Dual EC

a standardized back door

Ruben Niederhagen

Joint work with Stephen Checkoway[1], Matthew Fredrikson[2], Matthew Green[1], Tanja Lange[3], Thomas Ristenpart[2], Daniel J. Bernstein[3,5], Jake Maskiewicz[4], and Hovav Shacham[4]

[1]Johns Hopkins University, [2]University of Wisconsin, [3]Technische Universiteit Eindhoven, [4]UC San Diego, [5]University of Illinois at Chicago

Technische Universiteit Eindhoven University of Technology

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Random Numbers in Cryptography

Random numbers are crucial for cryptography:

- generation of private keys for authentication
- generation of secret keys for encryption
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Must be impossible for an attacker to predict!

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Common approach:

- use *pseudo* random numbers
- start with a random *seed*
- compute subsequent values deterministically
  $\Rightarrow$ update a secret internal state

Random Numbers in Cryptography

s_0

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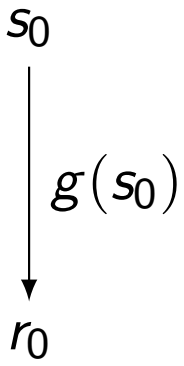

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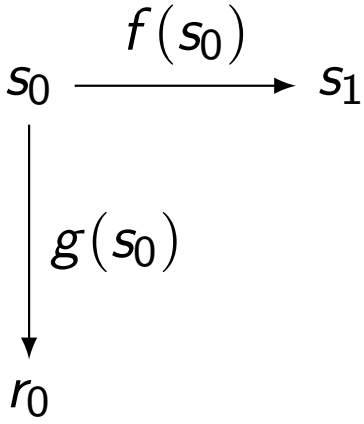

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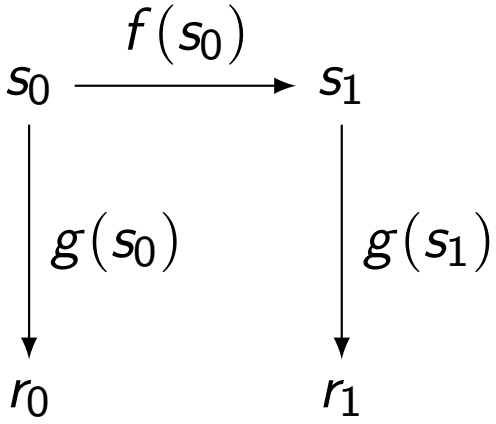

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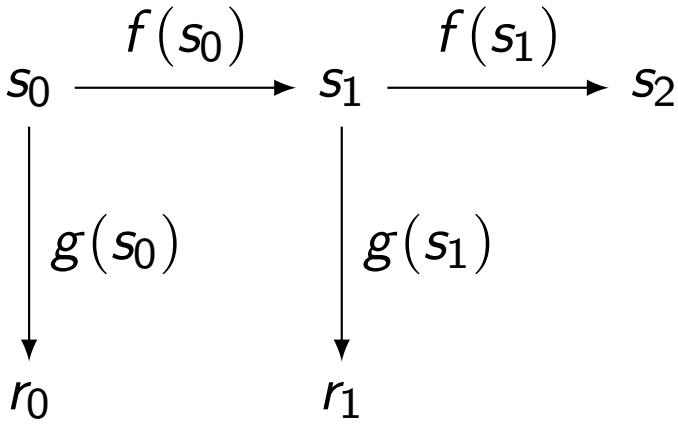

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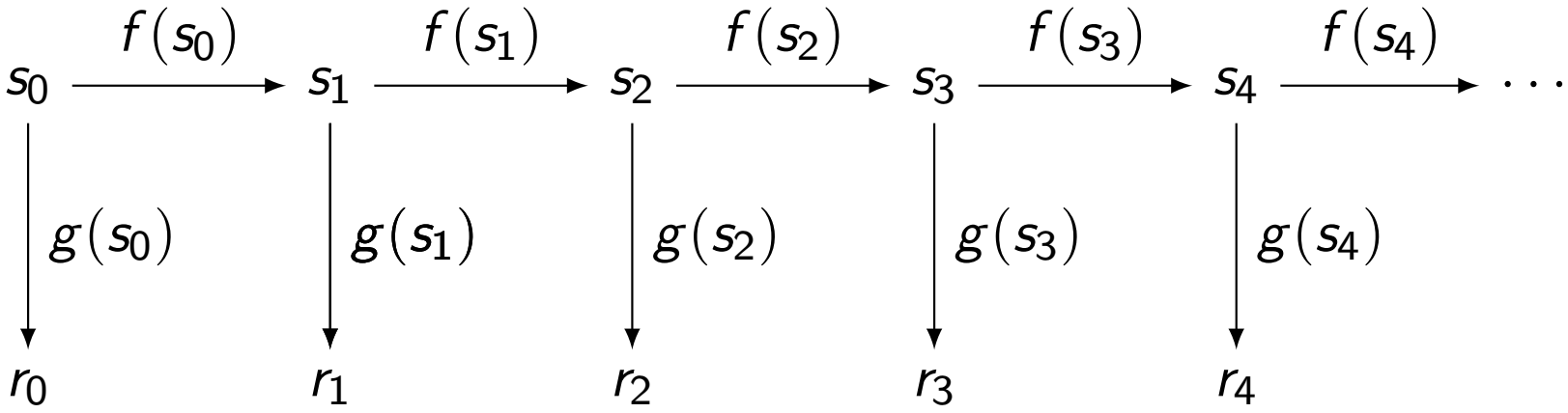

