

Fed Up Getting Shattered and Log Jammed? **A New Generation of Crypto is Coming**

David Wong



Snefru

MD4



~~Snefru~~

MD4



~~Snefru~~

MD4

MD5

SHA-1

SHA-2

Merkle-Damgård



~~Snefru~~

~~MD4~~

~~MD5~~

Merkle-Damgård

SHA-1

SHA-2



~~Snefru~~

~~MD4~~

~~MD5~~

~~SHA-1~~

SHA-2

Merkle-Damgård



Collision Attack: Two Different Documents, But Same SHA-1 Hash Fingerprint

SHAttered

The first concrete collision attack against SHA-1
<https://shattered.io>



Marc Stevens
Pierre Karpman



Elie Bursztein
Ange Albertini
Yarik Markov

SHAttered

The first concrete collision attack against SHA-1
<https://shattered.io>



Marc Stevens
Pierre Karpman



Elie Bursztein
Ange Albertini
Yarik Markov

```
└─ sha1sum *.pdf
38762cf7f55934b34d179ae6a4c80cadccbb7f0a 1.pdf
38762cf7f55934b34d179ae6a4c80cadccbb7f0a 2.pdf
```

```
└─ /tmp/sha1
└─ sha256sum *.pdf
```

```
2bb787a73e37352f92383abe7e2902936d1059ad9f1ba6daaa9c1e58ee6970d0 1.pdf
```

0.64G 8-11h

~~Snefru~~

~~MD4~~

~~MD5~~

~~SHA-1~~

SHA-2

Merkle-Damgård



Computer Security Division

Computer Security Resource Center

[CSRC Home](#) [About](#) [Projects / Research](#) [Publications](#) [News & Events](#)

Cryptographic Hash & SHA-3 Standard Development

[Pre-SHA3 Competition \(2004-2007\)](#)

[SHA-3 Competition \(2007-2012\)](#)

[Submission Requirements](#)

[Round 1](#)

[Round 2](#)

[Round 3](#)

[SHA-3 Standardization \(2013-2015\)](#)

[SHA-3 Derived Functions \(2016\)](#)

[NIST Policy on Hash Functions](#)

[Hash Forum](#)

[Contacts](#)

[CSRC HOME](#) > [GROUPS](#) > [CT](#) > [HASH PROJECT](#) > [SHA-3](#)

SHA-3 COMPETITION (2007-2012)

[Research Results on SHA-1 Collisions \(2017\)](#)

NIST announced a public competition in a [Federal Register Notice](#) on November 2, 2007 to develop a new cryptographic hash algorithm, called SHA-3, for standardization. The competition was NIST's response to advances made in the cryptanalysis of hash algorithms.

NIST received sixty-four entries from cryptographers around the world by October 31, 2008, and selected fifty-one [first-round](#) candidates in December 2008, fourteen [second-round](#) candidates in July 2009, and five finalists – BLAKE, Grøstl, JH, Keccak and Skein, in December 2010 to advance to the [third and final round](#) of the competition.

Throughout the competition, the cryptographic community has provided an enormous amount of feedback. Most of the comments were sent to NIST and a public [hash forum](#); in addition, many of the cryptanalysis and performance studies were published as papers in major cryptographic conferences or leading cryptographic journals. NIST also hosted a SHA-3 candidate conference in each round to obtain public feedback. Based on the public comments and internal review of the candidates, [NIST announced Keccak as the winner](#) of the SHA-3 Cryptographic Hash Algorithm Competition on October 2, 2012, and ended the five-year competition.

Computer Security Division

Computer Security Resource Center

[CSRC Home](#) [About](#) [Projects / Research](#) [Publications](#) [News & Events](#)

Cryptographic Hash & SHA-3 Standard Development

[Pre-SHA3 Competition \(2004-2007\)](#)

[SHA-3 Competition \(2007-2012\)](#)

[Submission Requirements](#)

[Round 1](#)

[Round 1 Candidates](#)

[Round 1 Conference](#)

[Round 1 Report](#)

[Round 2](#)

[Round 3](#)

[SHA-3 Standardization \(2013- \)](#)

[NIST Policy on Hash Functions](#)

[Hash Forum](#)

[Contacts](#)

[CSRC HOME](#) > [GROUPS](#) > [CT](#) > [HASH PROJECT](#) > [SHA-3](#) > [ROUND 1](#)

FIRST ROUND CANDIDATES

Official comments on the First Round Candidate Algorithms should be submitted using the "Submit Comment" link for the appropriate algorithm. Comments from hash-forum listserv subscribers will also be forwarded to the hash-forum listserv. We will periodically post and update the comments received to the appropriate algorithm.

Please refrain from using OFFICIAL COMMENT to ask administrative questions, which should be sent to hash-function@nist.gov

By selecting the "Submitter's Website" links, you will be leaving NIST webspace. We have provided these links to other web sites because they may have information that would be of interest to you. No inferences should be drawn on account of other sites being referenced, or not, from this page. There may be other web sites that are more appropriate for your purpose. NIST does not necessarily endorse the views expressed, or concur with the facts presented on these sites. Further, NIST does not endorse any commercial products that may be mentioned on these sites.

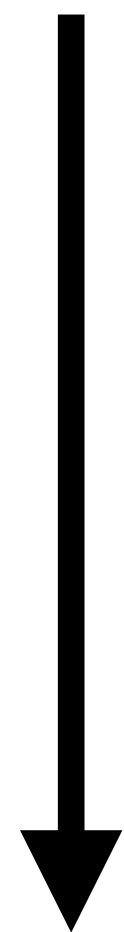
[History of Updates](#)

Algorithm Name	Principal Submitter*	Comments
** Abacus [9M]	Neil Sholer	Submit Comment View Comments
ARIRANG [18M] Updated Algorithm [16M] Submitter's Website***	Jongin Lim	Submit Comment View Comments
AURORA [12M] Updated Algorithm [11M]	Masahiro Fujita (Sony)	Submit Comment View Comments

Keccak

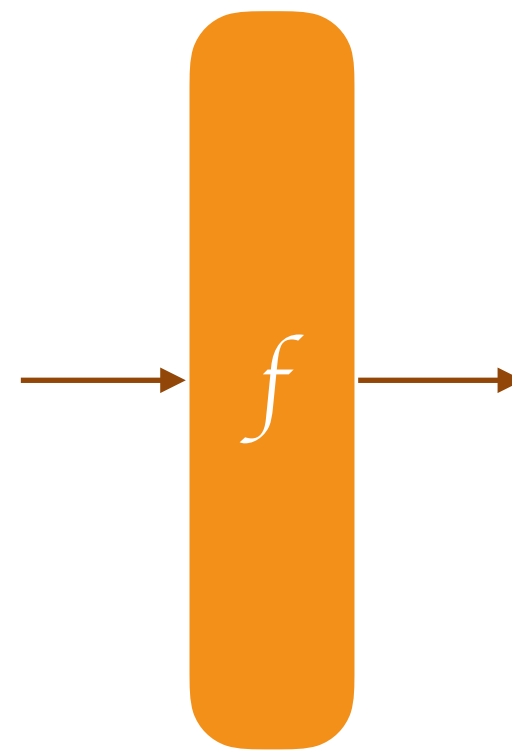
BLAKE, Grøstl, JH, Skein

outline

- 
1. Intro
 2. **SHA-3**
 3. Strobe, a protocol framework derived from SHA-3
 4. Noise, a full protocol framework not derived from SHA-3
 5. Strobe + Noise = Disco

