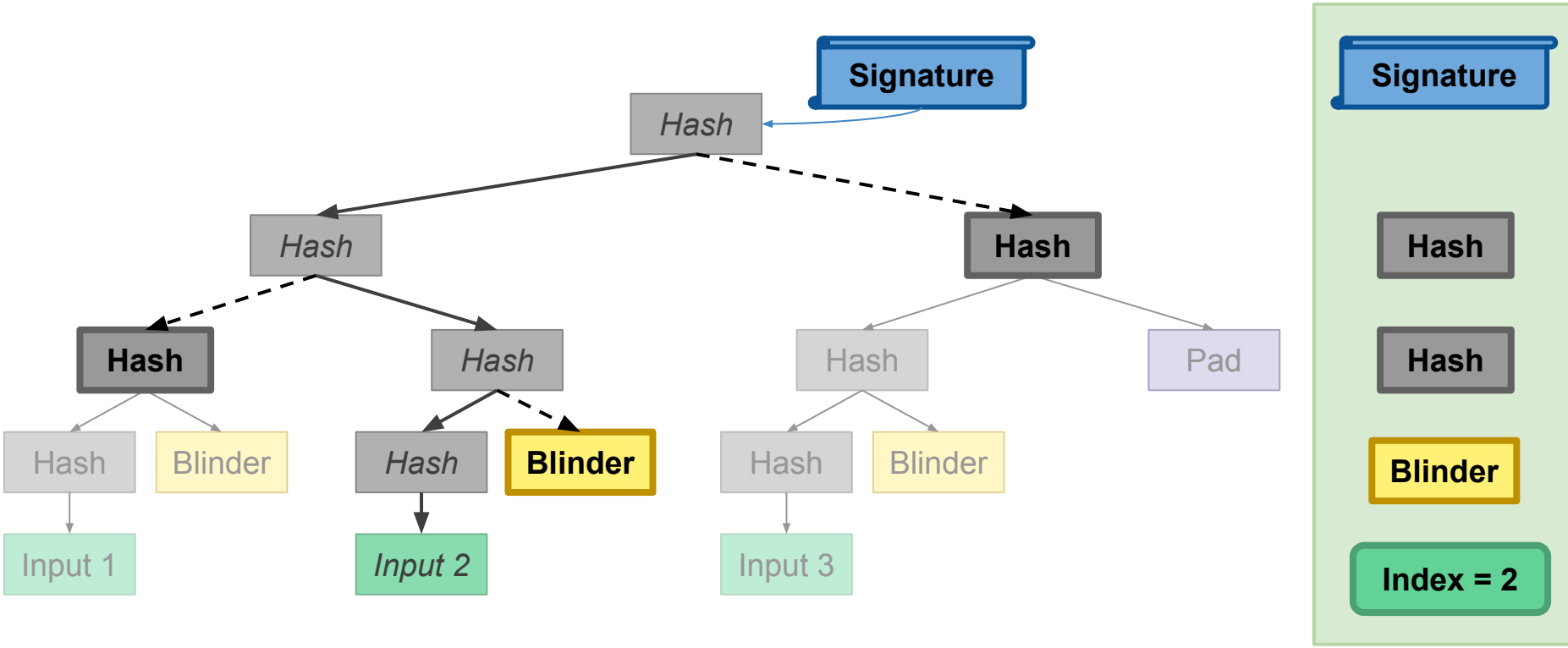
- Combine signing inputs into Merkle tree
- Sign the root once
- Ship Merkle tree paths to each client

```
HashLeaf(msg) = Hash(0x00 || msg)
HashNode(left, right) = Hash(0x01 || left || right)

opaque Node[Hash.length];

struct {
    uint32 index;
    Node path<Hash.length..2^16-1>;
    opaque root_signature<0..2^16-1>;
} BatchSignature;
```

# Example


Signature
Hash
Hash
Hash
Hash
Hash
Hash
Pad
Hash
Blinder
Hash
Blinder
Hash
Blinder
Input 1
Input 2
Input 3

# Signature for input 2



# Verifying

- Hash input
- Recompute root hash by hashing path nodes
  - Index determines whether to hash on left or right
- Verify signature against recomputed root

```
HashLeaf(msg) = Hash(0x00 || msg)
HashNode(left, right) = Hash(0x01 || left || right)

opaque Node[Hash.length];

struct {
    uint32 index;
    Node path<Hash.length..2^16-1>;
    opaque root_signature<0..2^16-1>;
} BatchSignature;
```

# Advertising support

- New SignatureScheme code points specify hash and base algorithm
  - ecdsa_secp256r1_sha256_batch
  - ecdsa_secp384r1_sha384_batch
  - ecdsa_secp521r1_sha512_batch
  - ed25519_batch
  - ed448_batch
  - rsa_pss_pss_sha256_batch
  - rsa_pss_rsae_sha256_batch