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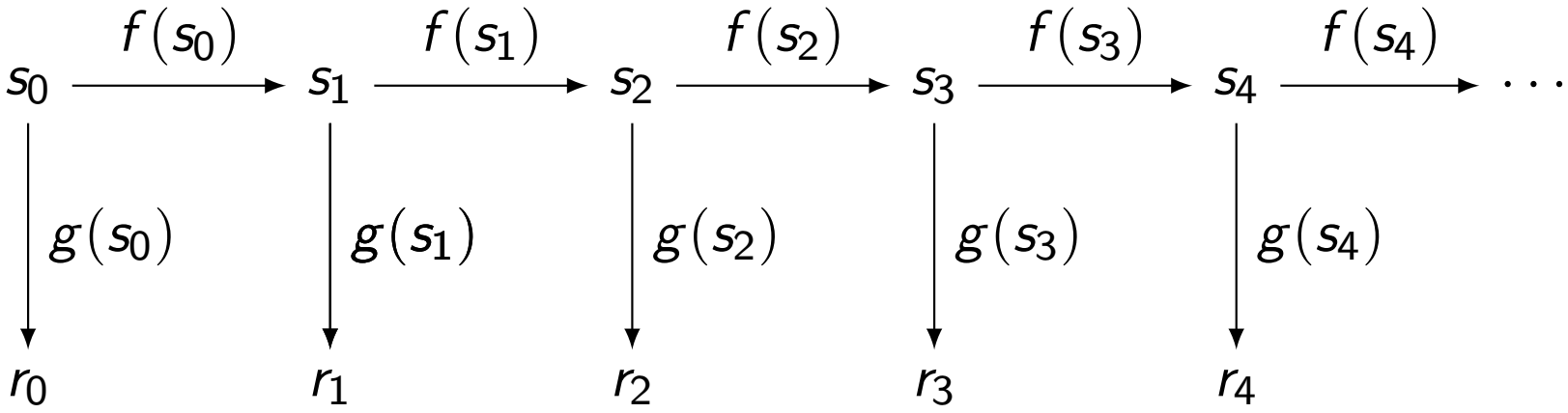

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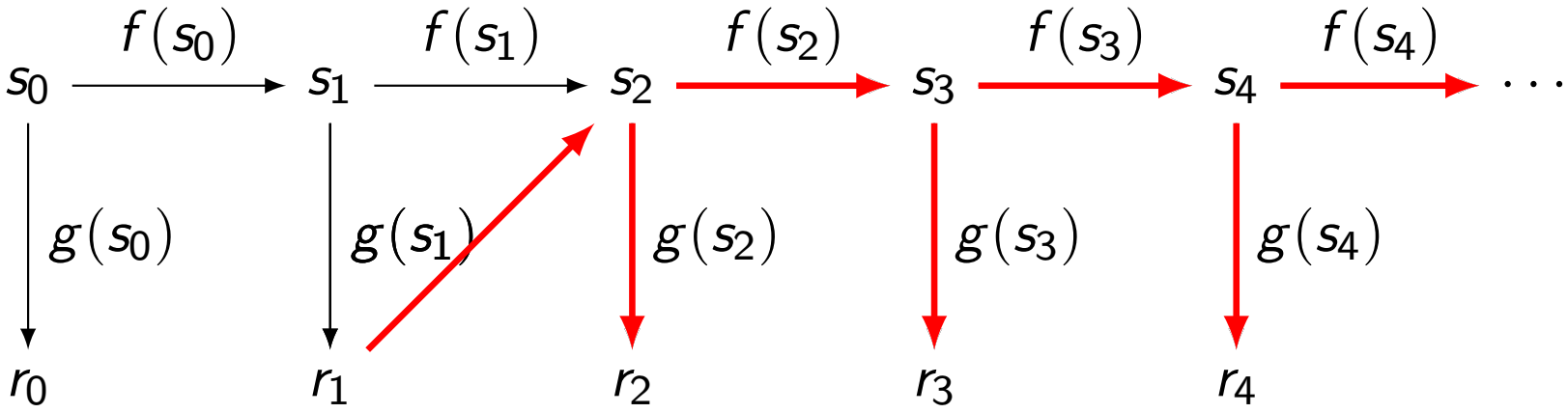

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Dual EC – a Standardized Back Door

Topic of this talk:

The "potential" back door in the
Dual Elliptic Curve Deterministic Random Bit Generator (Dual EC)
standardized by ANSI, ISO, and NIST.