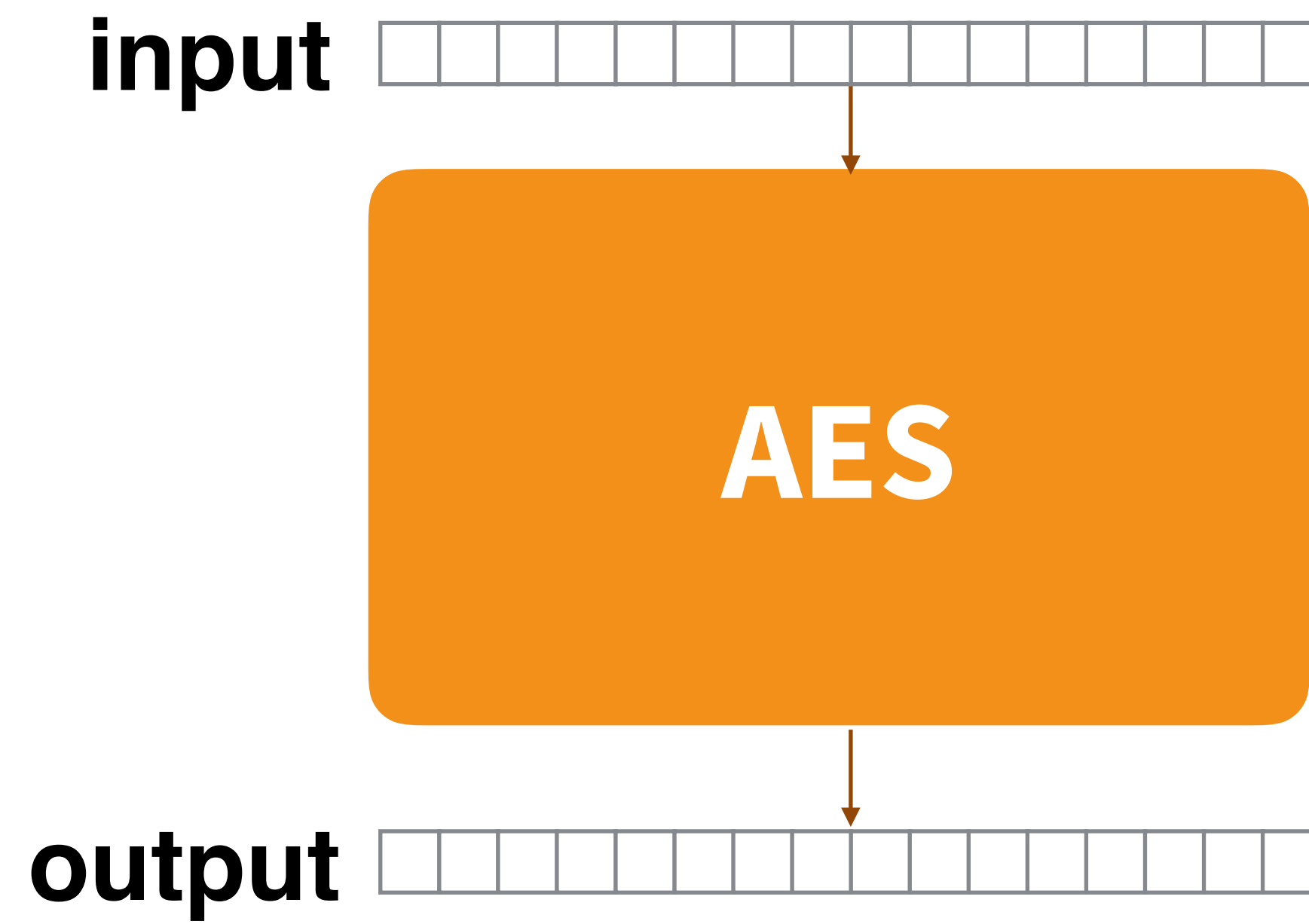
Part I: SHA-3

Big things have small beginnings

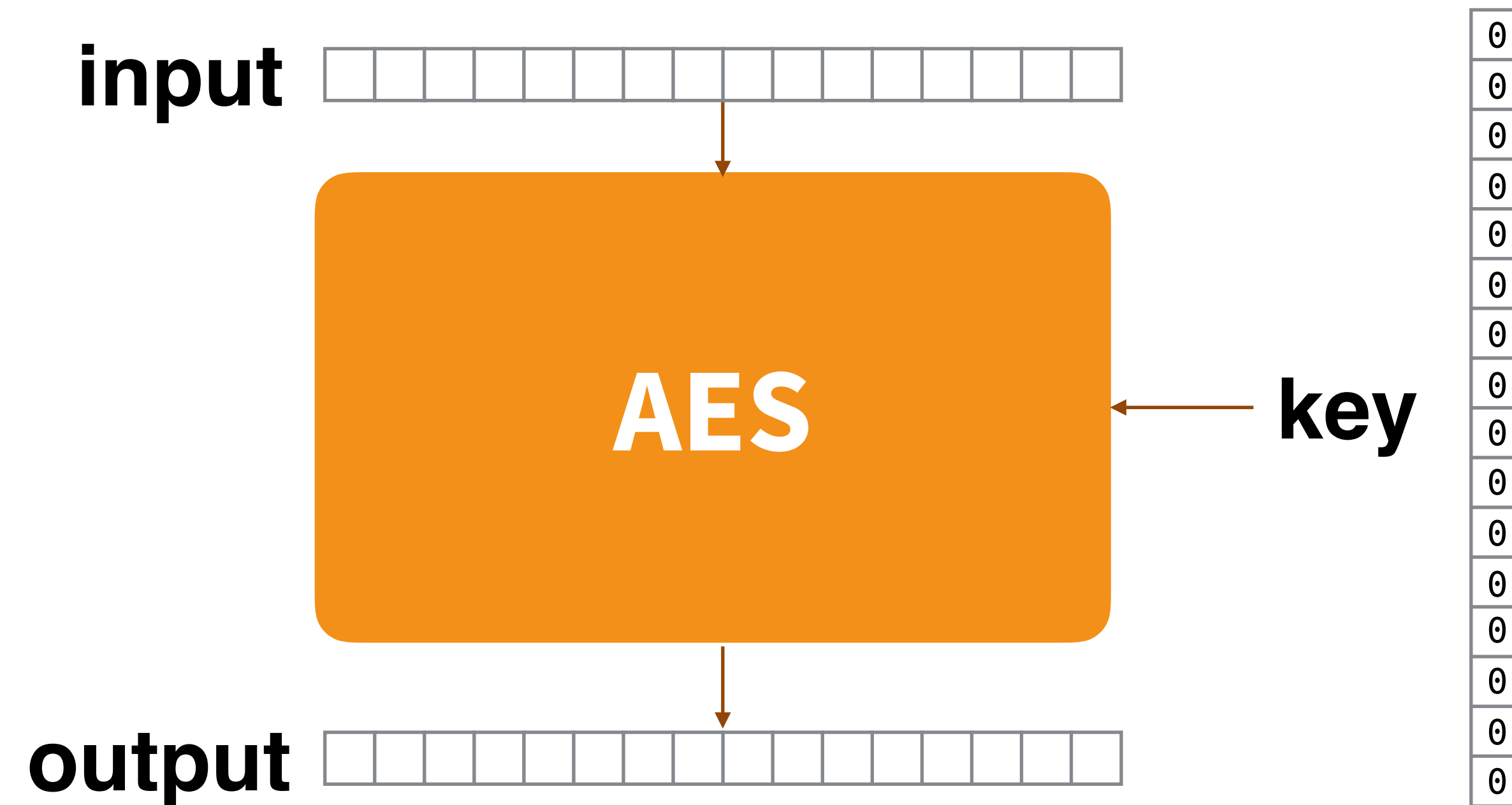


permutation-based cryptography

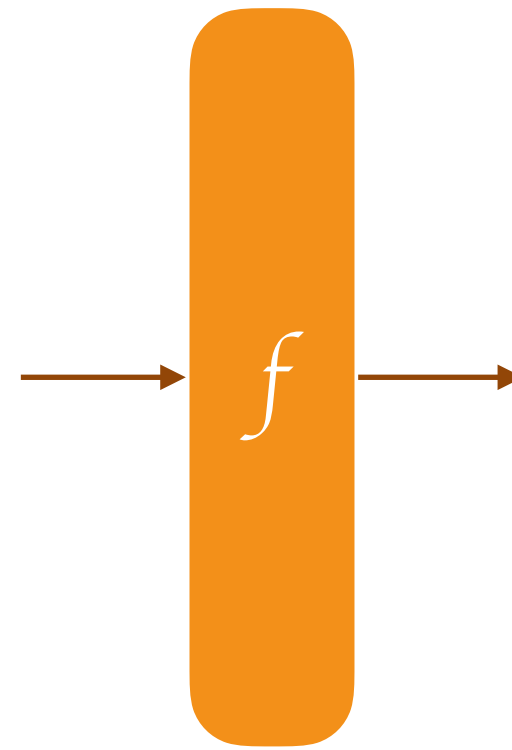
AES is a permutation



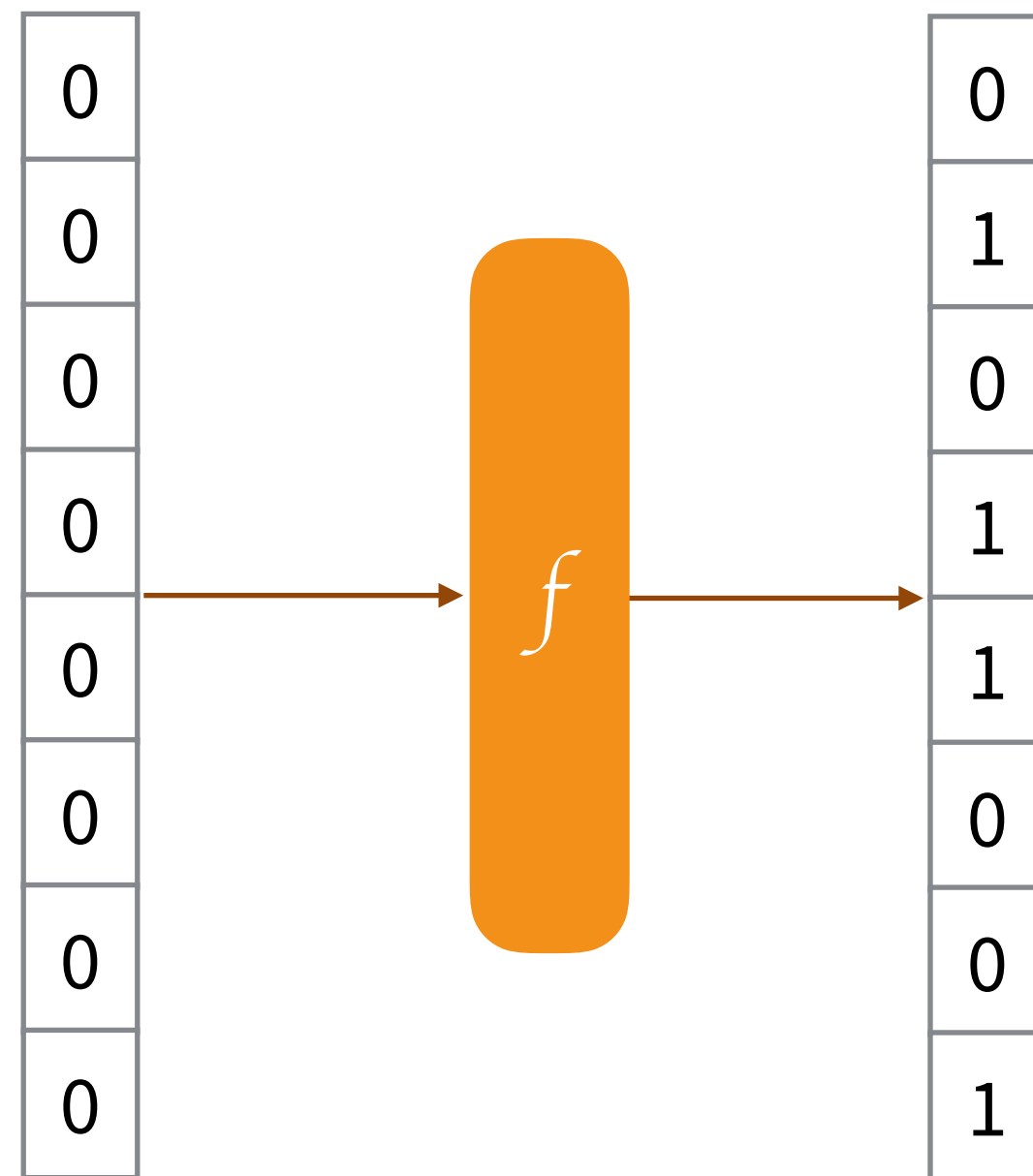
AES is a permutation



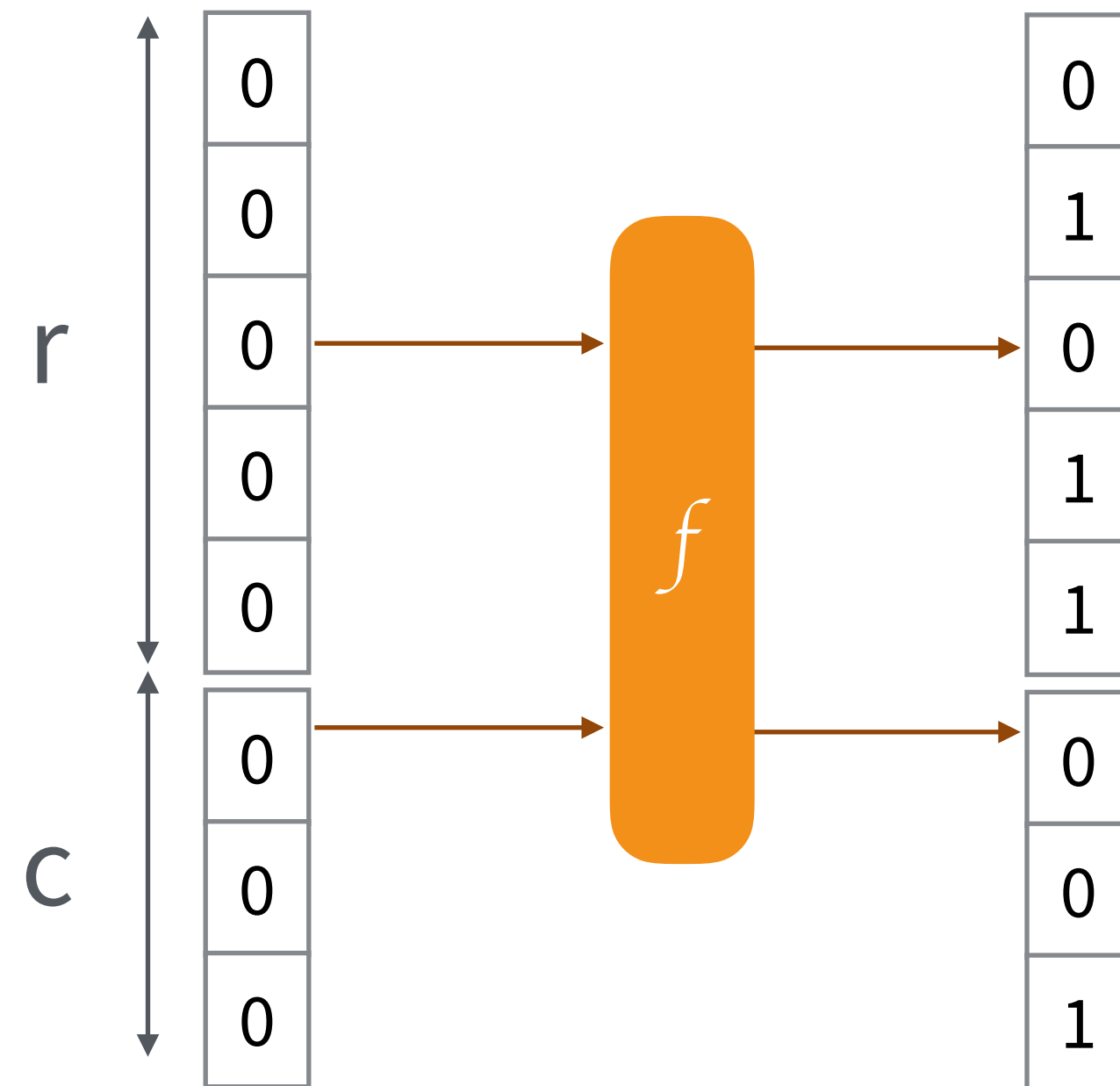
Sponge Construction



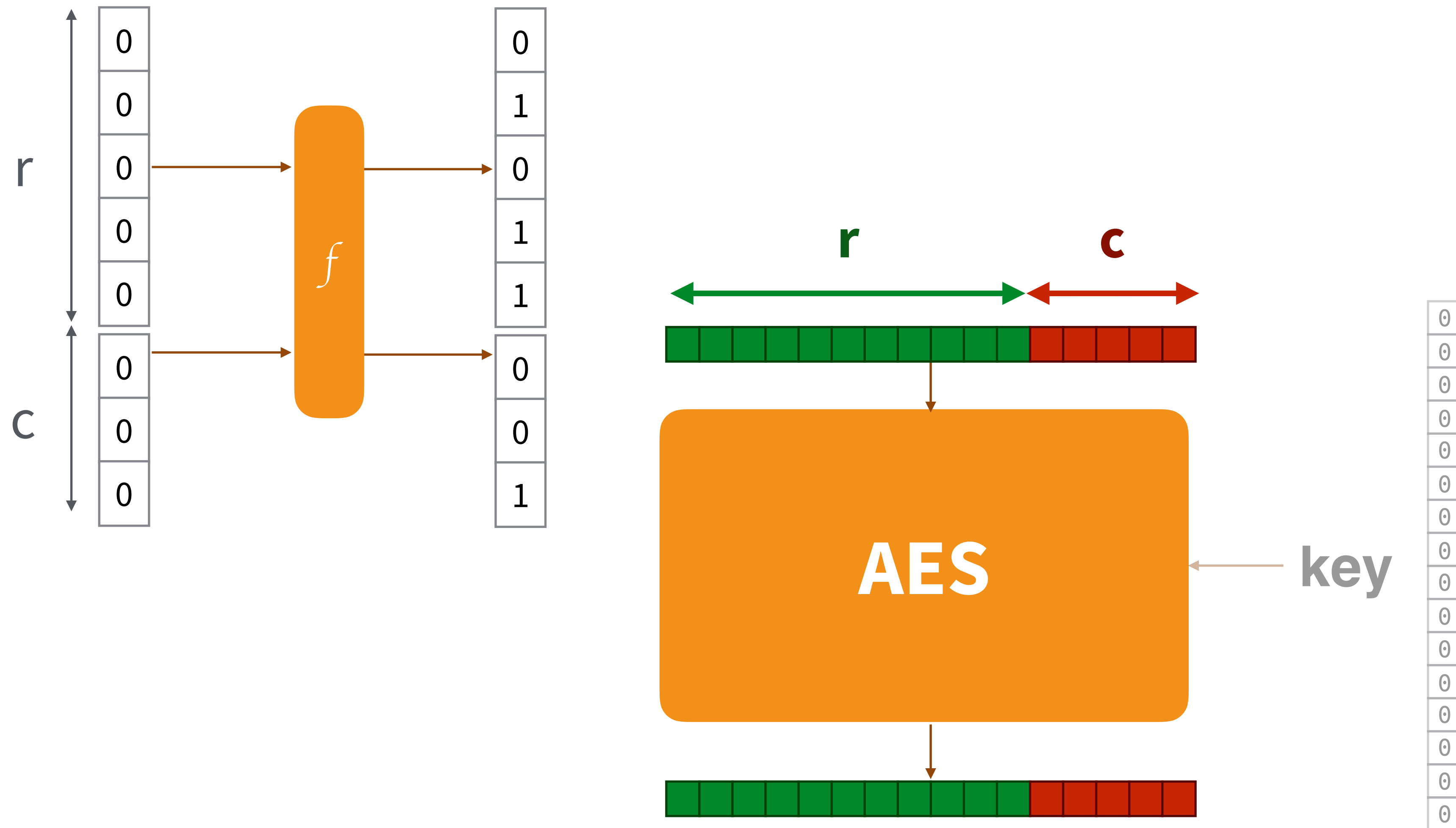
Sponge Construction



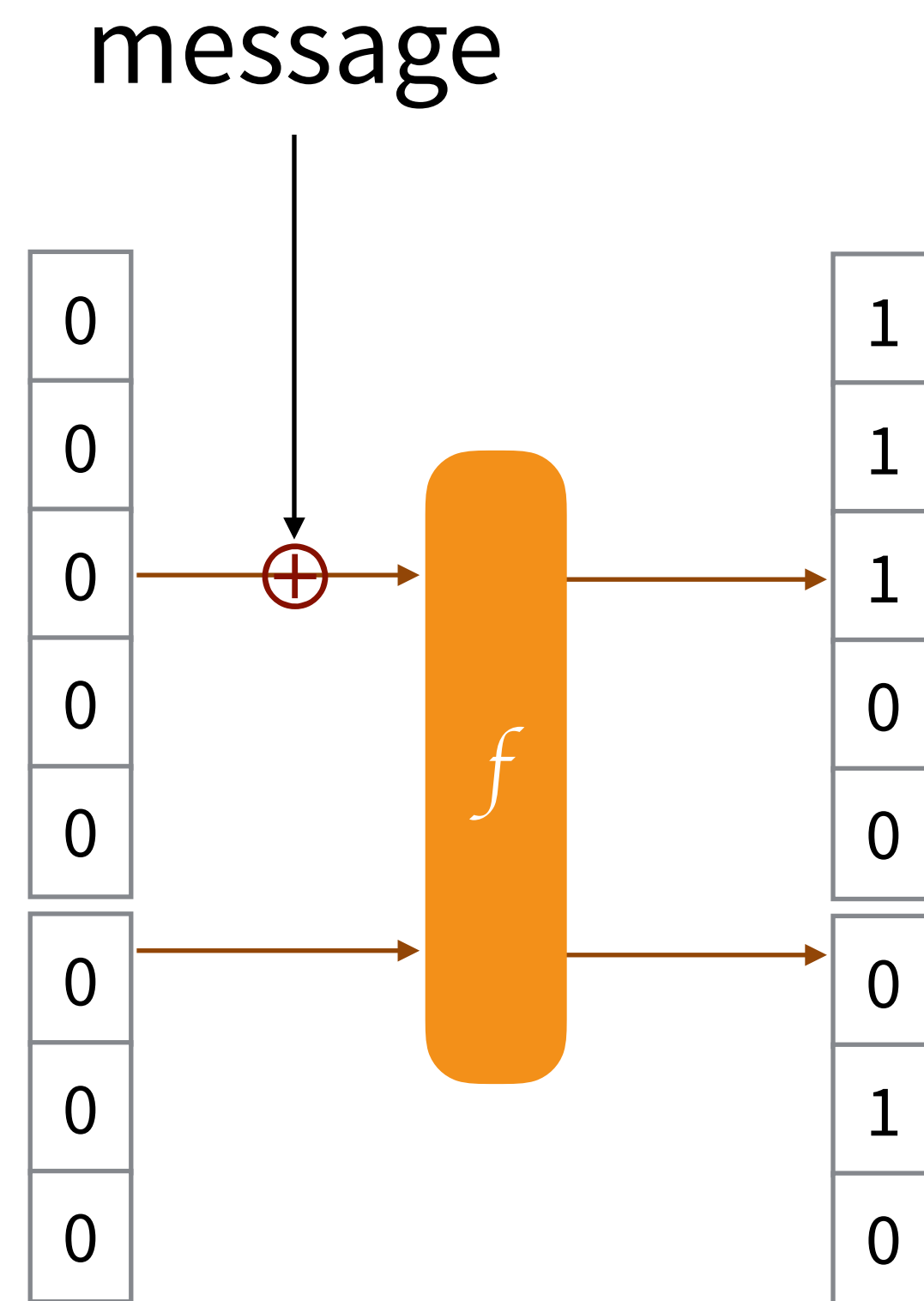
Sponge Construction



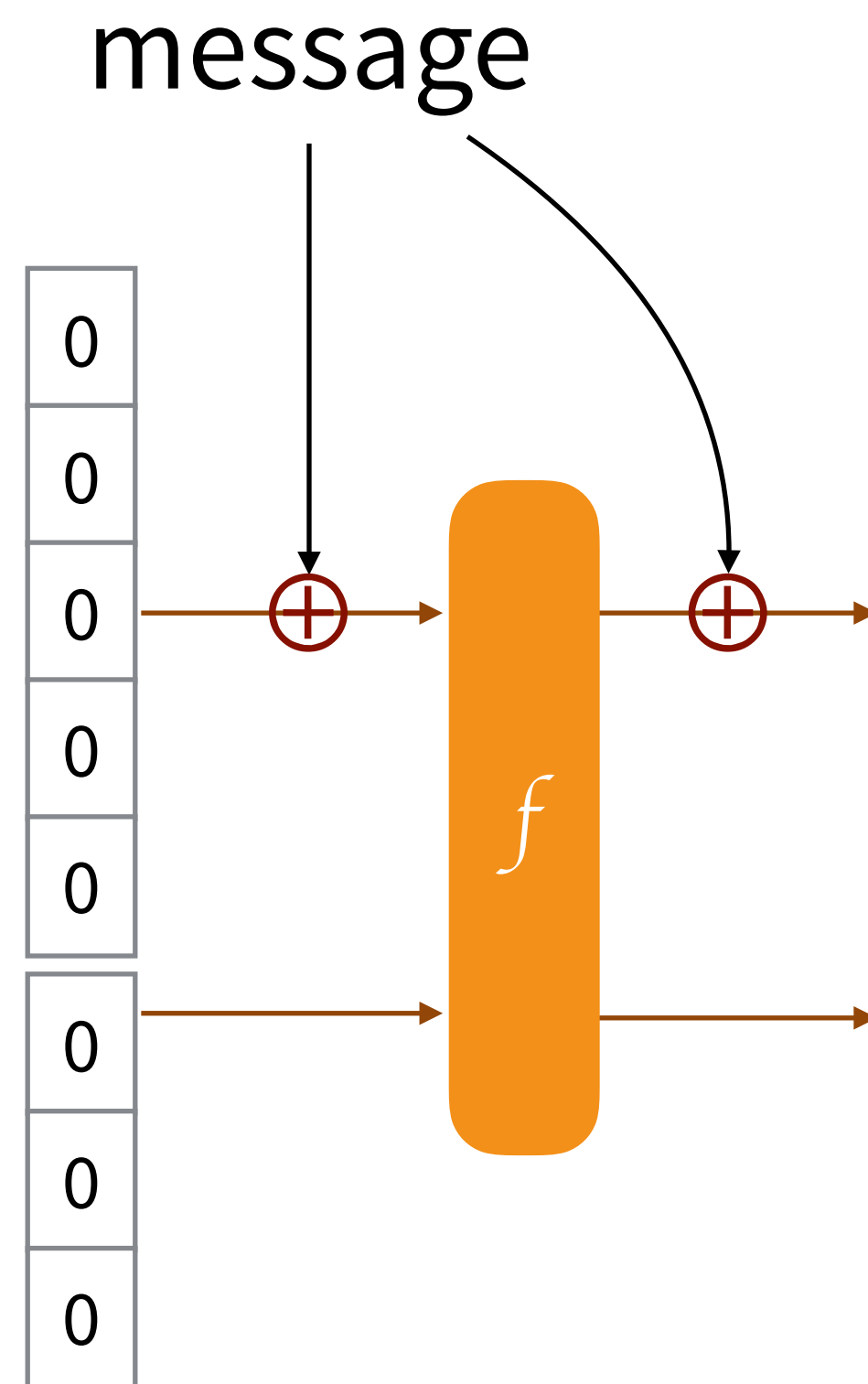
Sponge Construction



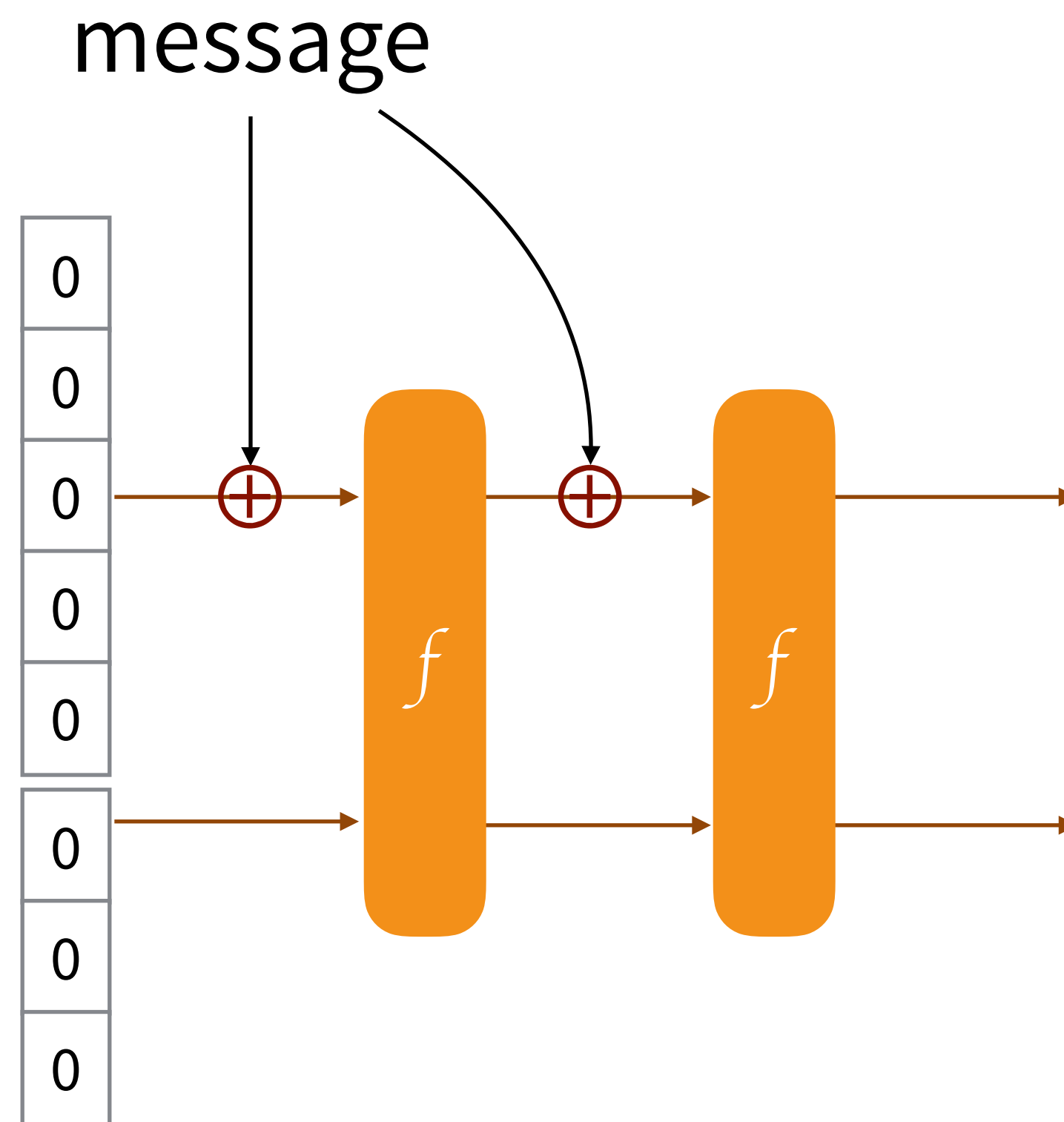
Sponge Construction



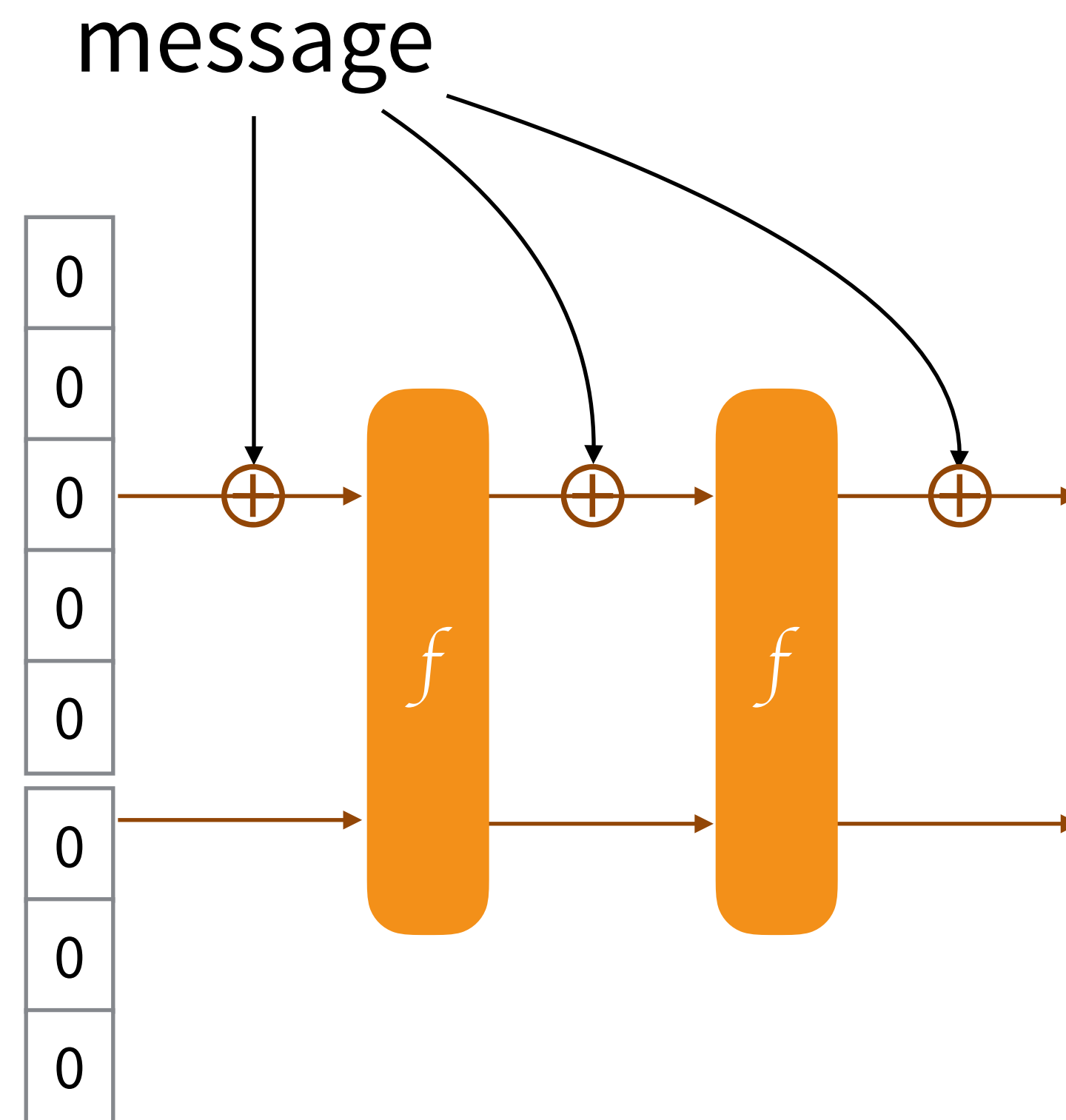
Sponge Construction



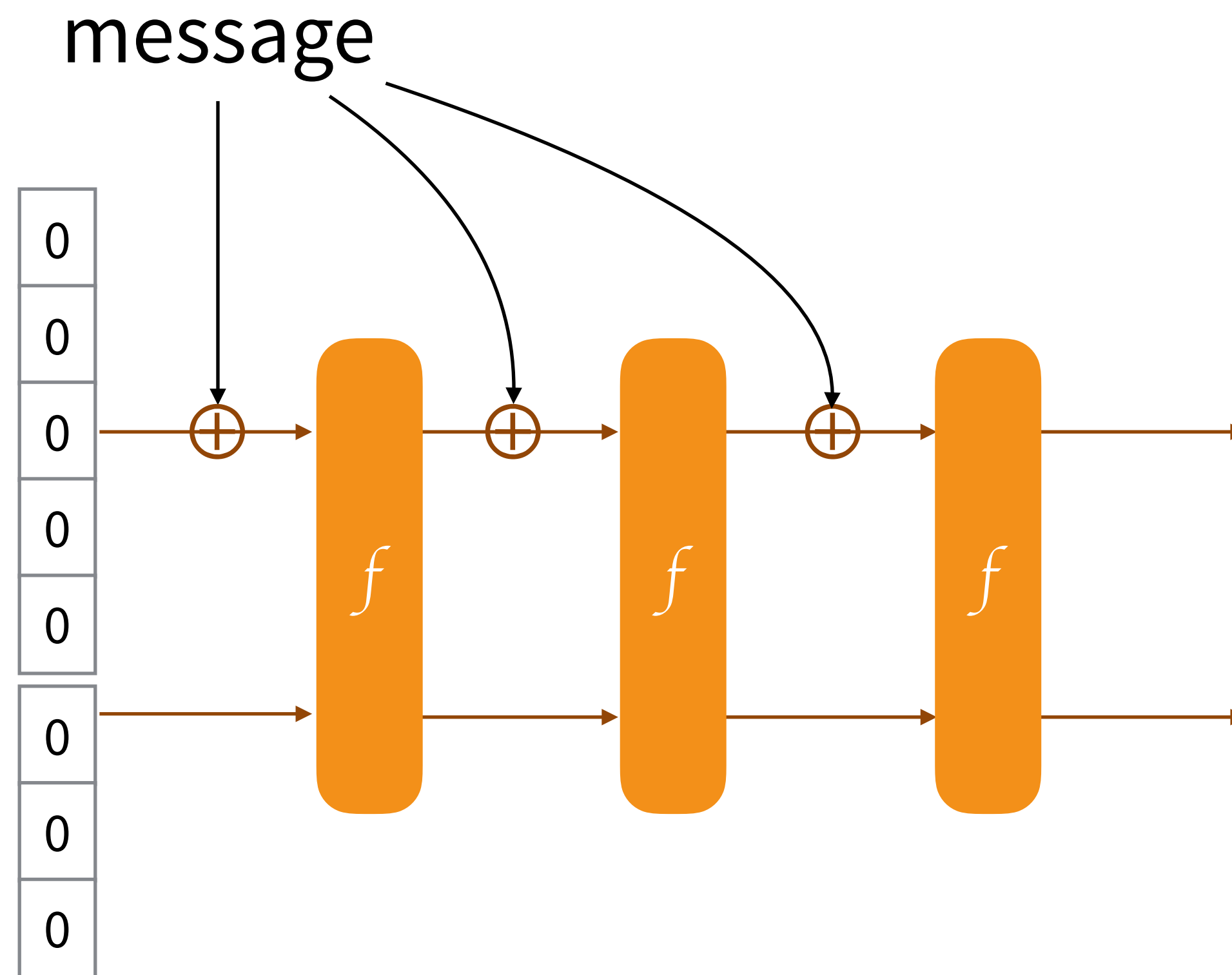
Sponge Construction



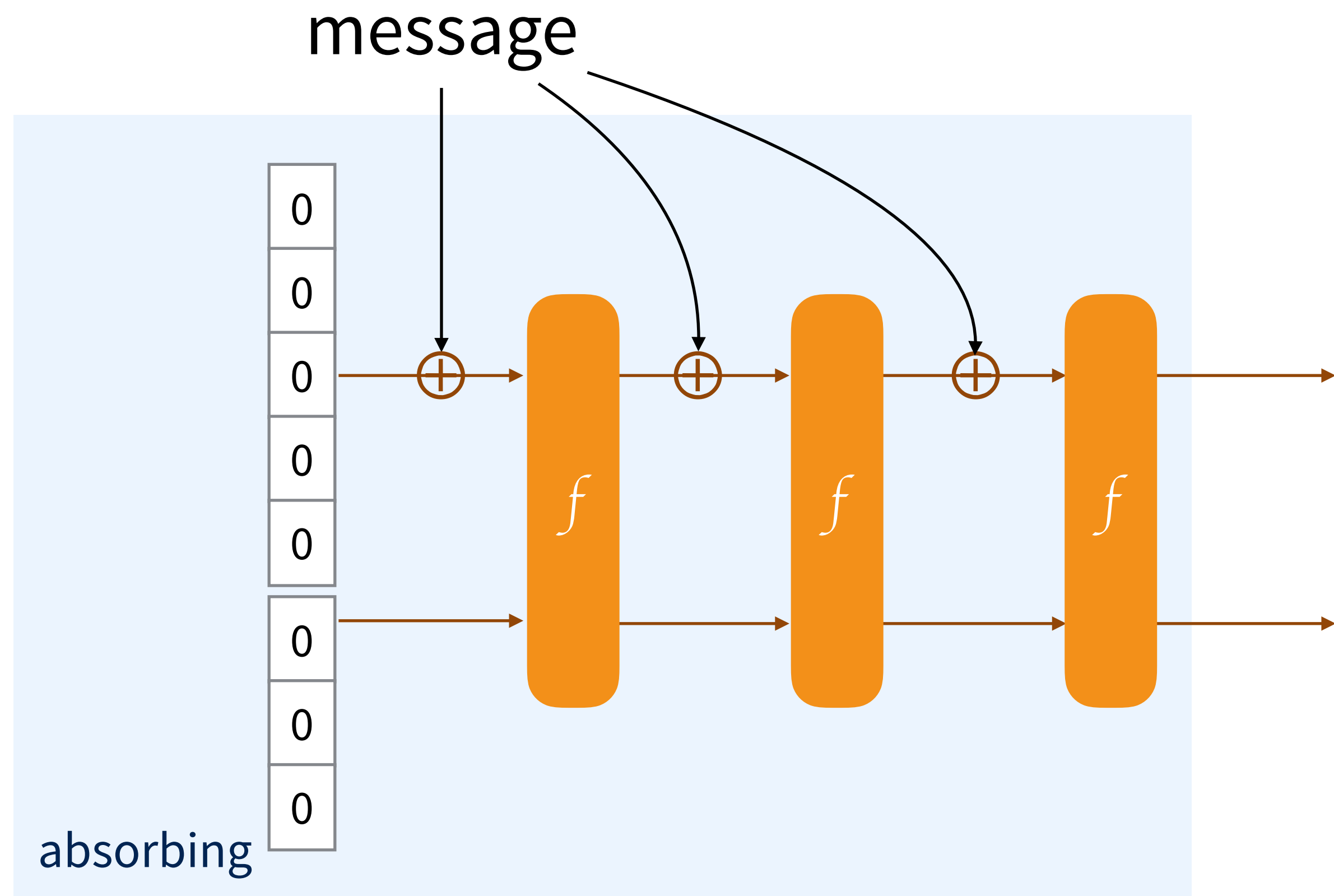
Sponge Construction



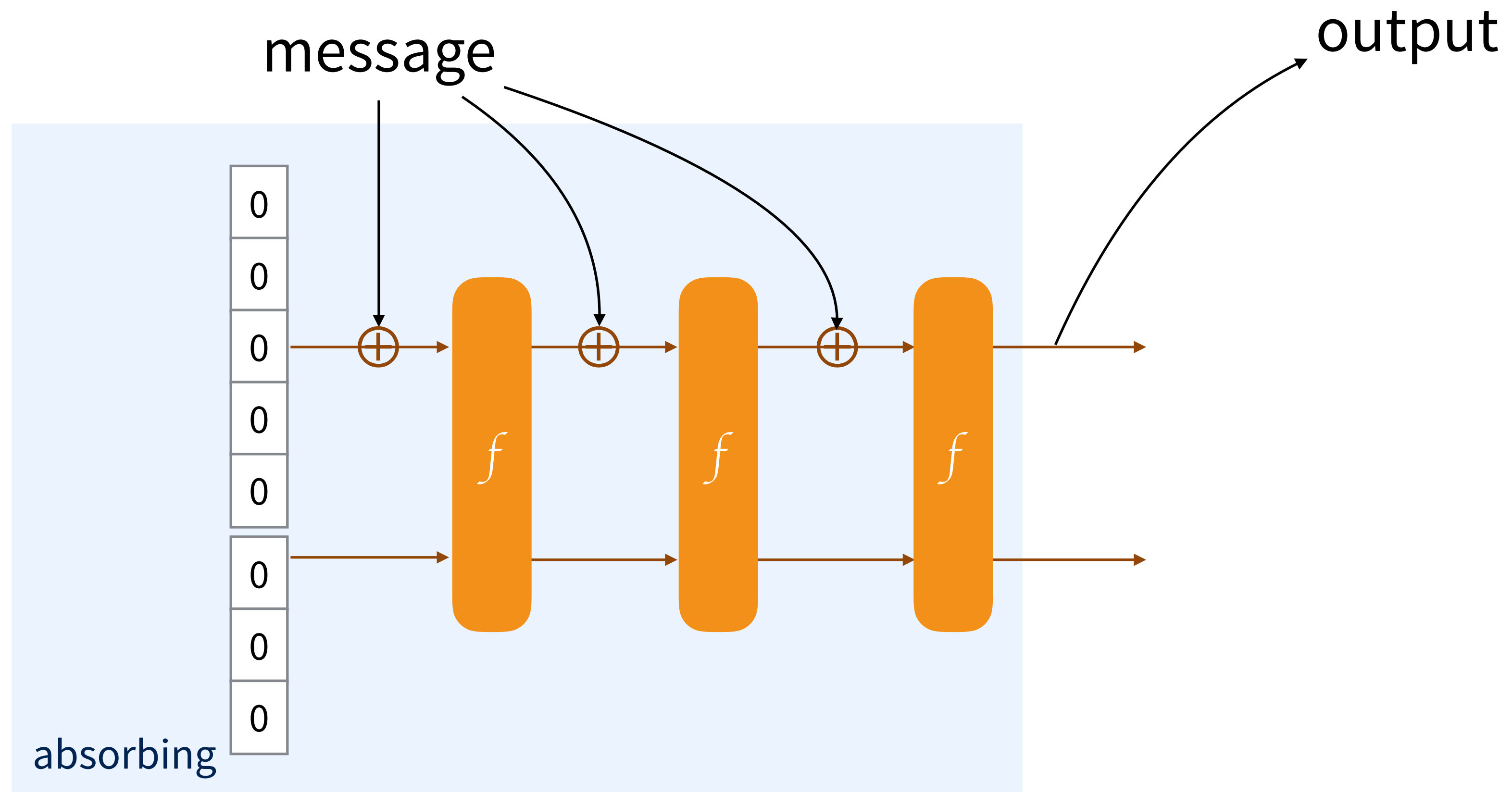
Sponge Construction



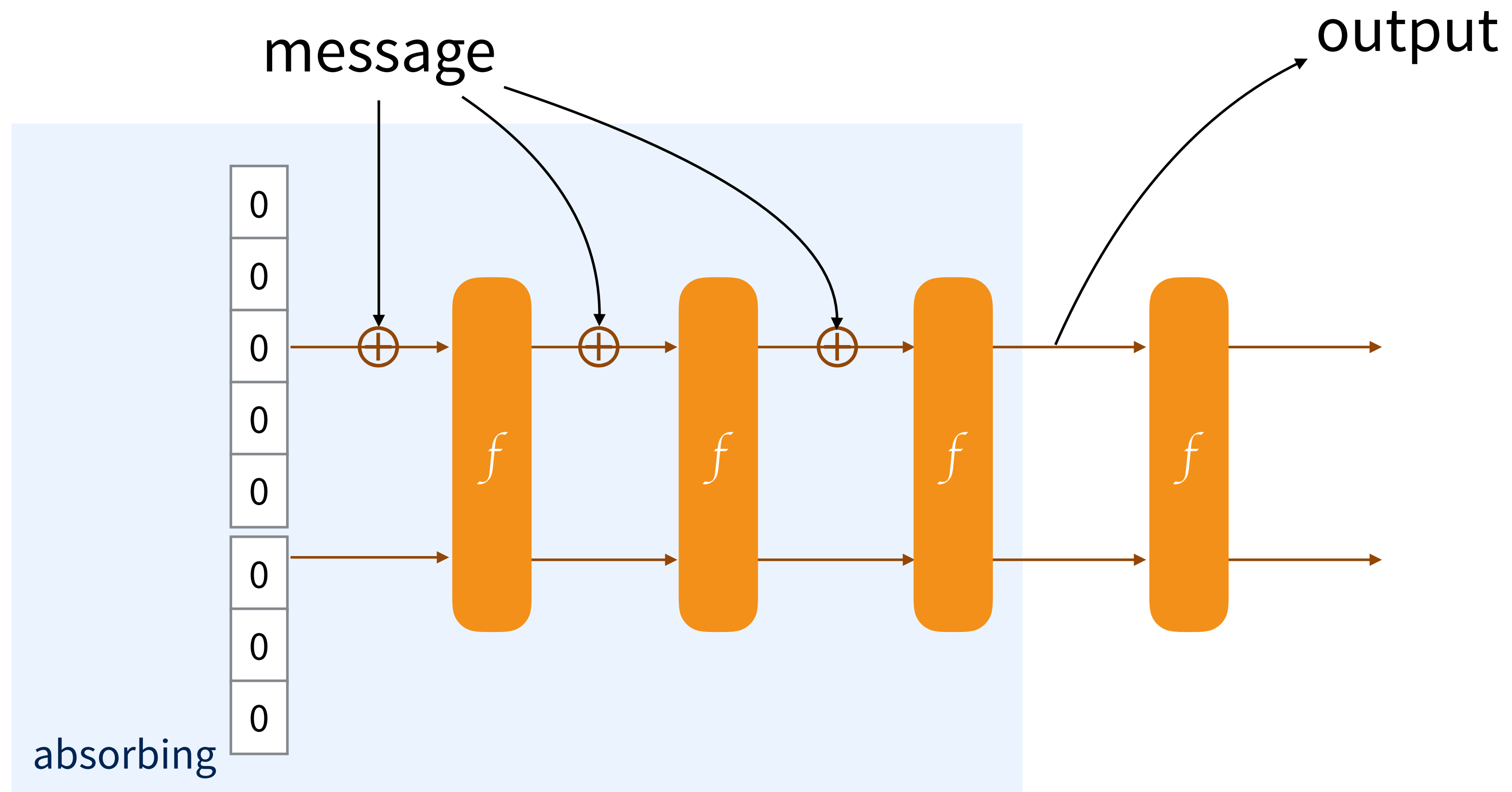
Sponge Construction



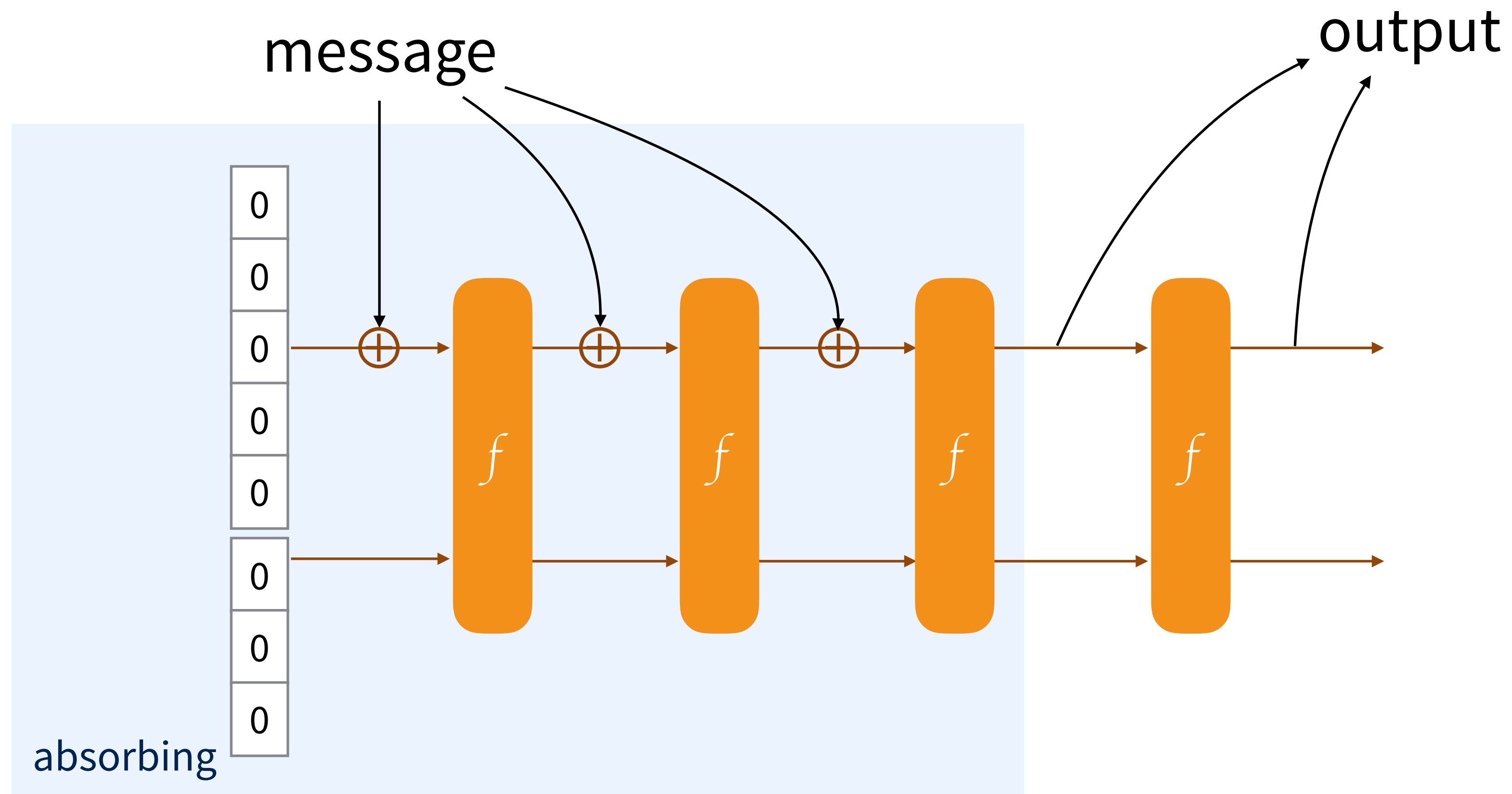
Sponge Construction



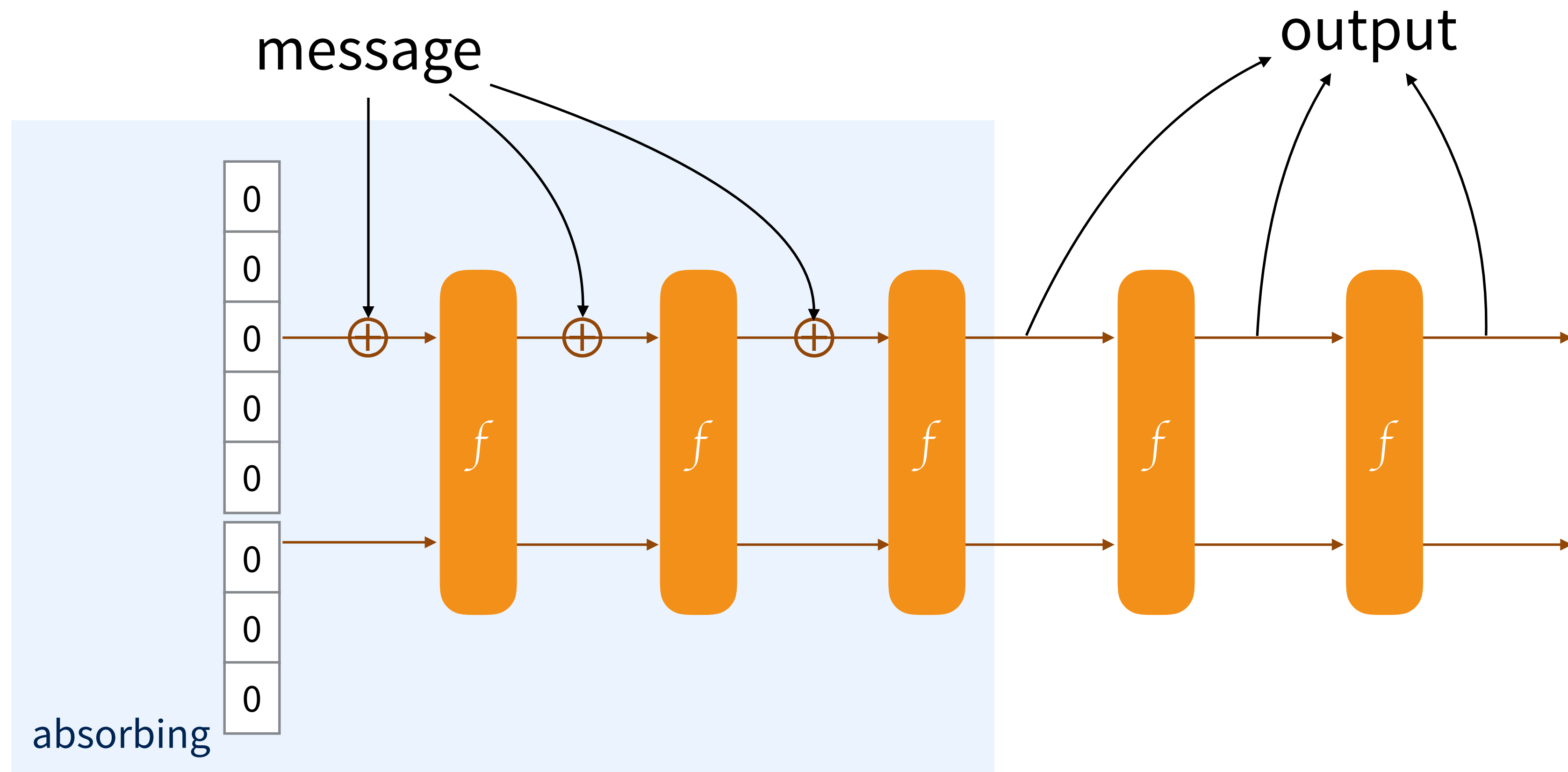
Sponge Construction



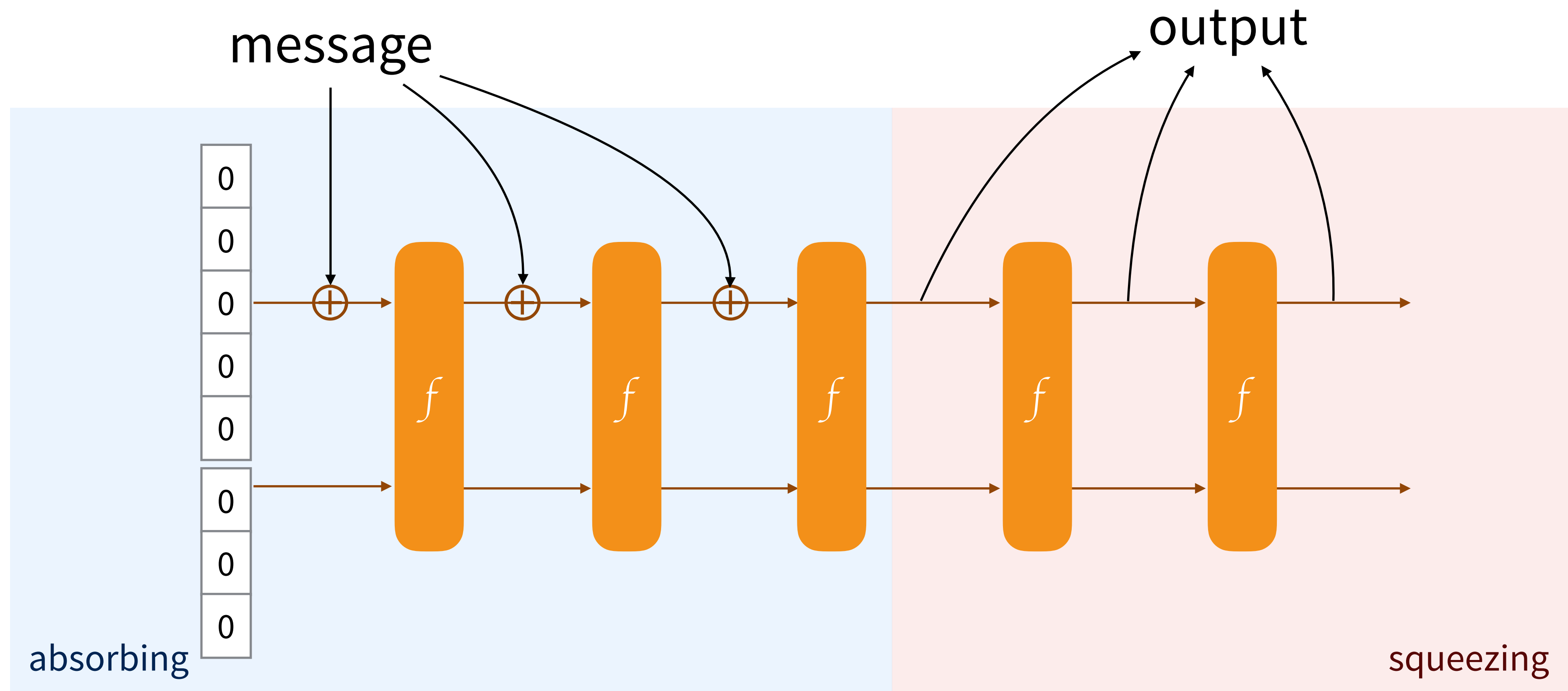
Sponge Construction



Sponge Construction



Sponge Construction



Third-party cryptanalysis