# Amortize signing costs

- While signer is busy, batch up inputs for the next signature
- N hashes multiplies signing capacity by $2^{N-1}$
  - 264 extra bytes in signature (using SHA-256) gives 128×
  - 360 extra bytes gives 1,024×
  - 680 extra bytes gives 1,048,576×...
- Signer and verifier TLS stacks must be modified
- Works with unmodified certificate and signing infrastructure
  - Only signing input changes
- Requires modified peers
  - Average load of existing deployments decreases if many peers support it
  - Under load, preferentially serve batchable peers as DoS mitigation

# Details

- Domain separation
  - Signing inputs preserve input context string
  - Root is signed with distinct context string
- Blinding nodes avoid leaking information about tree siblings
  - Signing payloads are potentially confidential with ESNI
  - Costs one hash output in batch signature size
- Padding nodes come from other nodes in tree level
- Reveals some information about signer load

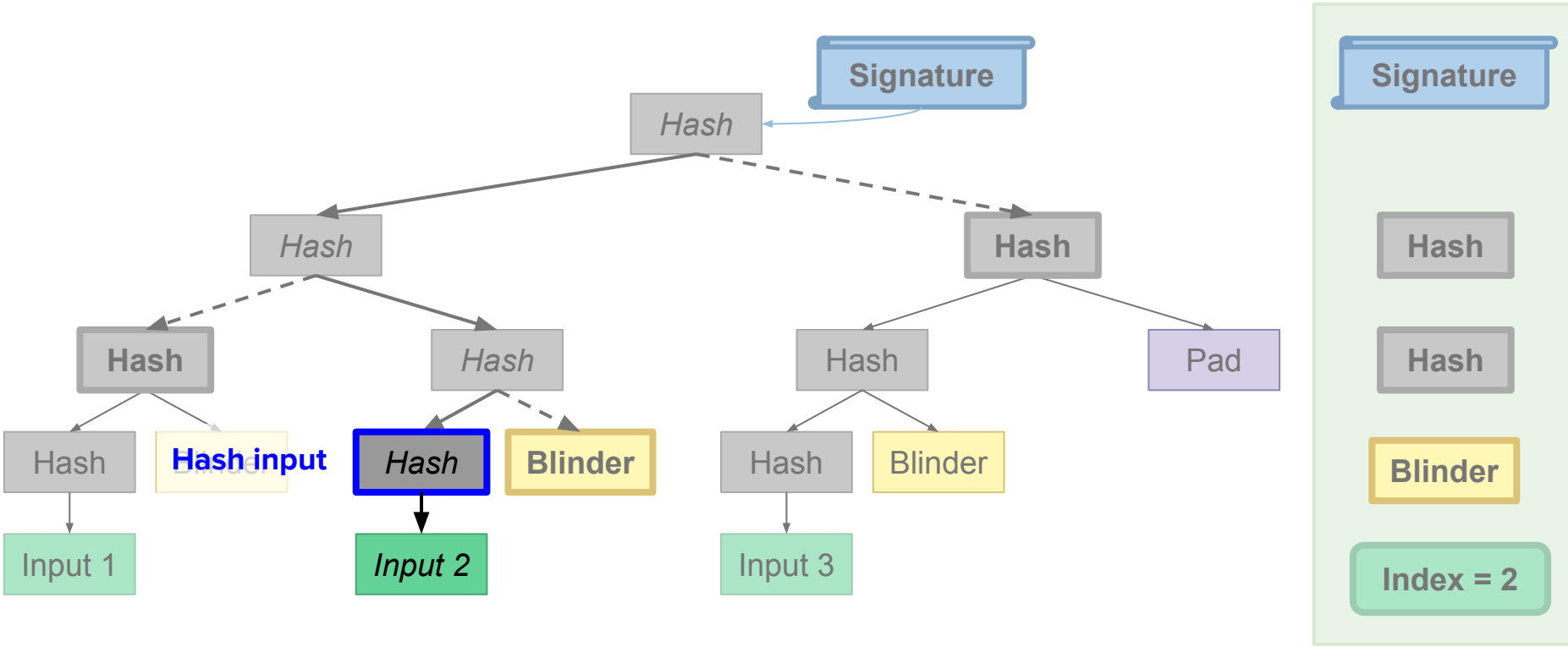
# Questions?