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Aug. 2007	Shumow and Ferguson demonstrate the basic back door.

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21 Apr. 2014	NIST removes Dual EC from the standard.

Authors of Dual EC

Kelsey, in December 2013 slides:

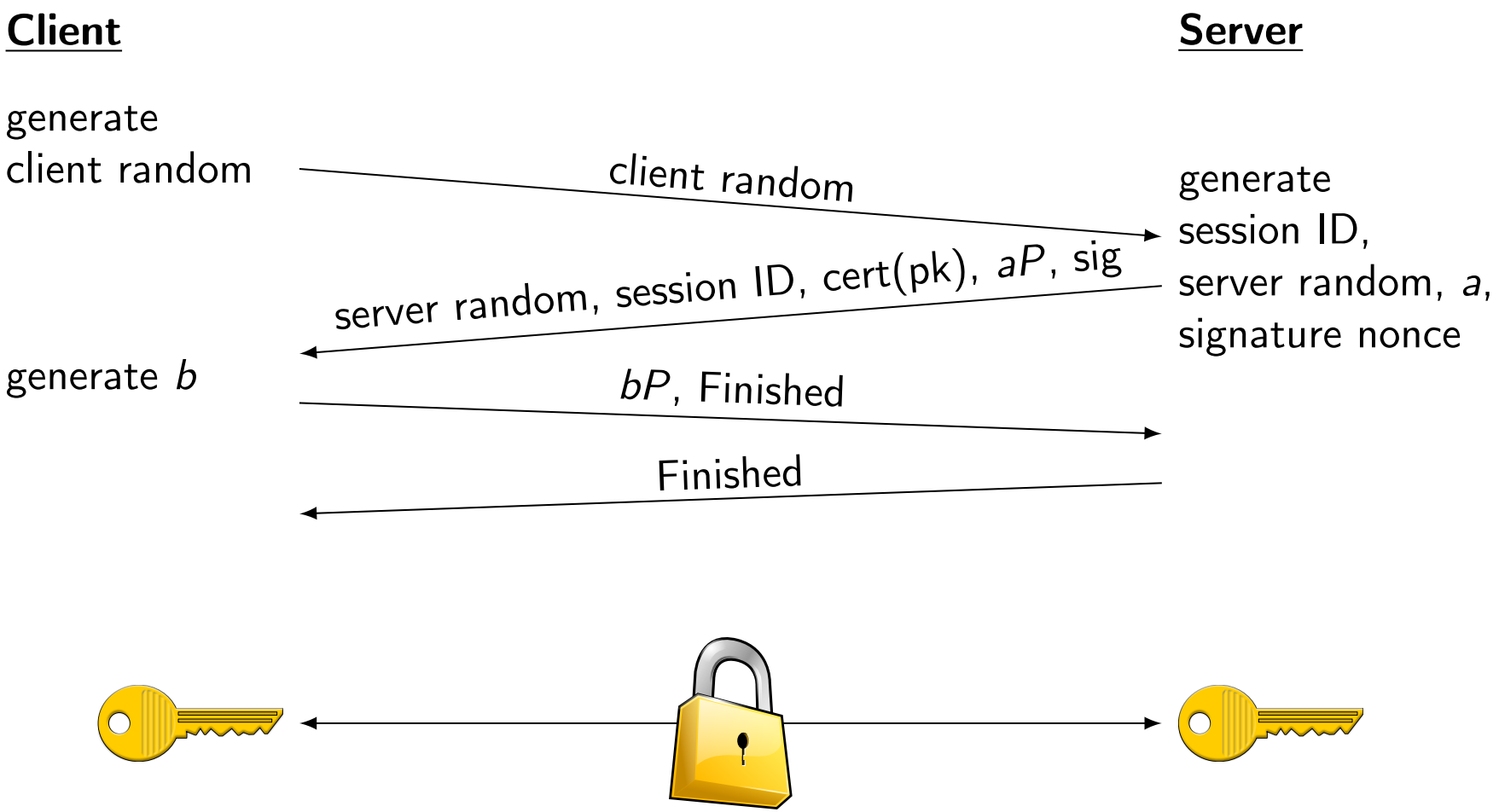
- Standardization effort by "NIST and NSA, with some participation from CSE".
- "Most of work on standards done by US federal employees (NIST and NSA, with some help from CSE)"
- The standard Dual EC parameters P and Q come "ultimately from designers of Dual EC DRBG at NSA".

Attack Target — TLS

Transport Layer Security (TLS)

- Used in the Internet for encryption of communication.
  Examples:
  - eMail transport
  - online banking
  - online shopping
  - ...
- Standard covers a fast amount of protocols and optional features.
- Client and server agree on what parameters to use.
- Client and server agree on a random secret key.