This page lists all the third-party cryptanalysis results that we know of on `KECCAK`, including FIPS 202 and SP 800-185 instances, `KANGAROOTWELVE` and the authenticated encryption schemes `KETJE` and `KEYAK`. We may have forgotten some results, so if you think your result is relevant and should be on this page, please do not hesitate to contact us.

The results are divided into the following categories:

- analysis of the `KECCAK` (covering also `KANGAROOTWELVE`, FIPS 202 and SP 800-185 instances) in the context of (unkeyed) hashing;
- analysis that is more specifically targetting keyed modes of use of `KECCAK`, including the `KETJE` and `KEYAK` authenticated encryption schemes;
- analysis on the (reduced-round) `KECCAK-f` permutations that does not extend to any of the aforementioned cryptographic functions.

In each category, the most recent results come first.

Analysis of unkeyed modes

First, the [Crunchy Crypto Collision and Pre-image Contest](#) contains third-party cryptanalysis results with practical complexities.

K. Qiao, L. Song, M. Liu and J. Guo, [New Collision Attacks on Round-Reduced `KECCAK`](#), Eurocrypt 2017

In this paper, Kexin Qiao, Ling Song, Meicheng Liu and Jian Guo develop a hybrid method combining algebraic and differential techniques to mount collision attacks on `KECCAK`. They can find collisions on