https://tools.ietf.org/html/draft-davidben-tls-batch-signing-02

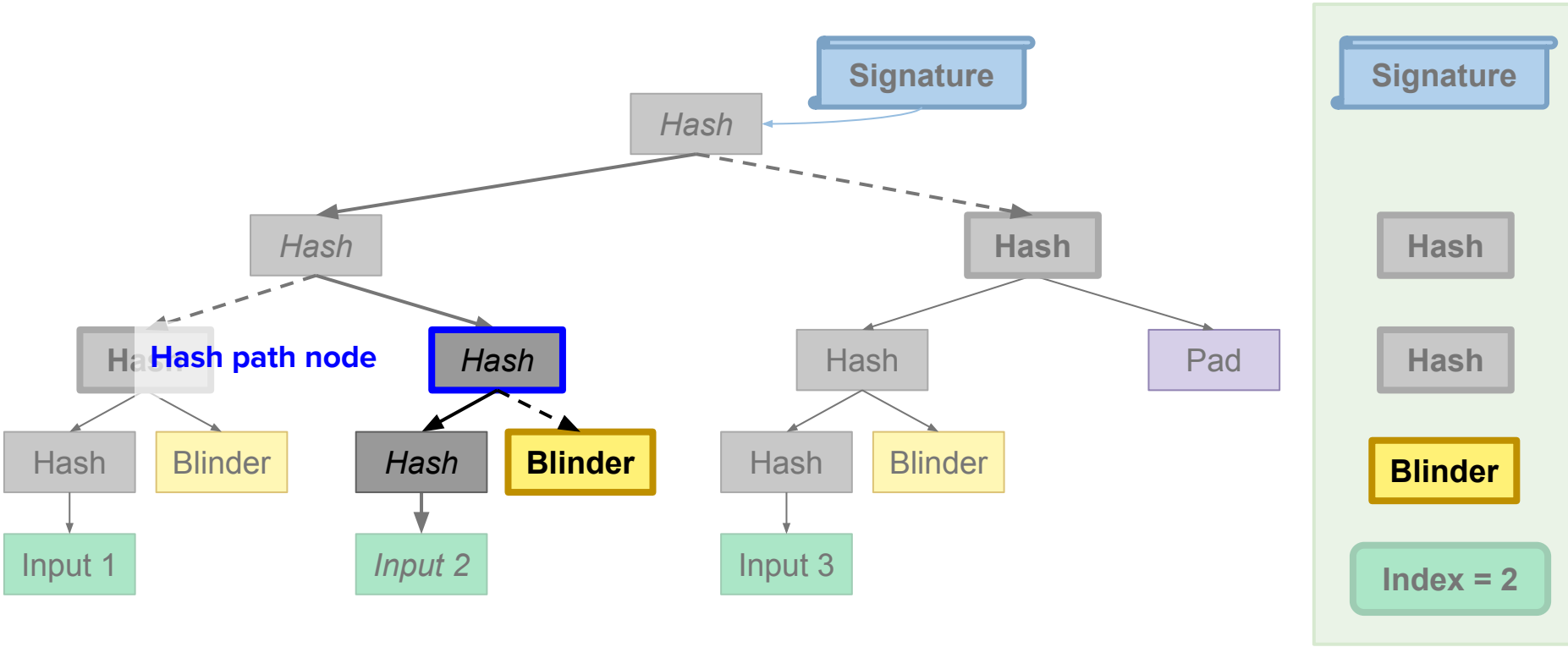
# Bonus slides

Gratuitous slide-based animation

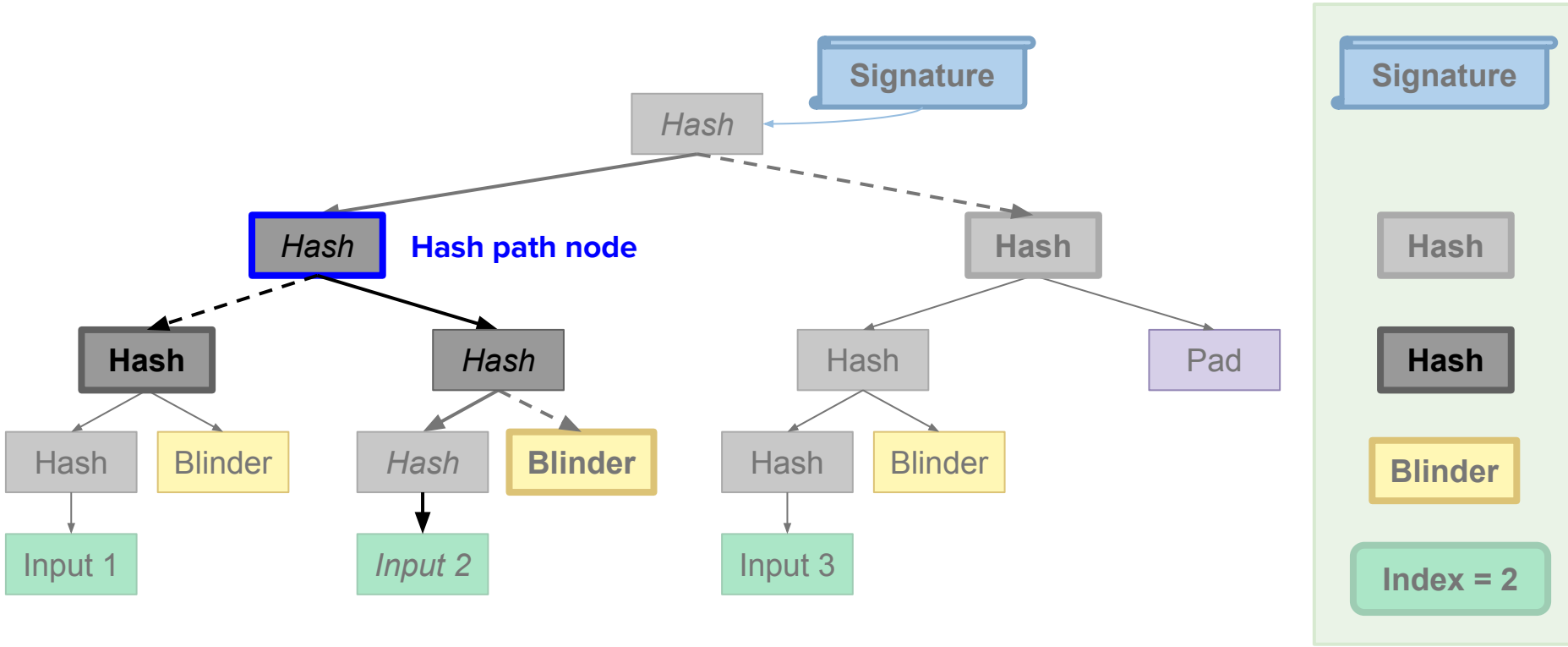