TLS Handshake



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Elliptic Curve Discrete Logarithm Problem

Arithmetic on Elliptic Curves

Operate on points $P = (x_P, y_P)$ on an elliptic curve.

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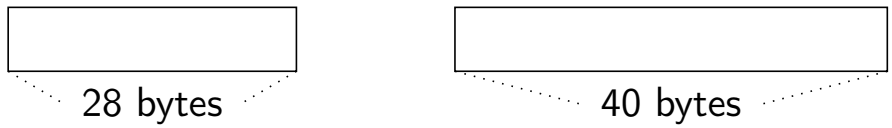
It is *hard* to find k such that $B = k \cdot A$!

Dual EC — Basic Procedure



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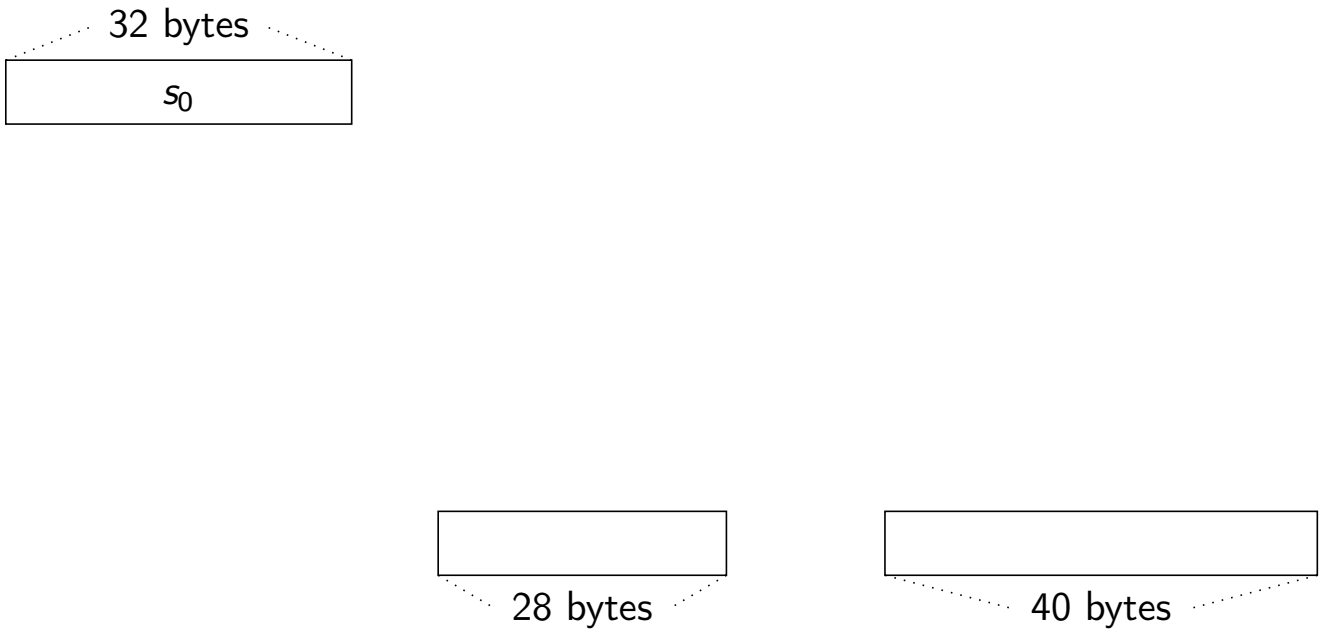
Points Q and P on an elliptic curve.



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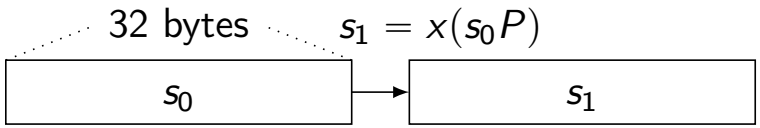