various instances of `KECCAK` with the permutation `KECCAK-f[1600]` or `KECCAK-f[800]` reduced to 5 rounds. This includes the 5-round collision challenges in the [Crunchy Contest](#). In the meanwhile, they refined their attack and produced a 6-round collision that took 2^{50} evaluations of reduced-round `KECCAK-f[1600]`.

D. Saha, S. Kuila and D. R. Chowdhury, [SymSum: Symmetric-Sum Distinguishers Against Round Reduced](#)

Pages

- [Home](#)
- [News](#)
- [Files](#)
- [Specifications summary](#)
- [Tune `KECCAK` to your requirements](#)
- [Third-party cryptanalysis](#)
- [Our papers and presentations](#)
- [KECCAK Crunchy Crypto Collision and Pre-image Contest](#)
- [The `KECCAK` Team](#)

Documents

- [The FIPS 202 standard](#)
- [The `KECCAK` reference](#)
- [Files for the `KECCAK` reference](#)
- [The `KECCAK` SHA-3 submission](#)
- [KECCAK implementation overview](#)
- [Cryptographic sponge functions](#)
- [all files...](#)

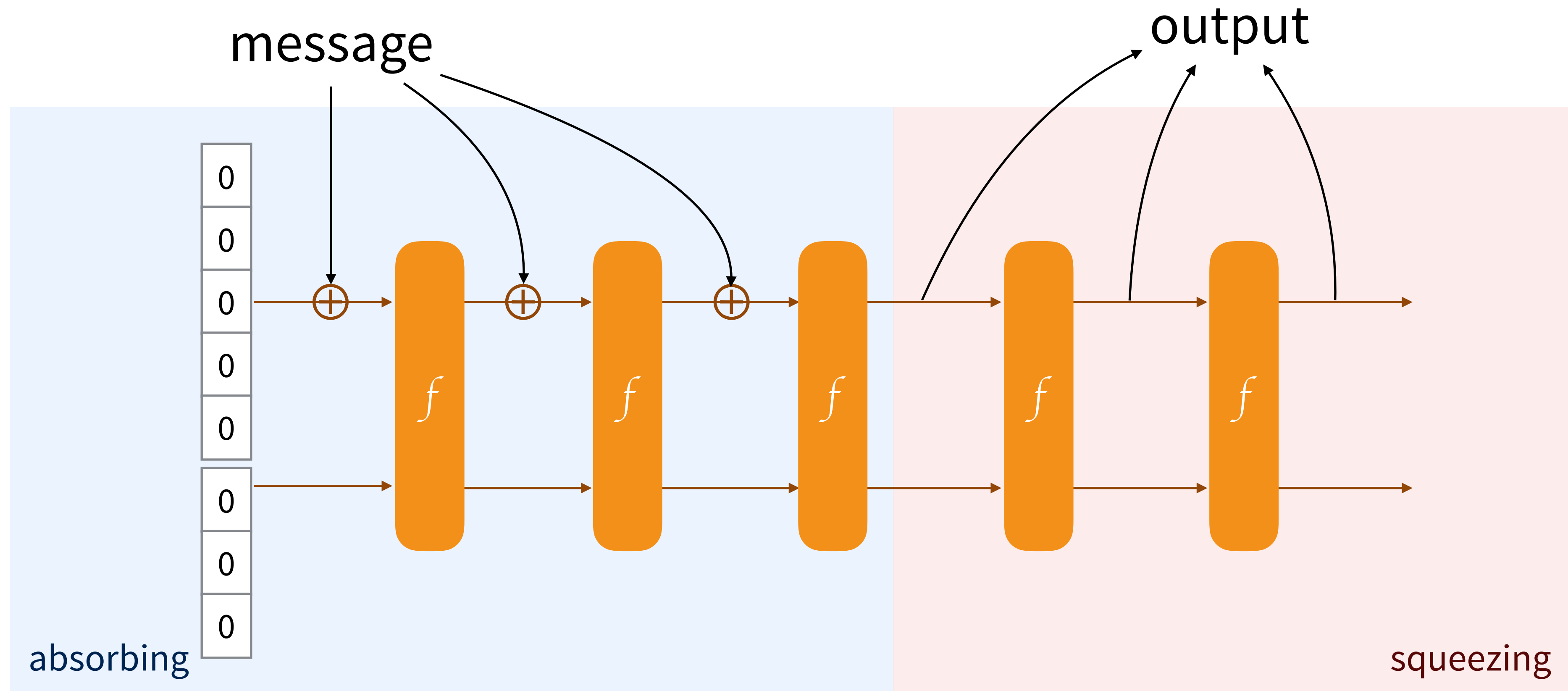
Notes

- [Note on side-channel attacks and their countermeasures](#)
- [Note on zero-sum distinguishers of `KECCAK-f`](#)
- [Note on `KECCAK` parameters and usage](#)
- [On alignment in `KECCAK`](#)
- [SAKURA: a flexible coding for tree hashing](#)
- [A software interface for `KECCAK`](#)