# Verifying signatures



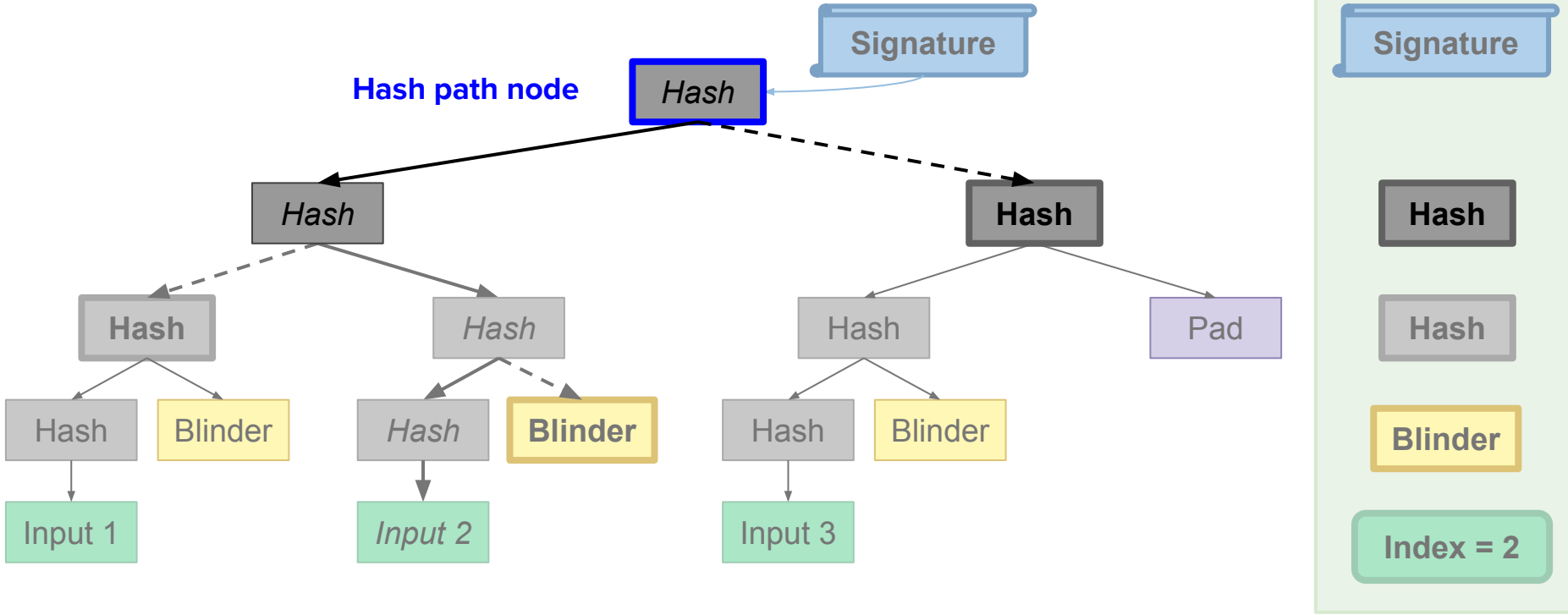
# Verifying signatures



# Verifying signatures



# Verifying signatures



# Verifying signatures