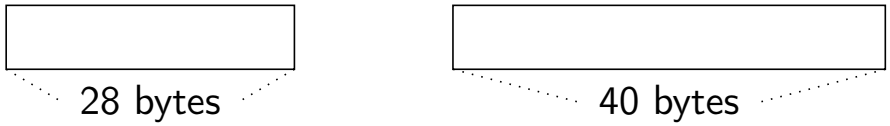

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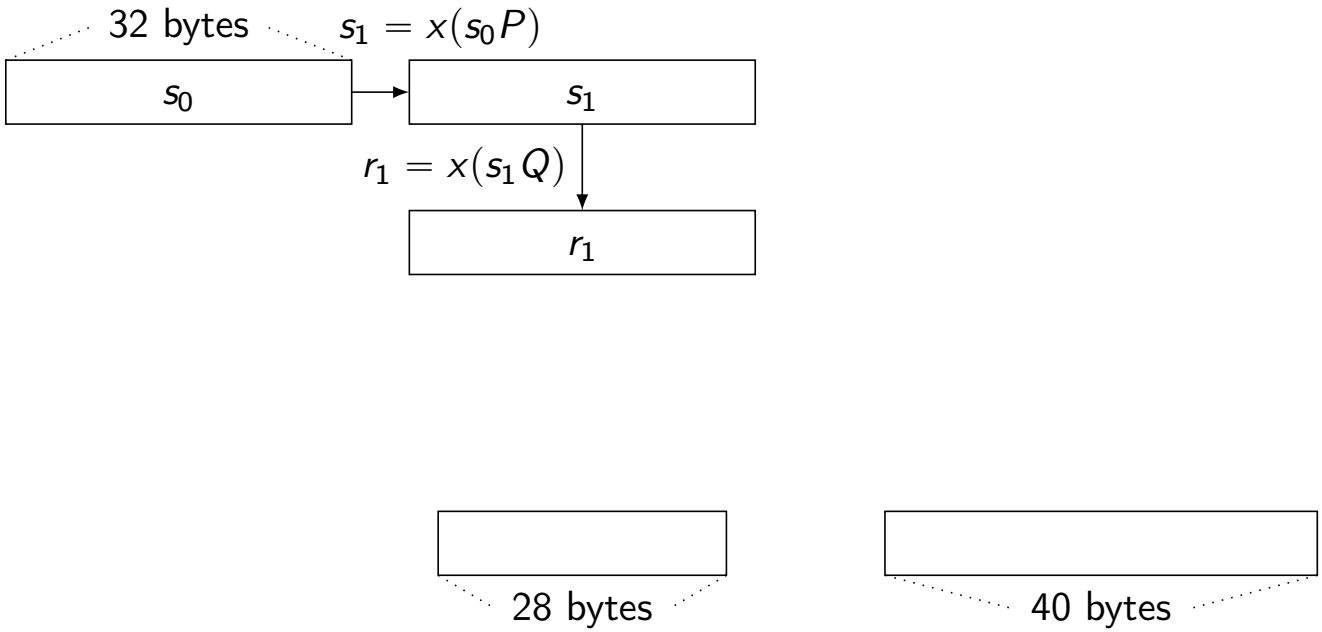

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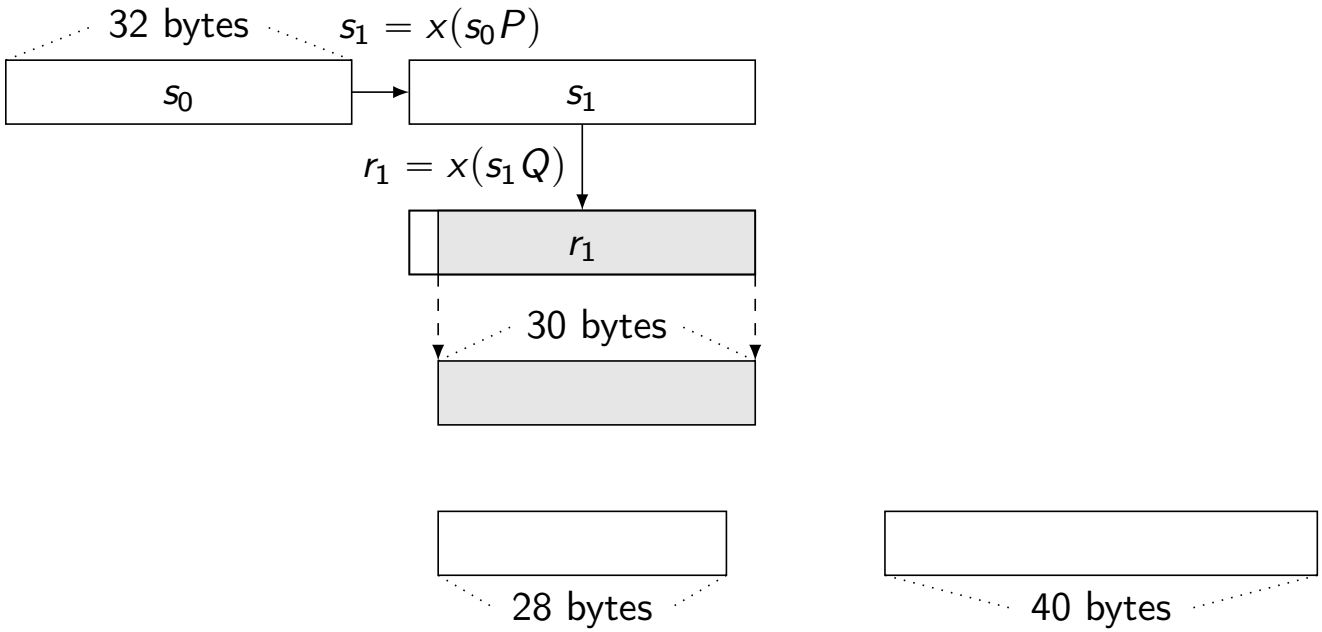