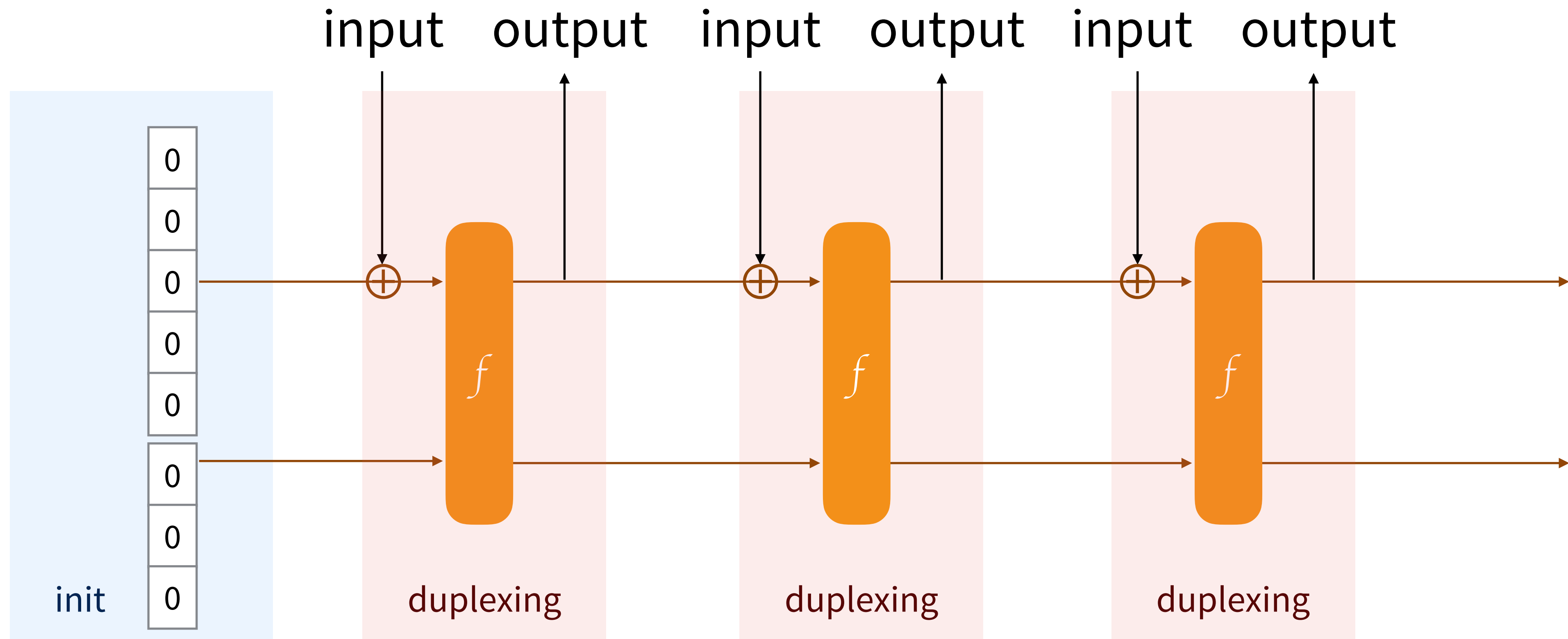
Part II: Strobe

From SHA-3 to protocols

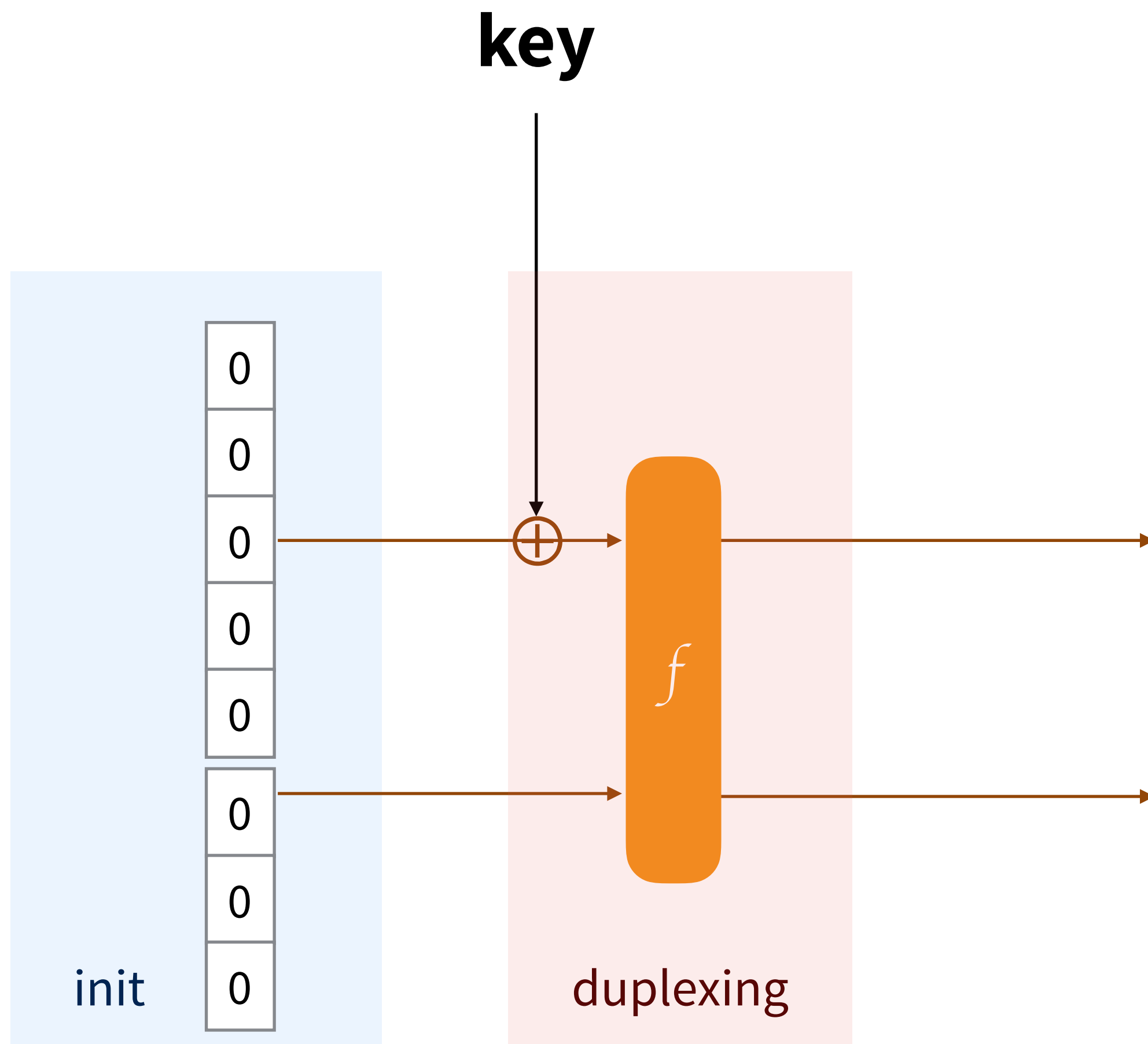
Sponge Construction



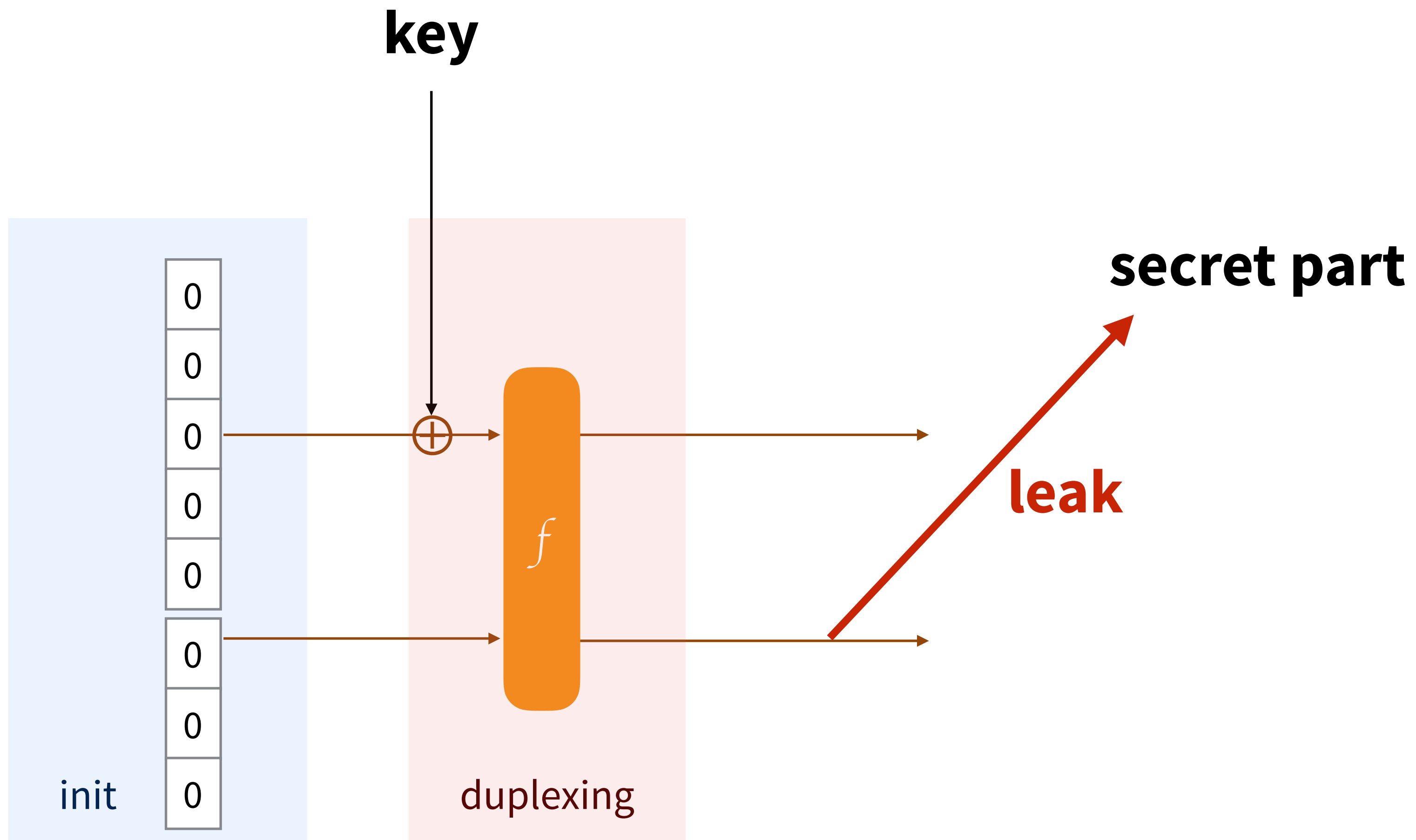
Duplex Construction



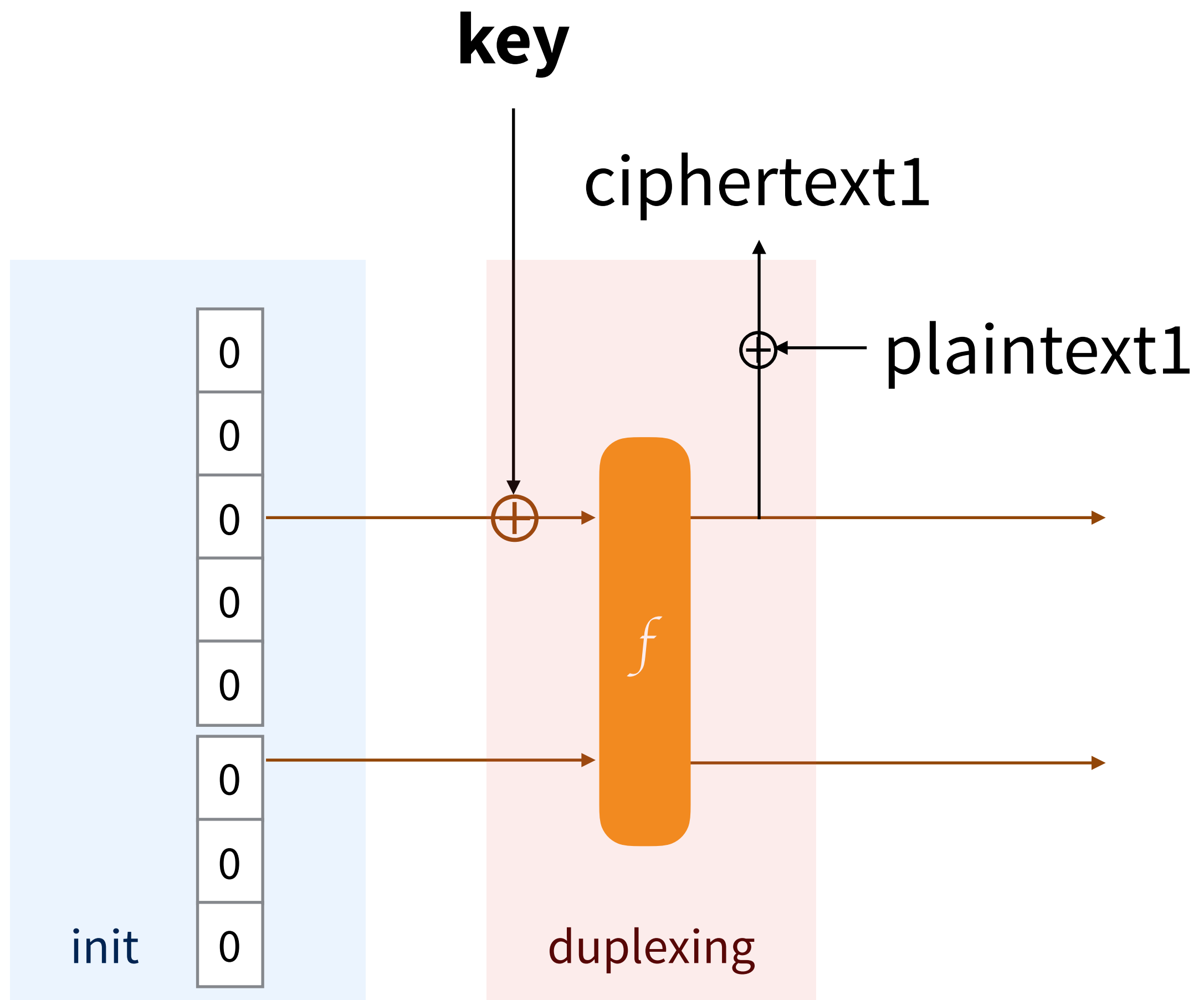
Keyed-mode



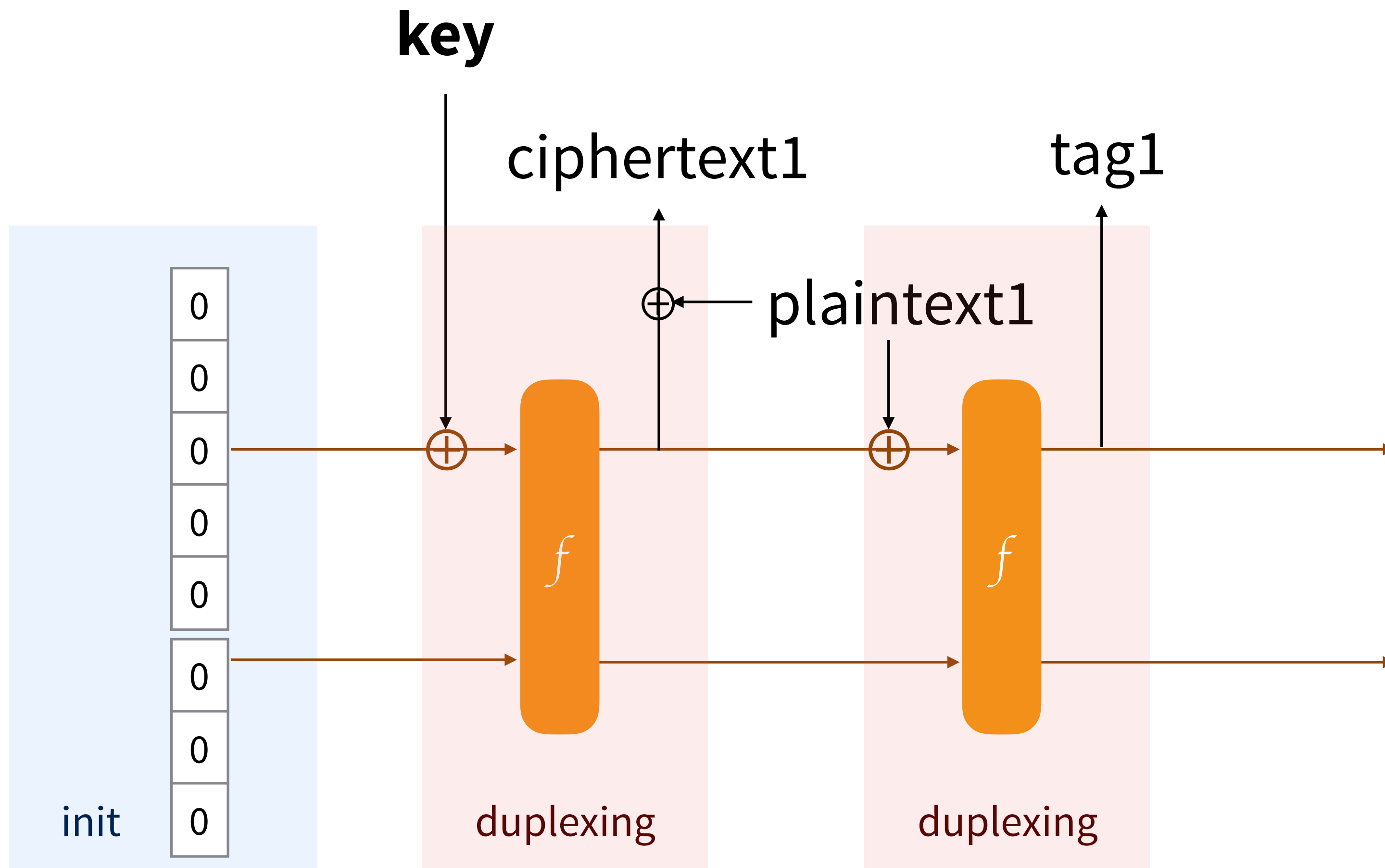
Keyed-mode



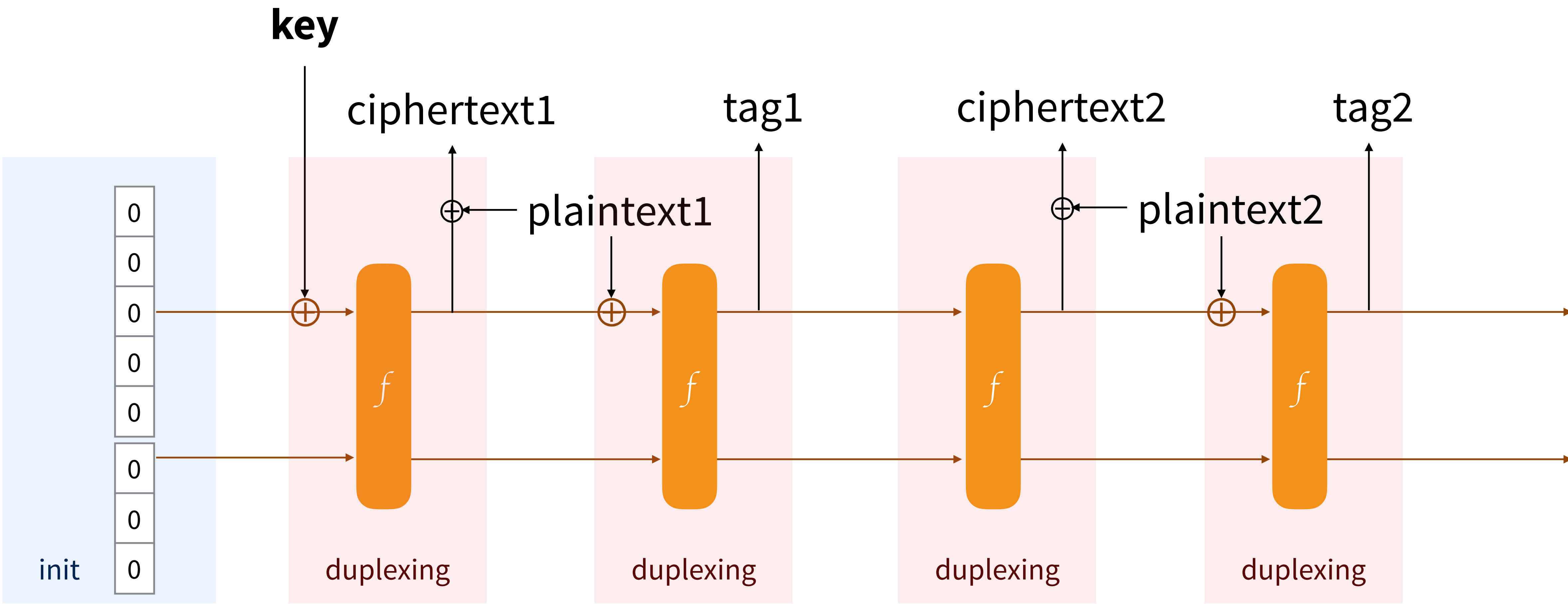
Encryption



Authenticated Encryption



Sessions



Strobe

```
myProtocol = Strobe_init("myWebsite.com")
myProtocol.AD(sharedSecret)
buffer = myProtocol.send_ENC("GET /")
buffer += myProtocol.send_MAC(len=16)
// send the buffer
// receive a ciphertext
message = myProtocol.recv_ENC(ciphertext[:-16])
ok = myProtocol.recv_MAC(ciphertext[-16:])
if !ok {
    // reset the connection
}
```

Strobe

```
buffer = myProtocol.send_ENC(plaintext1)
buffer += myProtocol.send_MAC(len=16)
// send the buffer
buffer = myProtocol.send_ENC(plaintext2)
buffer += myProtocol.send_MAC(len=16)
// send the buffer
buffer = myProtocol.send_ENC(plaintext3)
buffer += myProtocol.send_MAC(len=16)
// send the buffer
buffer = myProtocol.send_ENC(plaintext4)
buffer += myProtocol.send_MAC(len=16)
// send the buffer
```

Operation	Flags
AD	A
KEY	A C
PRF	I A C
send_CLR	A T
recv_CLR	I A T
send_ENC	A C T
recv_ENC	I A C T
send_MAC	C T
recv_MAC	I C T
RATCHET	C

Hash Function

```
myHash = Strobe_init("hash")  
myHash.AD("something to be hashed")  
hash = myHash.PRF(outputLen=16)
```

Key Derivation Function

```
KDF = Strobe_init("deriving keys")  
KDF.AD(keyExchangeOutput)  
keys = KDF.PRF(outputLen=32)  
key1 = keys[:16]  
key2 = keys[16:]
```

operation = AD



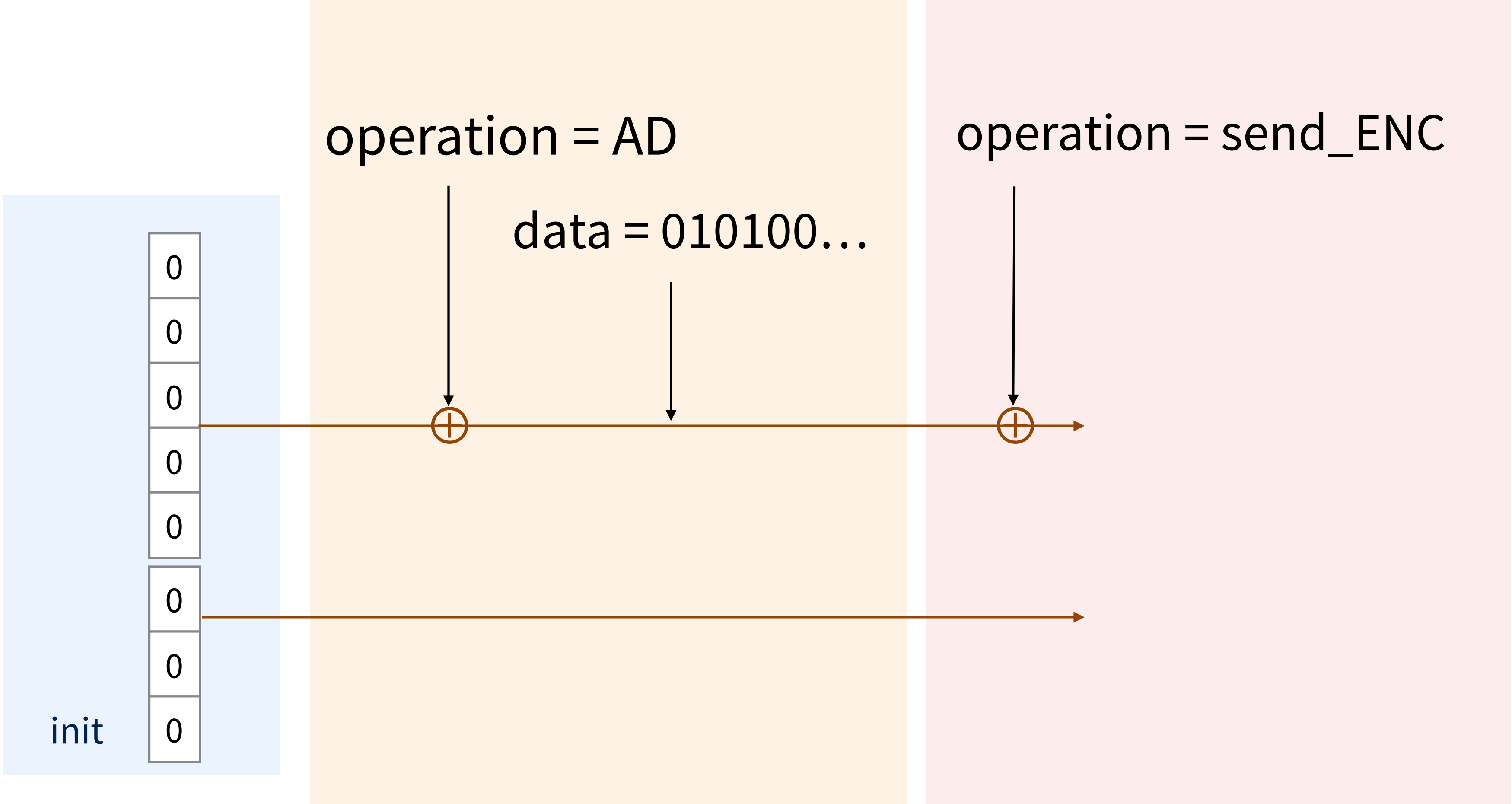
0
0
0
0
0
0
0
0
0

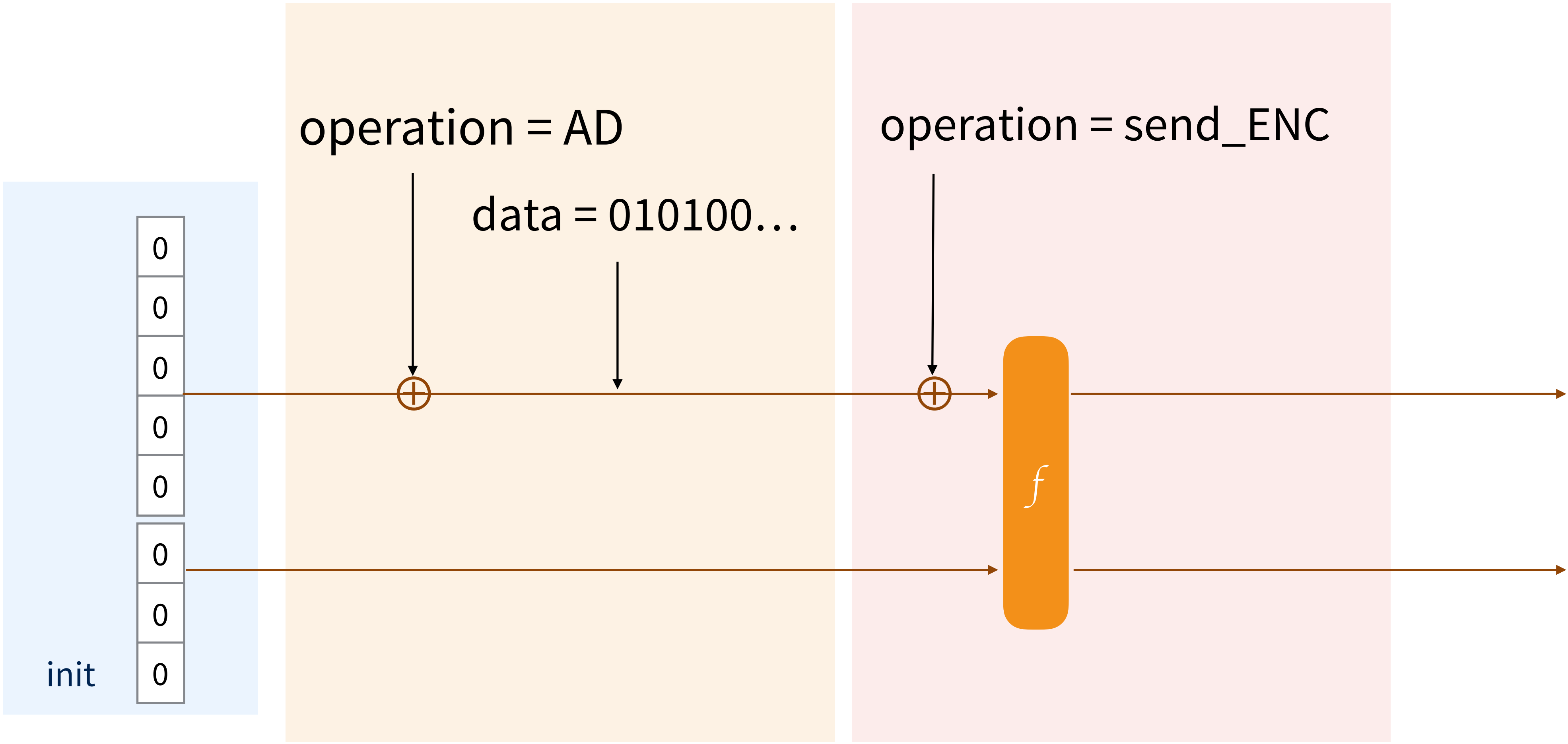
init

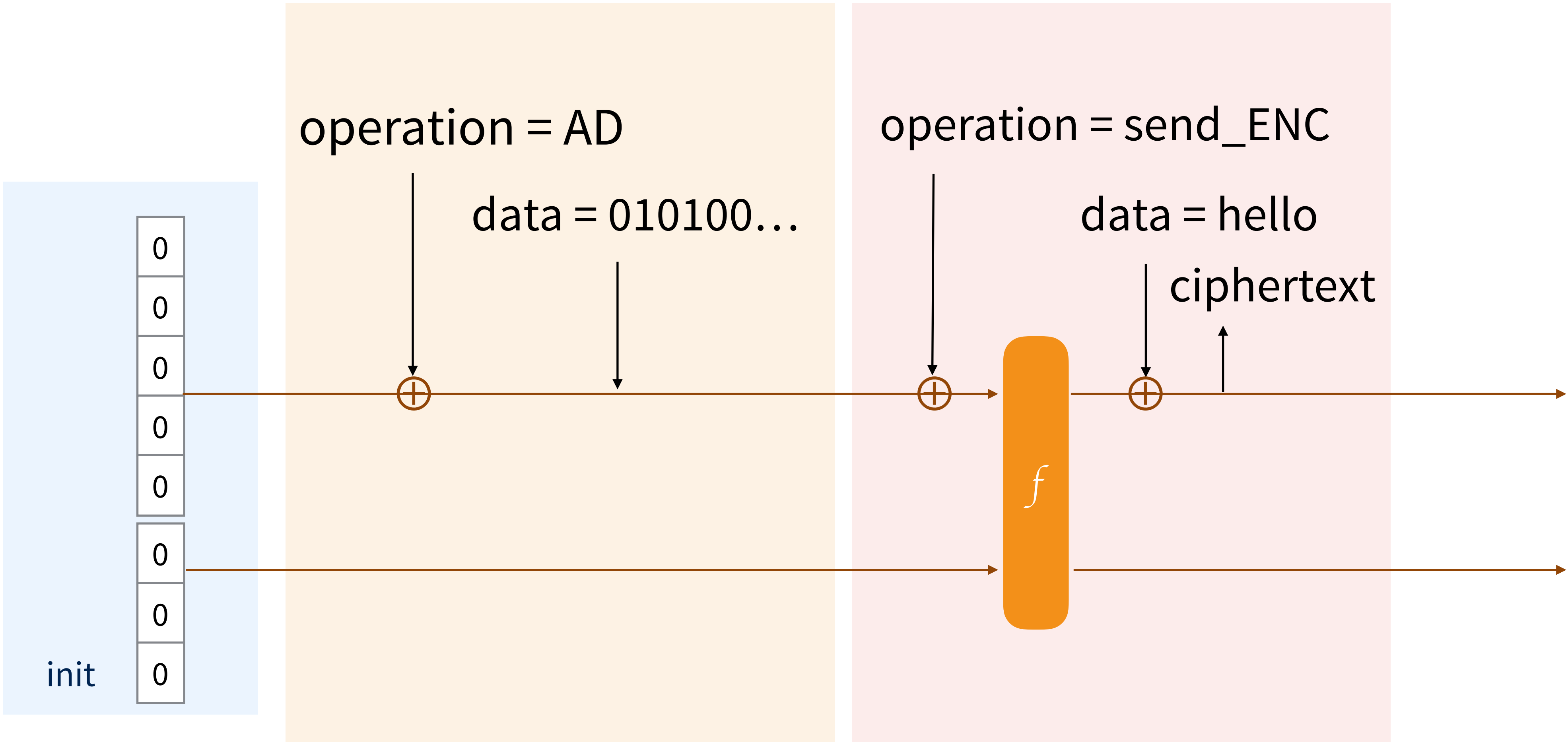
operation = AD

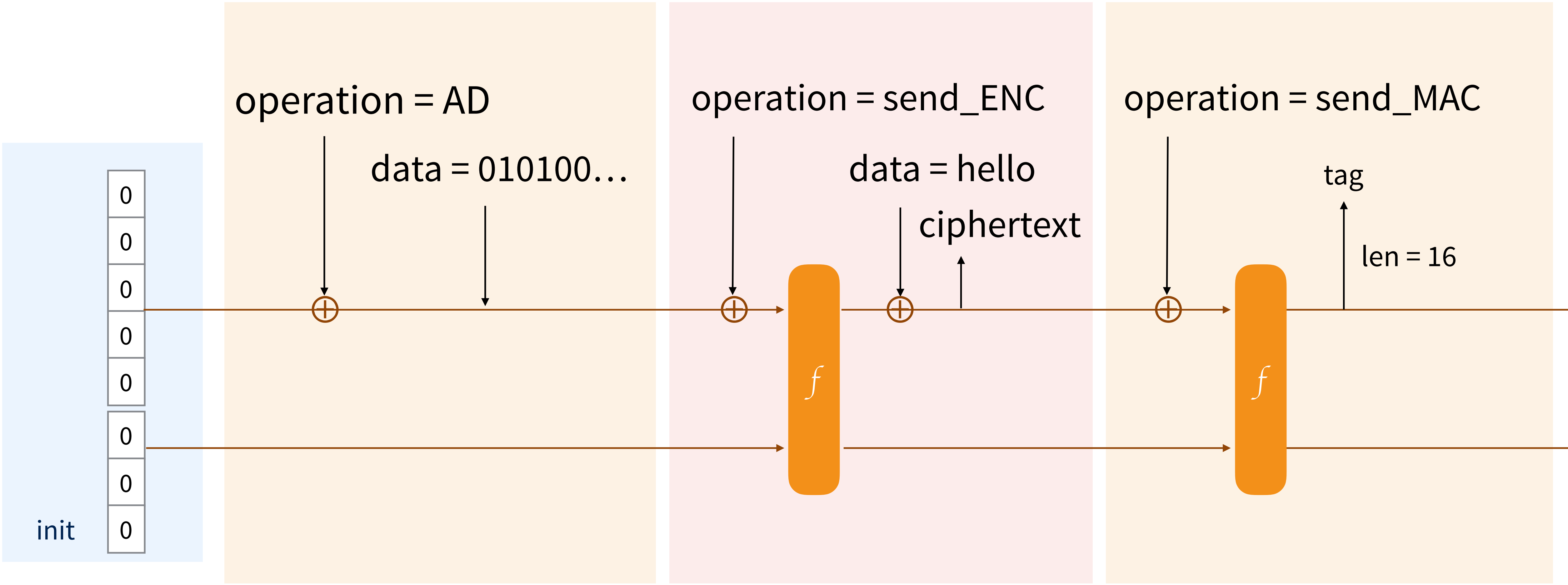
data = 010100...



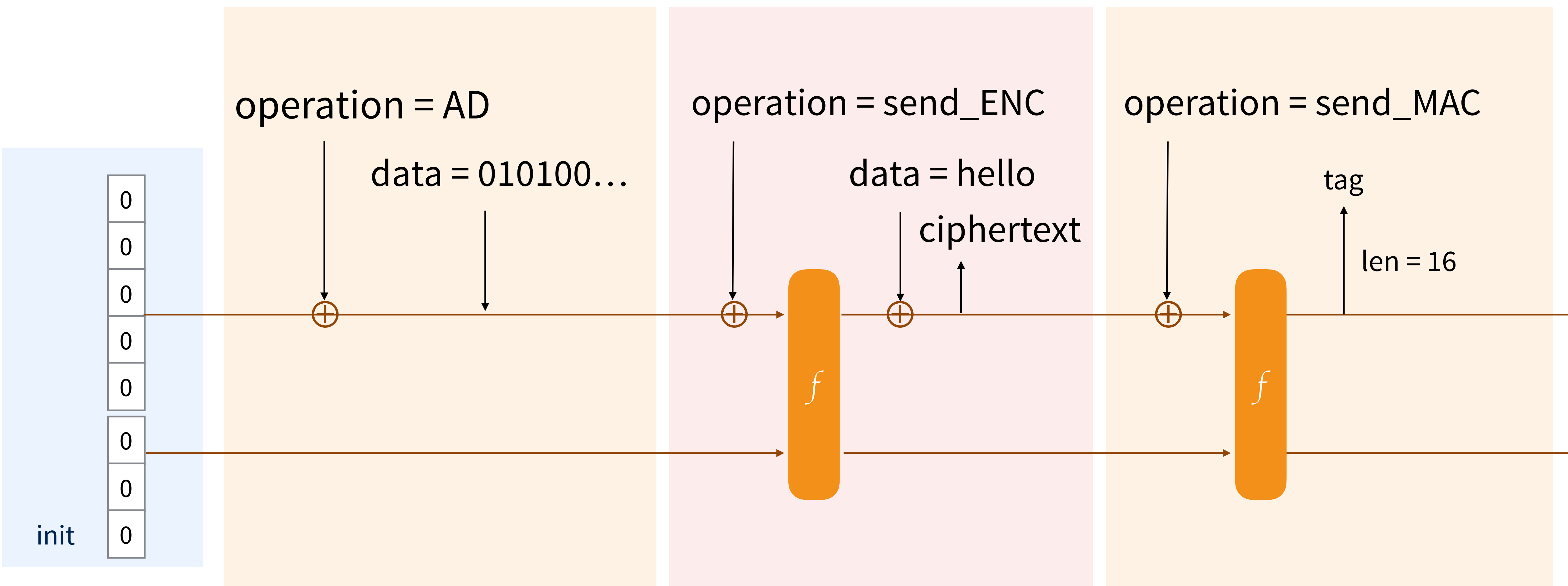


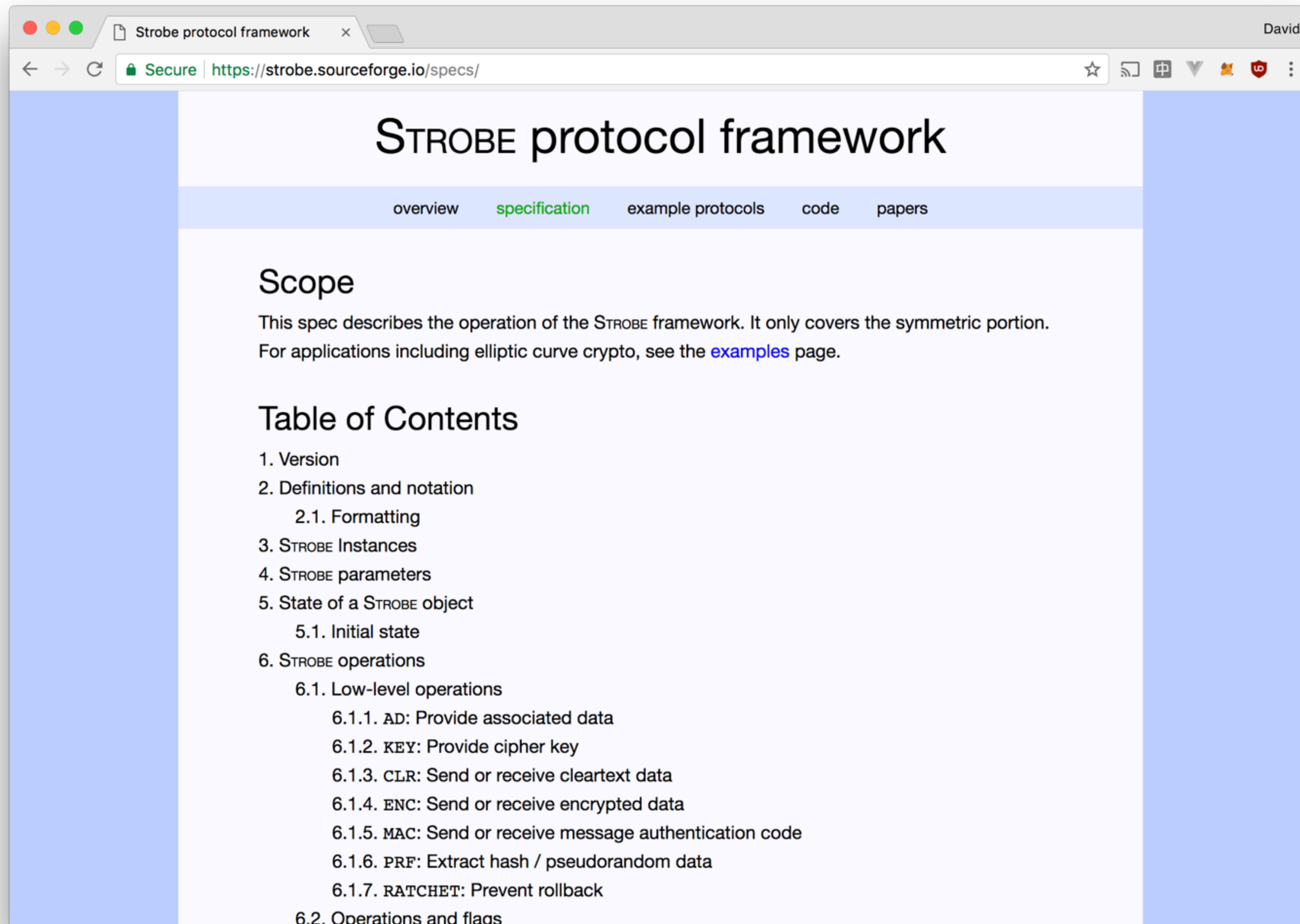






send_AEAD





Strobe

- **flexible** framework to support a large number of protocols
- large **symmetric cryptography** library
- fits into **tiny** IoT devices (**less than 1000 lines of code**)
- relies on strong **SHA-3** standard

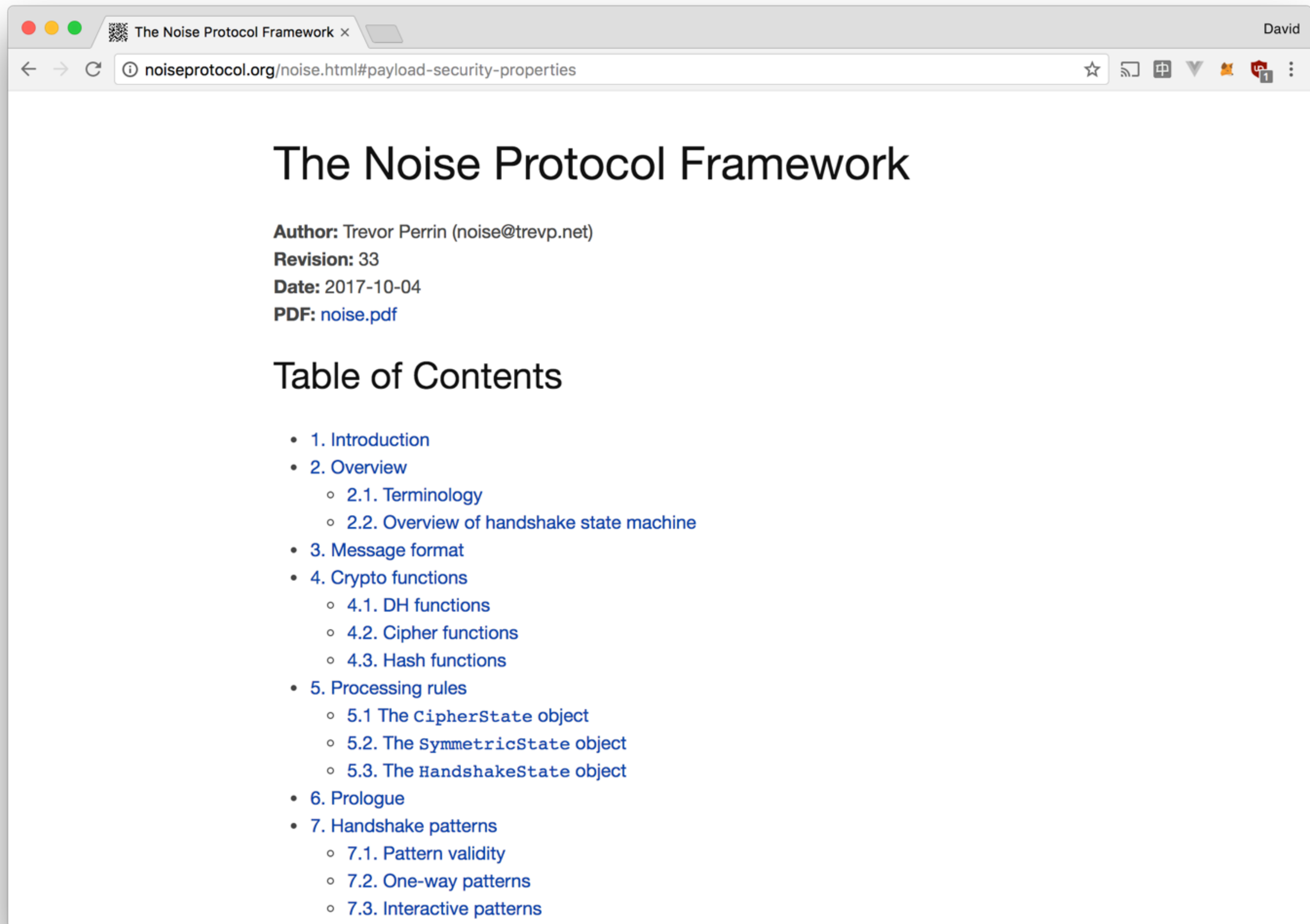
Part III: Noise

A modern protocol framework

TLS

- TLS is the **de facto standard** for securing communications
- **complex** specification
 - supported by other complex specs (asn.1, x509, extensions, ...)
- design carrying a lot of **legacy** decisions
- **huge** and **scary** libraries
 - **cumbersome** configuration...
- often **dangerously** re-implemented (custom implementations)
 - or re-invented (proprietary protocols)

Complexity is the enemy of security



The Noise Protocol Framework

- it's a protocol **framework** to achieve something like TLS
- “easy” to **understand**, to **analyze**, to **extend** and to **implement**
- no need for a **PKI**
- many handshakes to choose from (**flexible**)
- it's **straight forward** to implement (<2k LOC)
 - and **small** (18kb for Arduino by Virgil Security)
- there are already **libraries** that you can leverage
- **minimal** (or zero) configuration
- if you have a good excuse not to use TLS, **Noise is the answer**