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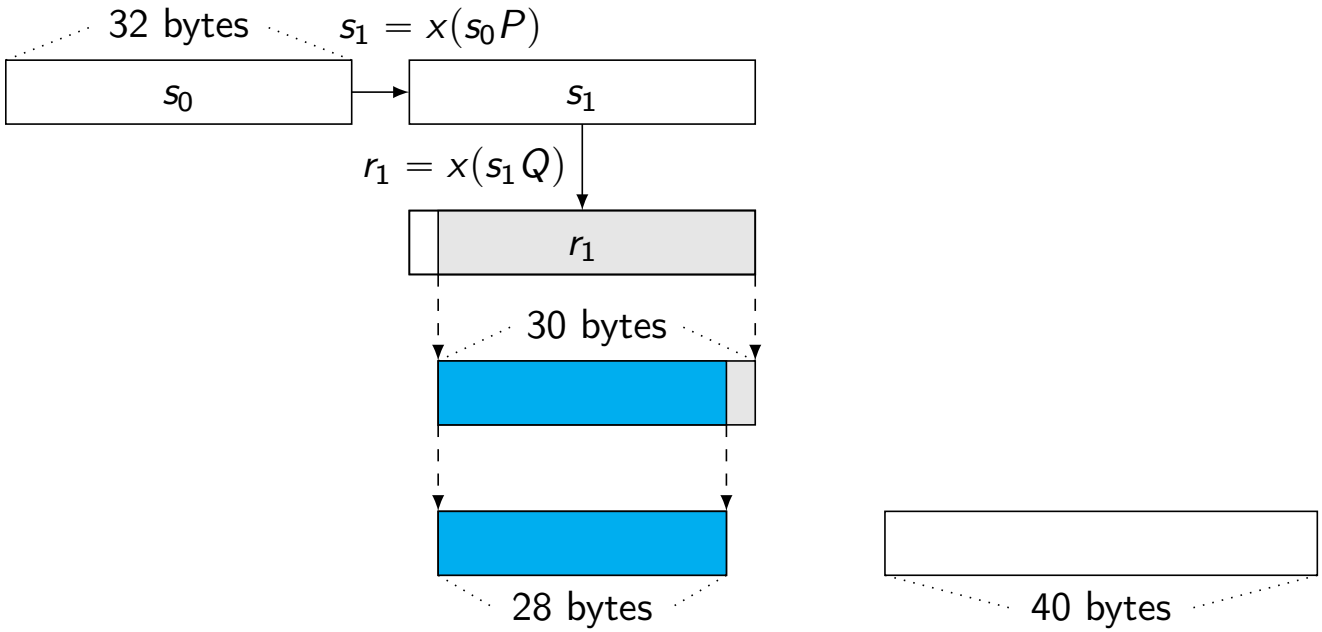

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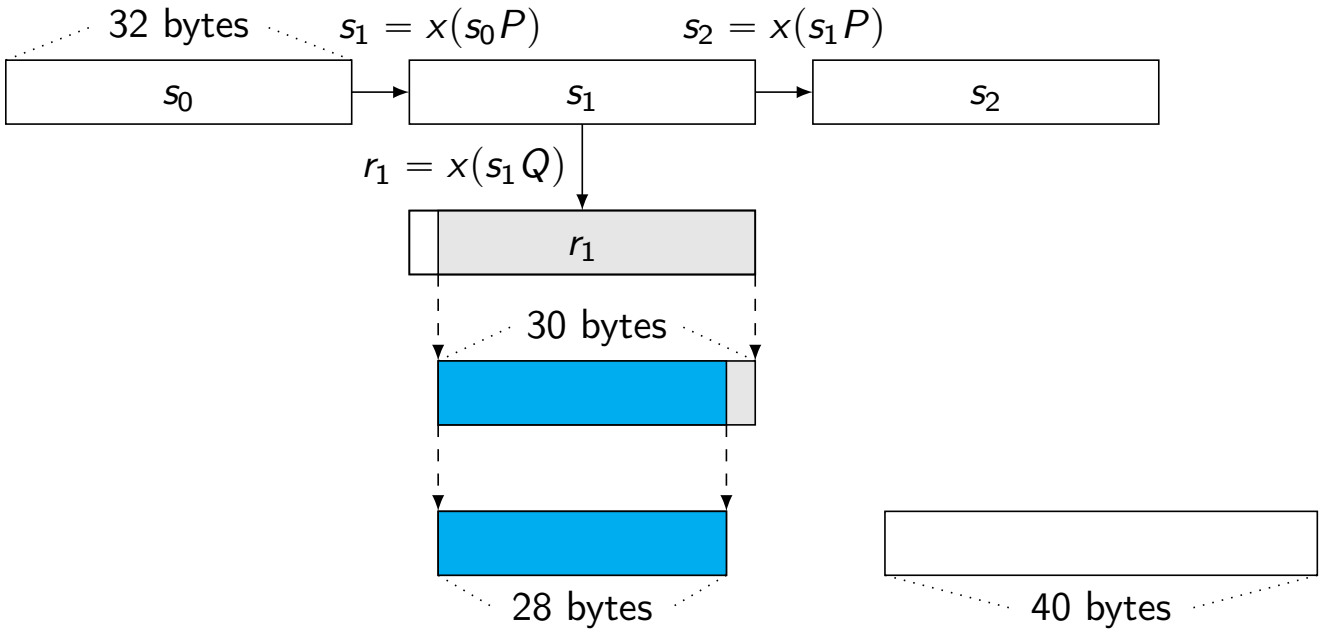