The **crypto** functions

- **DH**

- 25519

- 448

- **AEAD**

- Chacha20-Poly1305

- AES-GCM

- **HASH**

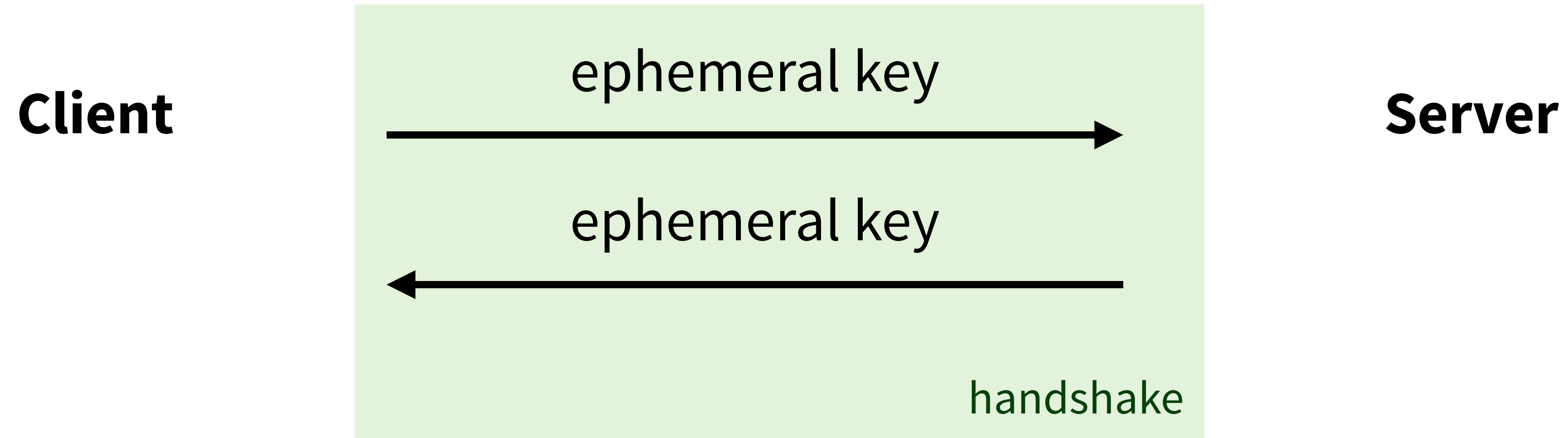
- SHA-256

- SHA-512

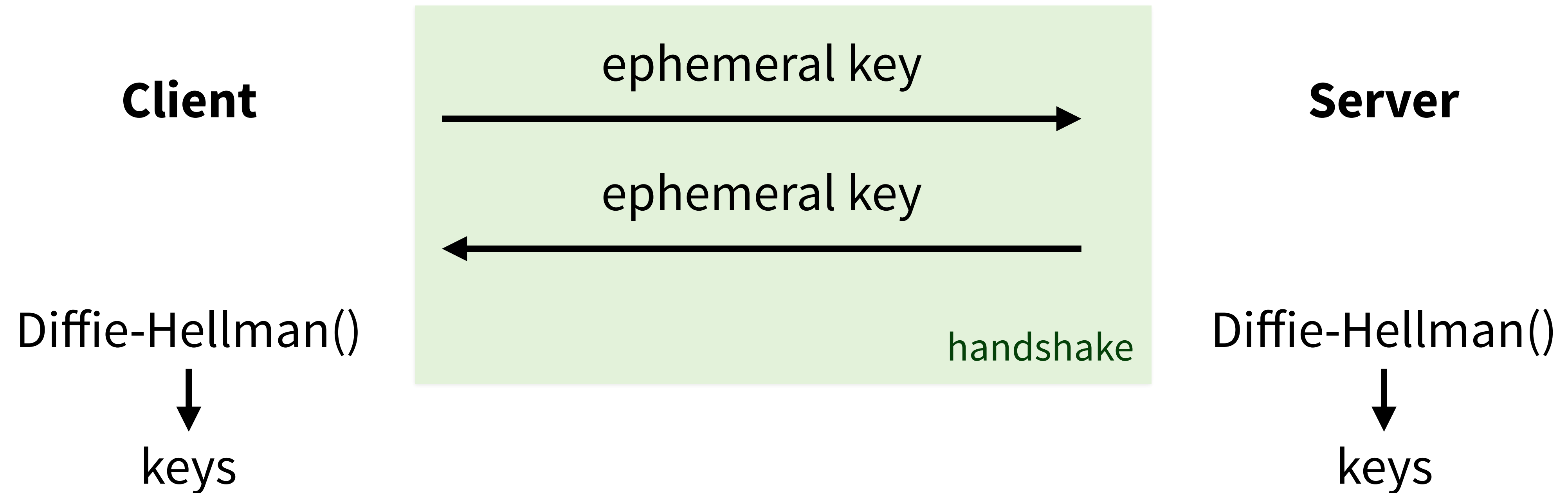
- BLAKE2s

- BLAKE2b

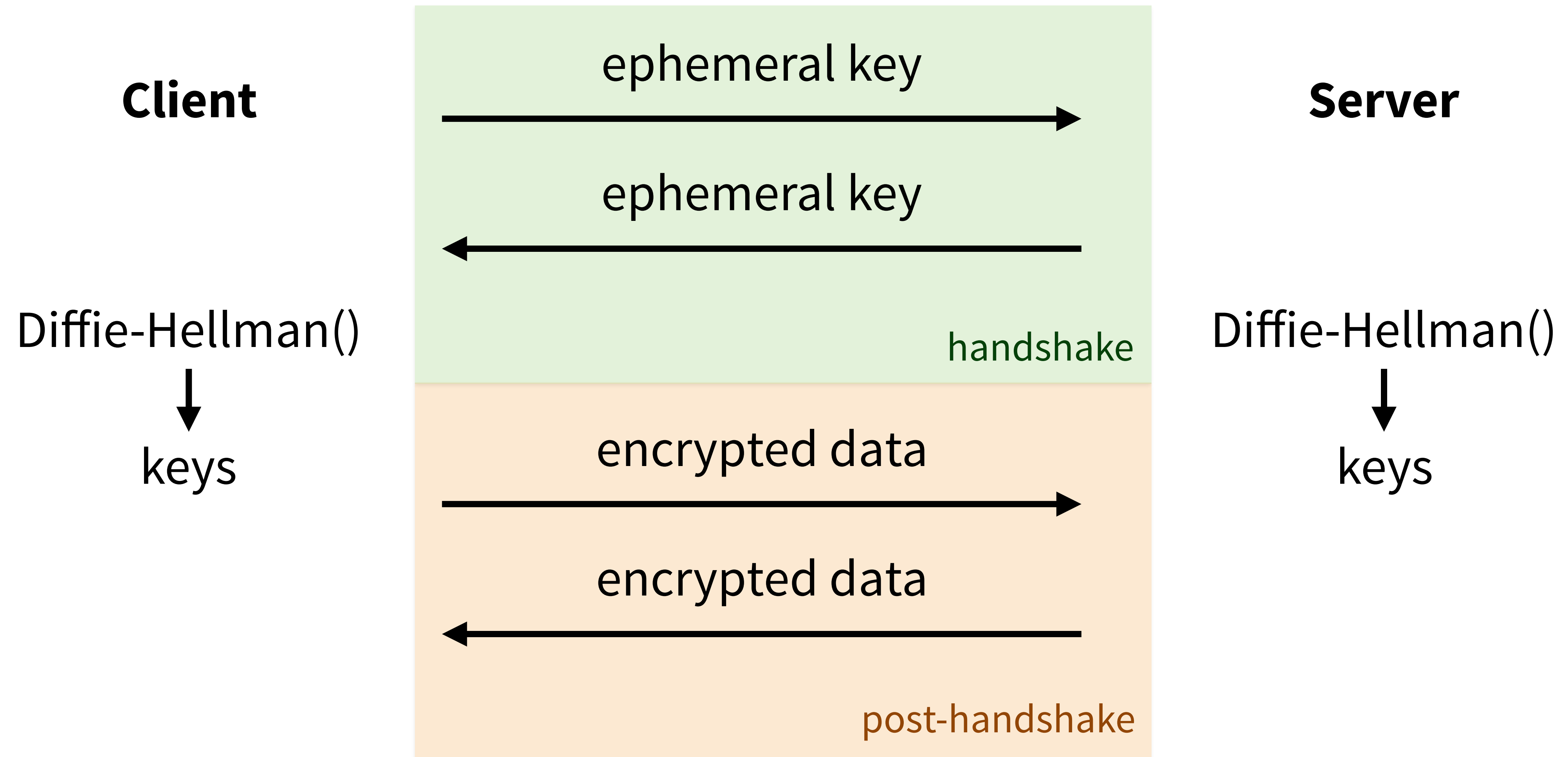
A **simple** state machine



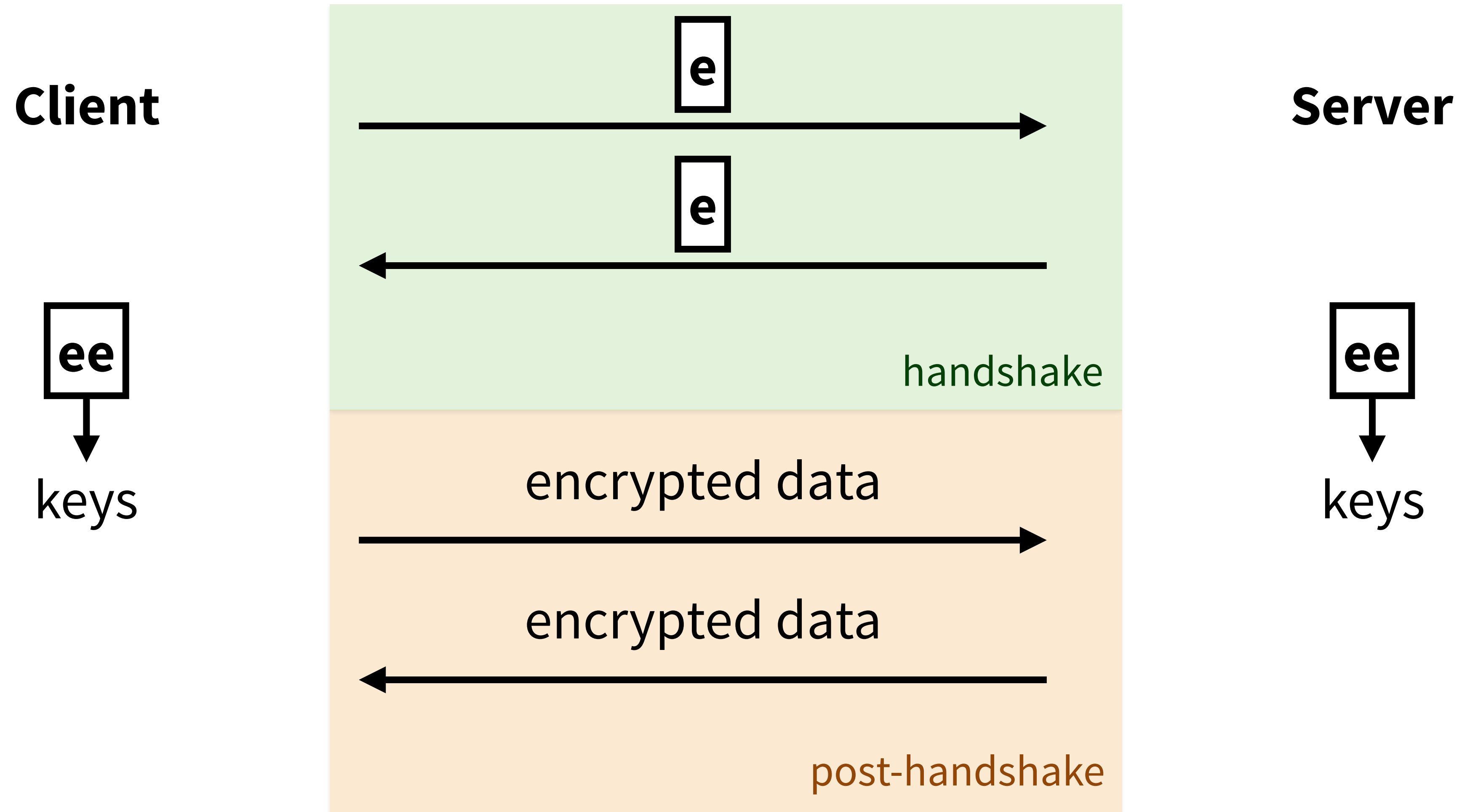
A **simple** state machine



A simple state machine



A simple state machine



Handshake Patterns

→ e

← e, ee

Handshake Patterns

Noise_**NN**():

→ e

← e, ee

Tokens

- **e**: ephemeral key
- **s**: static key
- **ee**: DH(client ephemeral key, server ephemeral key)
- **es**: DH(client ephemeral key, server static key)
- **se**: DH(client static key, server ephemeral key)
- **ss**: DH(client static key, server static key)
- **psk**: pre-shared key

The Noise Protocol Framework x

David

noiseprotocol.org/noise.html#handshake-patterns

NN () :

-> e

<- e, ee

NK(rs) :

<- s

...

-> e, es

<- e, ee

NX(rs) :

-> e

<- e, ee, s, es

XN(s) :

-> e

<- e, ee

-> s, se

XX(s, rs) :

-> e

<- e, ee, s, es

-> s, se

KN(s) :

-> s

...

-> e

<- e, ee, se

KK(s, rs) :

-> s

<- s

...

-> e, es, ss

<- e, ee, se

KX(s, rs) :

-> s

...

-> e

<- e, ee, se, s, es

IN(s) :

-> e, s

<- e, ee, se

IK(s, rs) :

<- s

...

-> e, es, s, ss

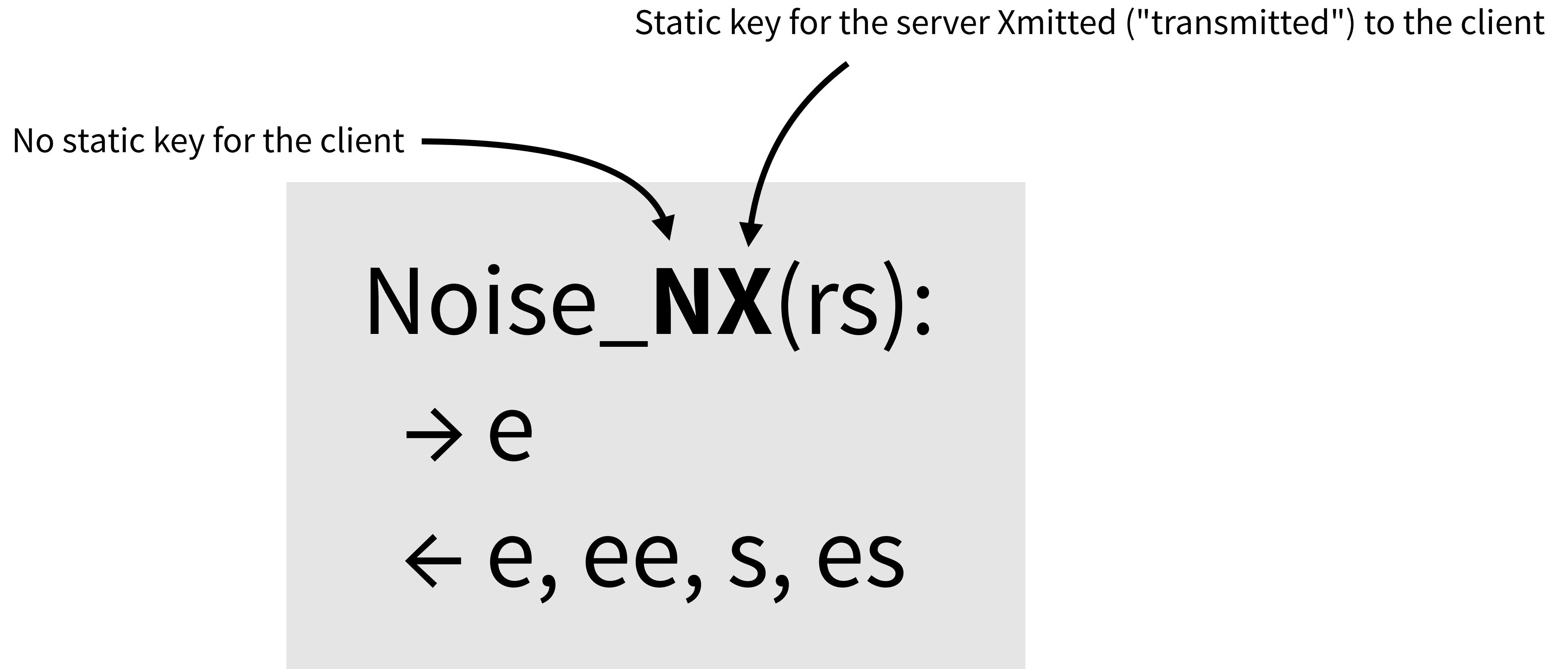
<- e, ee, se

IX(s, rs) :

-> e, s

<- e, ee, se, s, es

Handshake Pattern



Noise_**NX**(rs):

→ e

← e, ee, s, es

Client

Server

Noise_**NX**(rs):

→ **e**

← e, ee, s, es

Client

Server

e_{public}

```
sequenceDiagram
    participant Client
    participant Server
    Client->>Server: e_public
```

Noise_**NX**(rs):

$\rightarrow e$ ●

$\leftarrow e, ee, s, es$

Client

Server

e_{public}

payload1

Noise_XX(rs):

$\rightarrow e$

$\leftarrow e, ee, s, es$

Client

Server

e_{public}

payload1

re_{public}

Noise_XX(rs):

$\rightarrow e$

$\leftarrow e, ee, s, es$

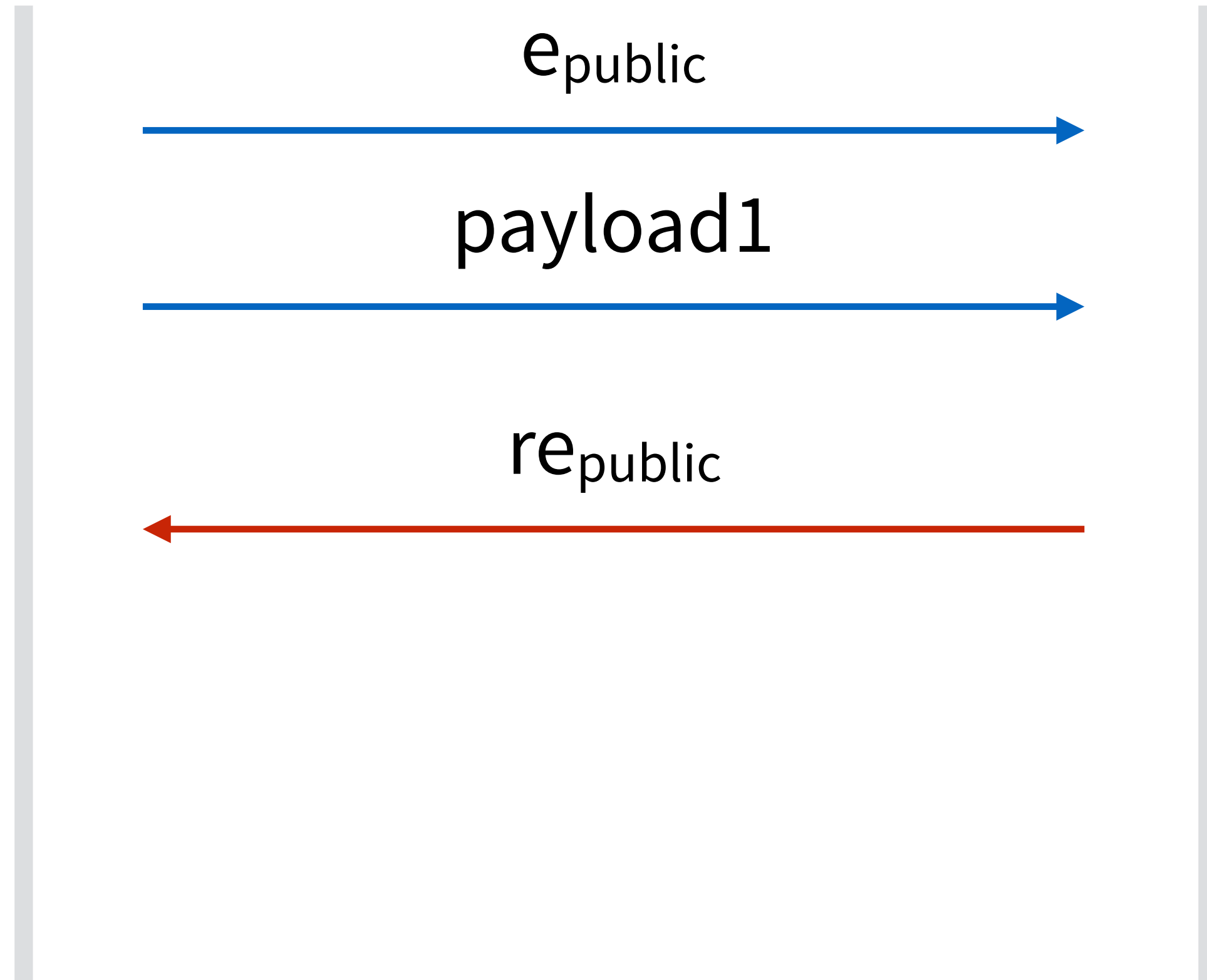
Client

Server

e_{public}

payload1

re_{public}



Noise_ **NX**(rs):

$\rightarrow e$

$\leftarrow e, ee, s, es$

Client

Server

e_{public}

payload1

re_{public}

$E_{k1}(s)$

Noise_**NX**(rs):

$\rightarrow e$

$\leftarrow e, ee, s, es$

Client

Server

e_{public}

payload1

re_{public}

$E_{K1}(s)$

Noise_XX(rs):

$\rightarrow e$

$\leftarrow e, ee, s, es$



Client

Server

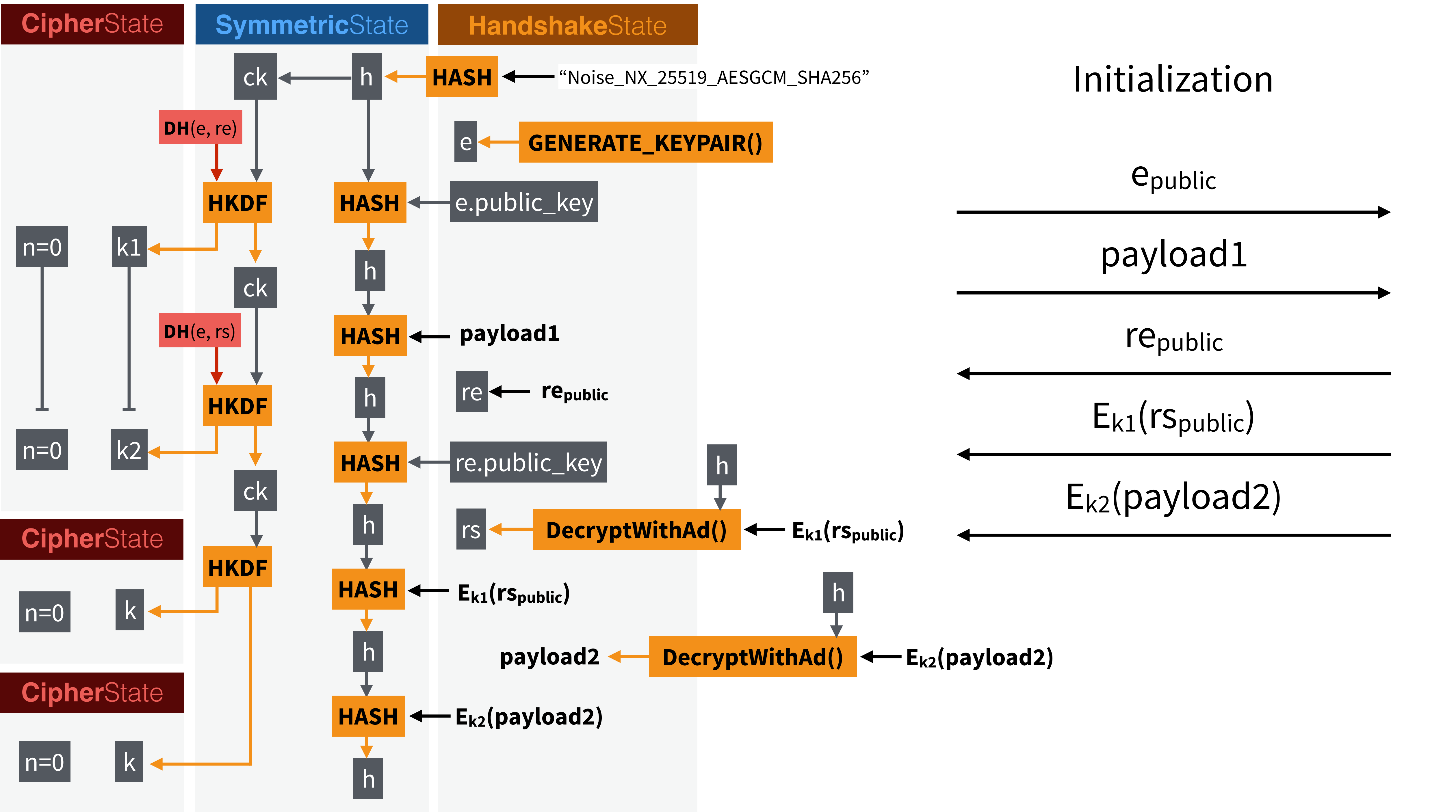
e_{public}

payload1

re_{public}

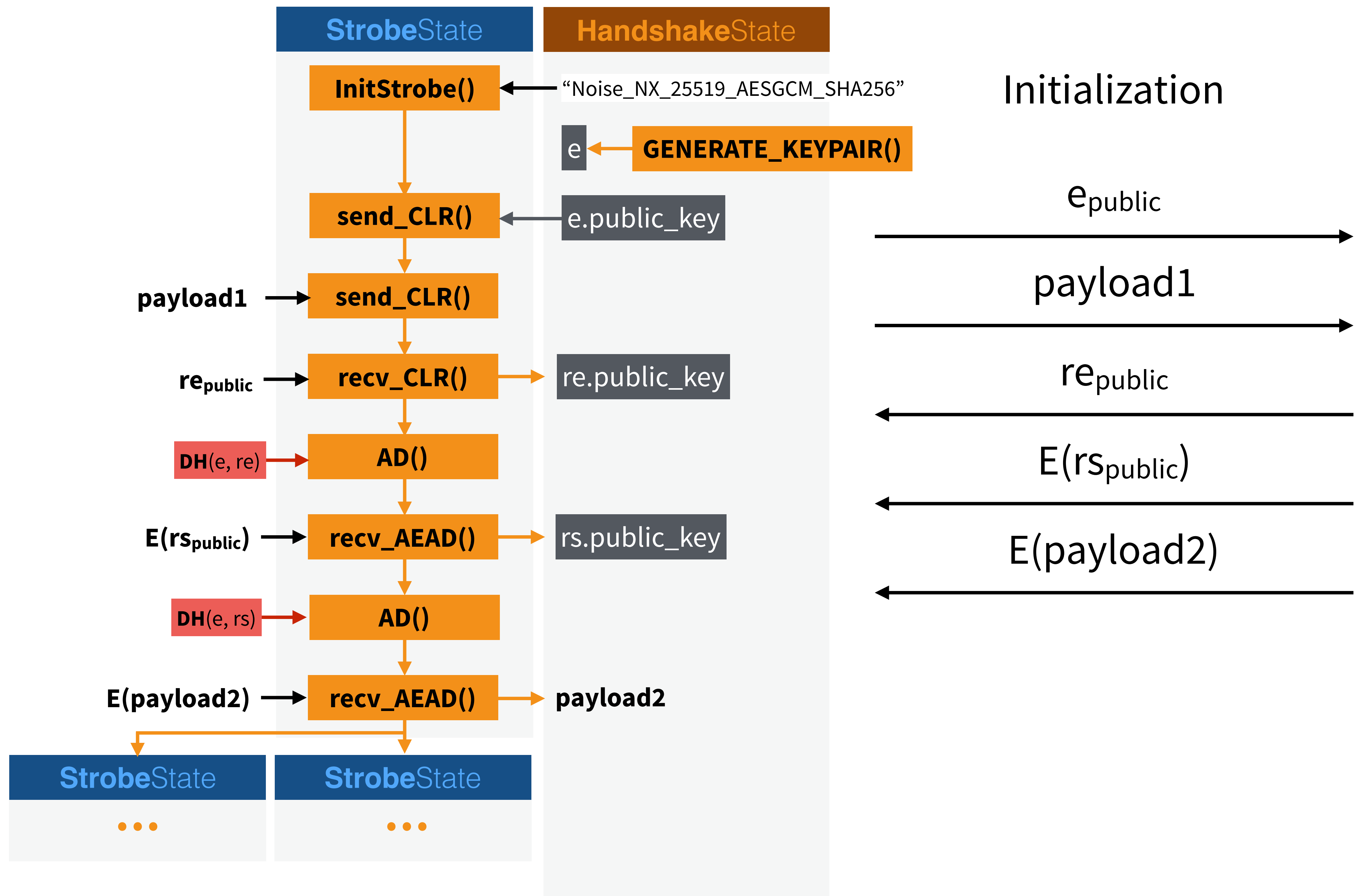
$E_{K1}(s)$

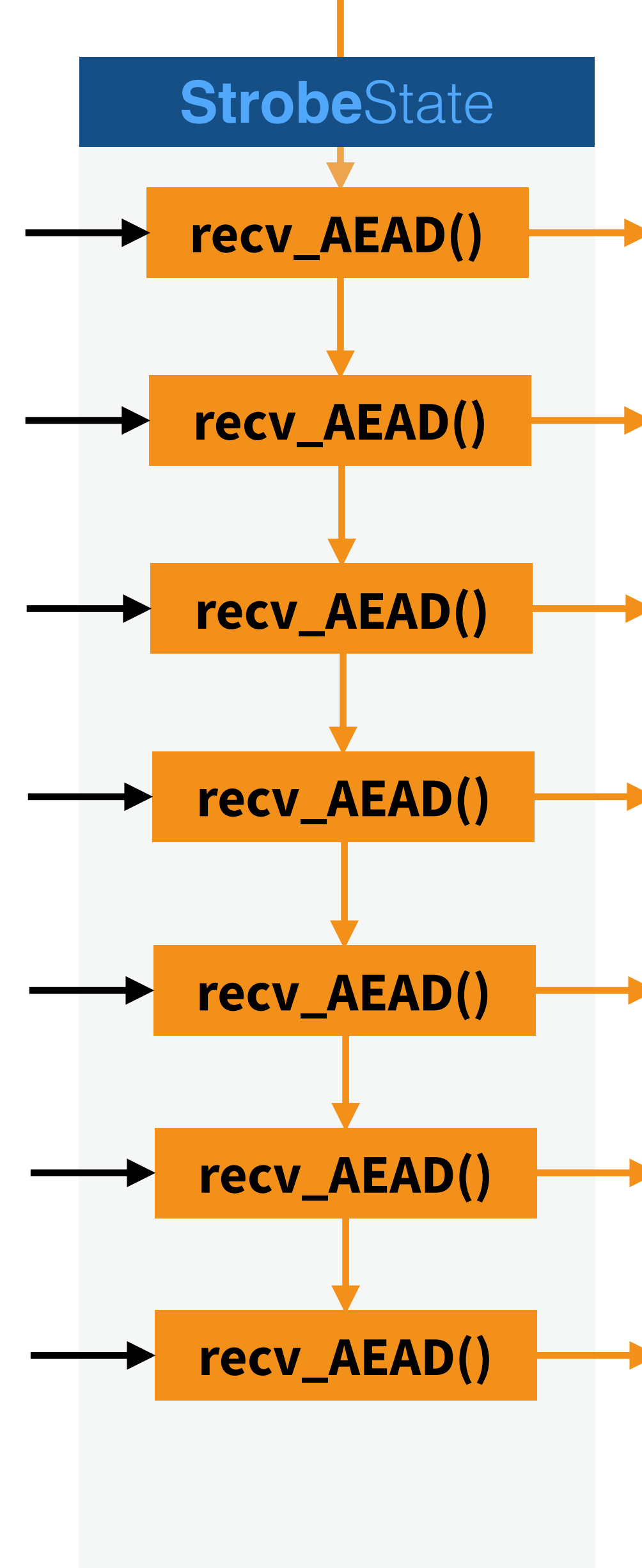
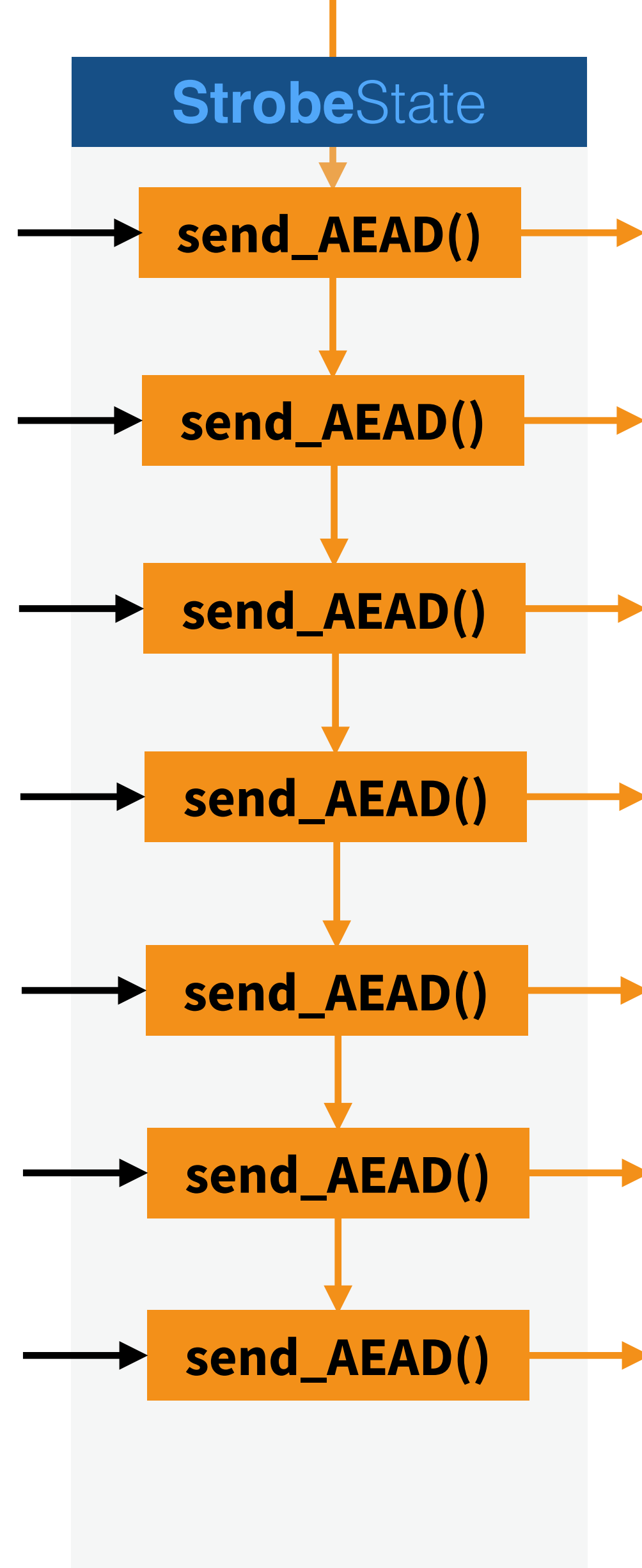
$E_{K2}(\text{payload2})$



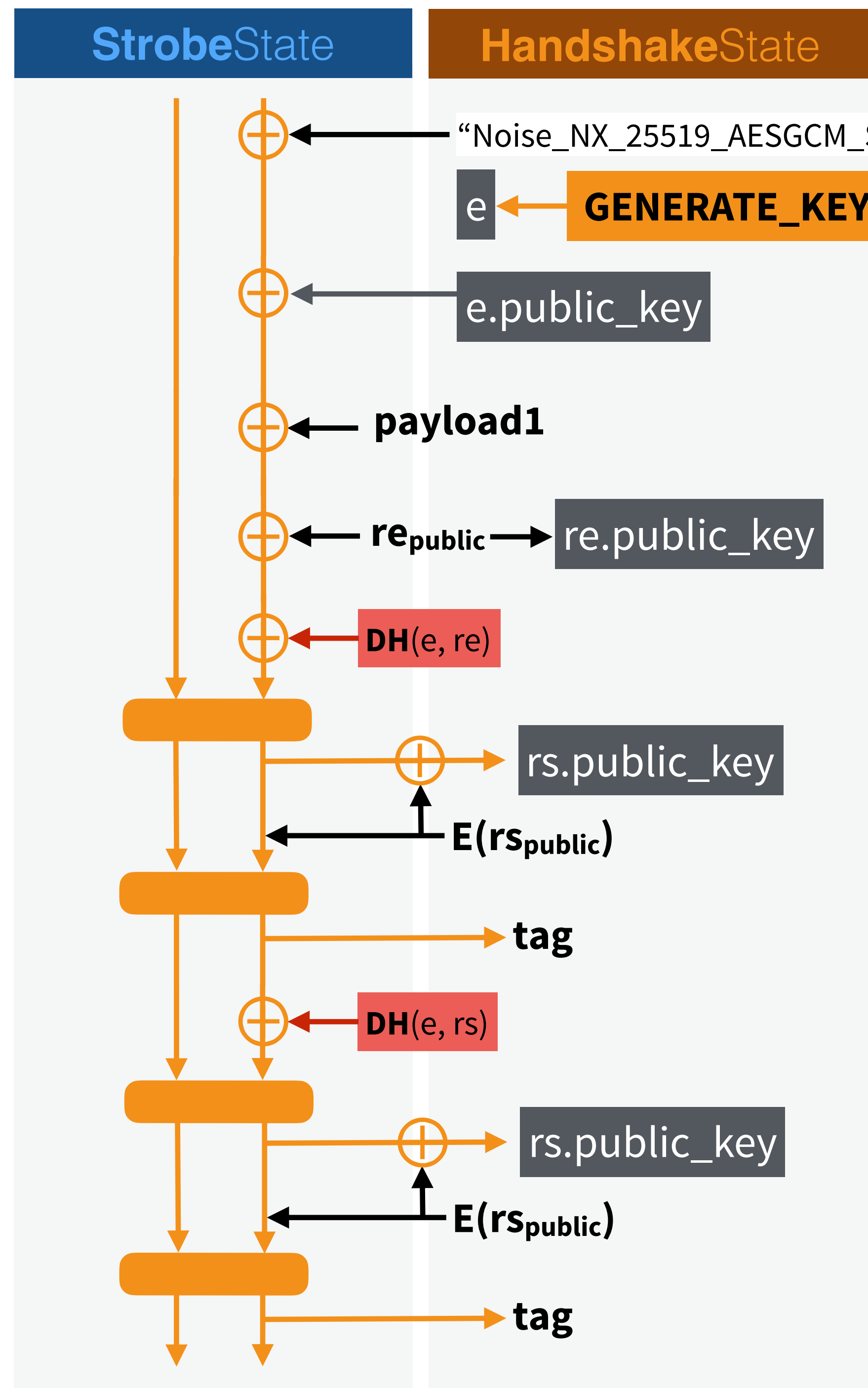
Part IV: Noise + Strobe = Disco

A modern cryptographic {protocol, library} based on
SHA-3 and Curve25519

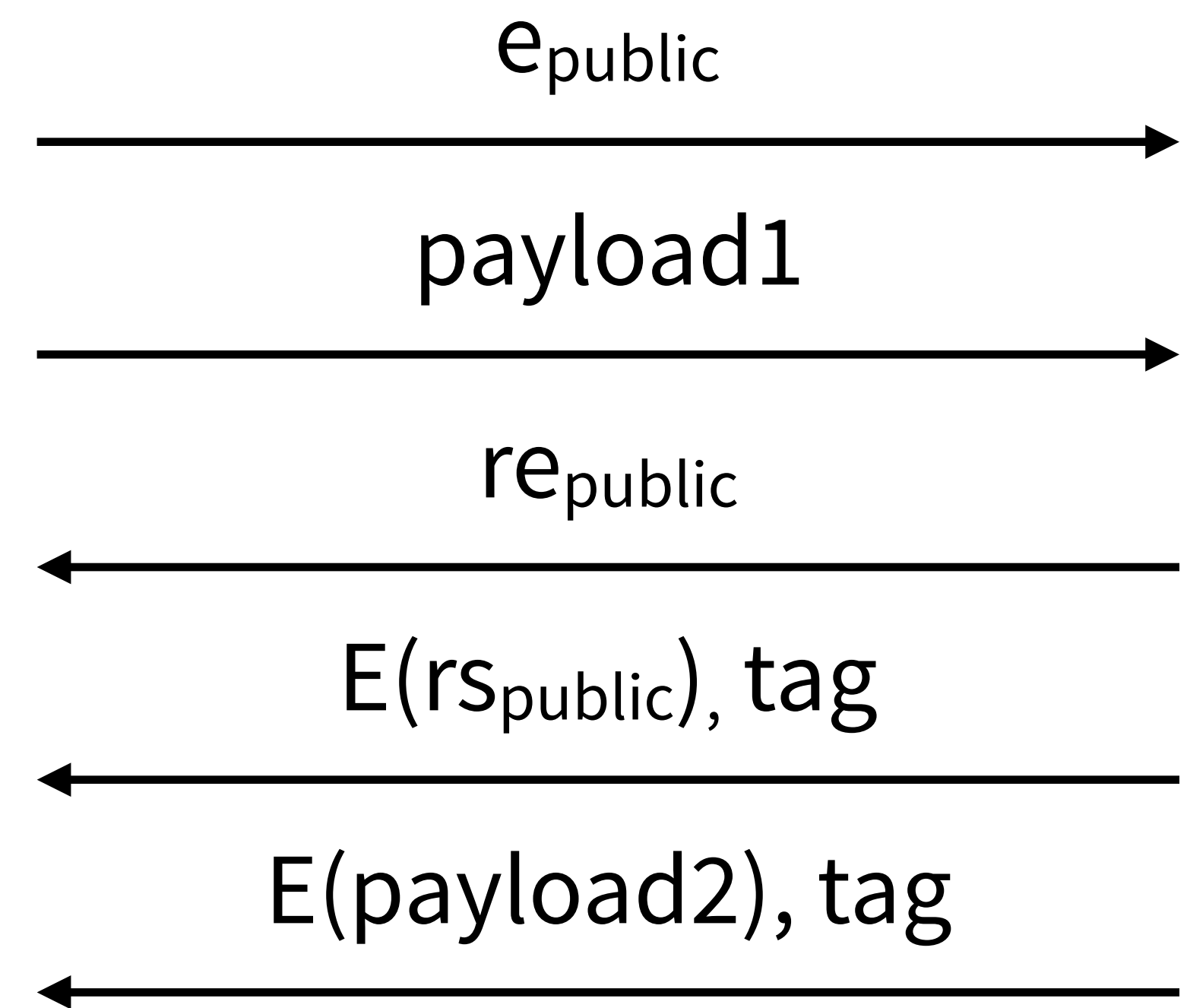




no need for IVs or nonces



Initialization



The **state** of **Disco**

- **Noise** is still a draft
- **Strobe** is alpha (v1.0.2)
- **Disco** is a draft specification extending Noise (**experimental**)
- **libDisco** is a **plug-and-play protocol+library**
 - the Golang library is here: www.discrocrypto.com
 - it's ~**1000 lines of code**
 - ~2000 lines of code with Strobe
 - +2000 lines of code with X25519
- ⚠ Disco and libdisco are still **experimental**
 - we need more eyes, more interoperability testing, ...
- ⚠ **THIS IS NOT REPLACING TLS**

I **write** about crypto at
www.cryptologie.net

I **tweet** my mind on
twitter.com/lyon01_david

and I work here