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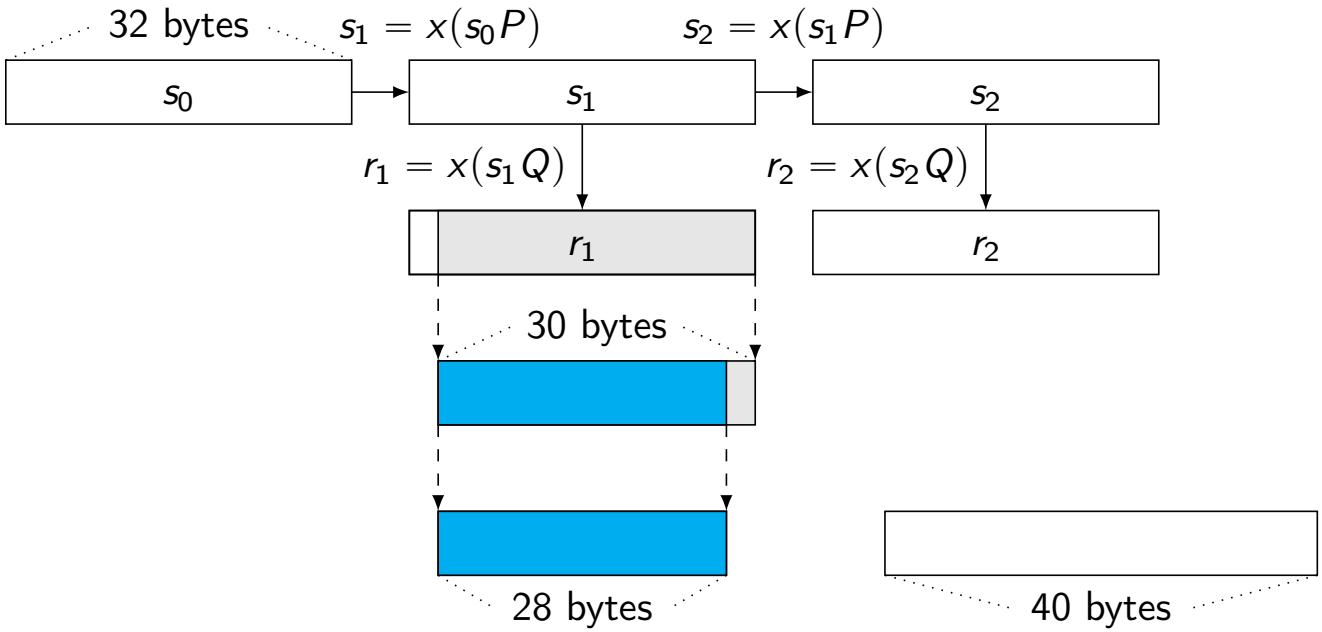

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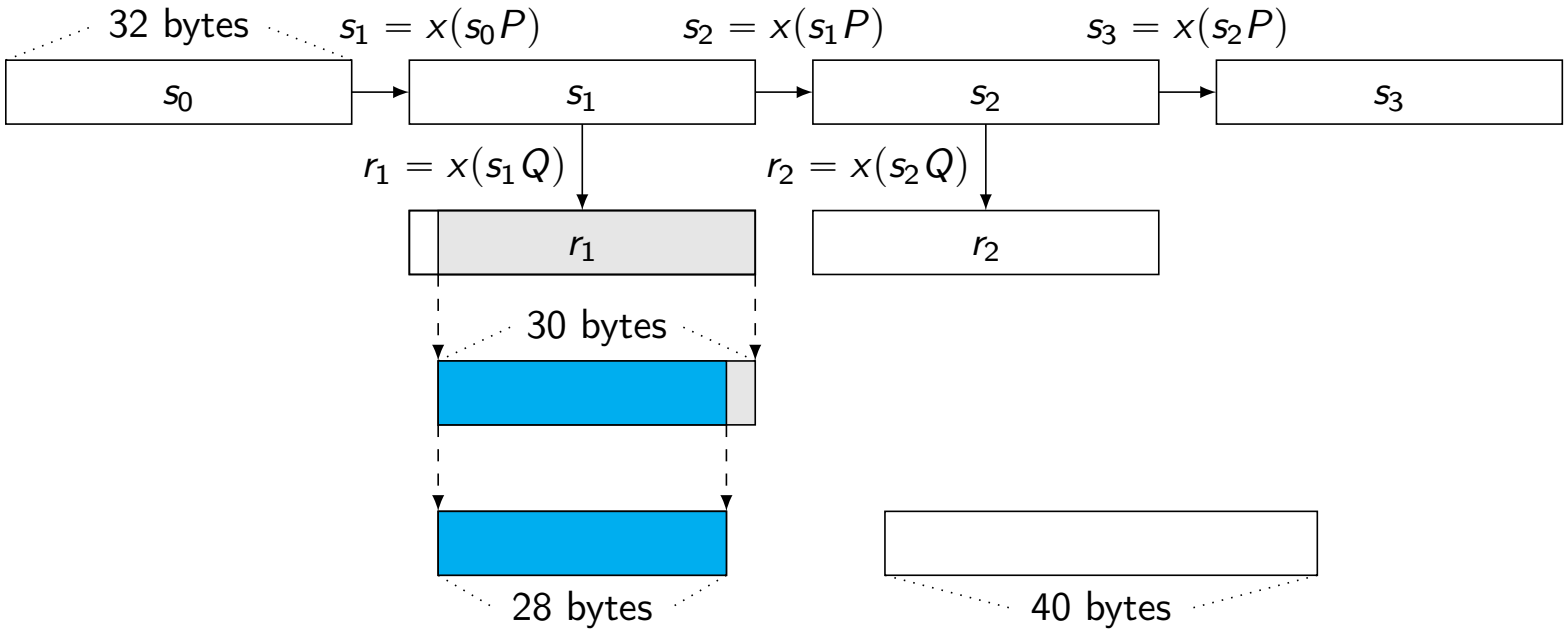

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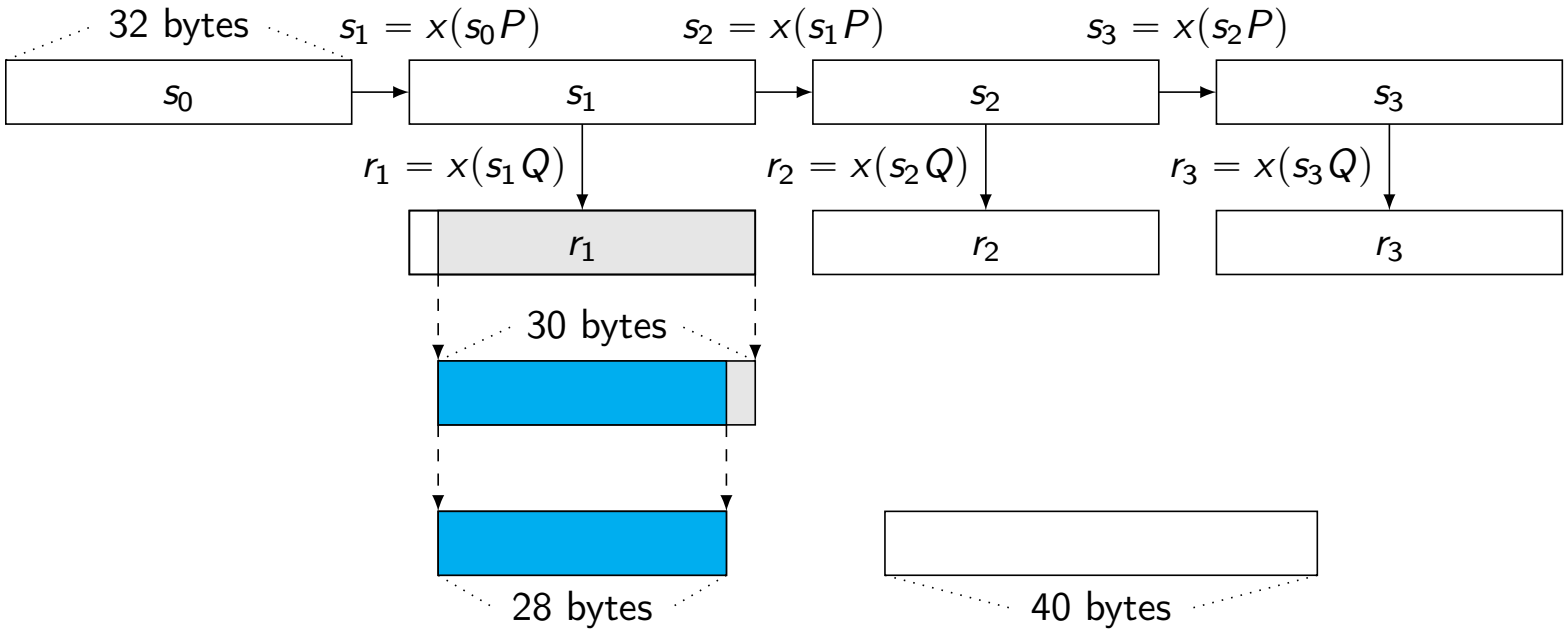

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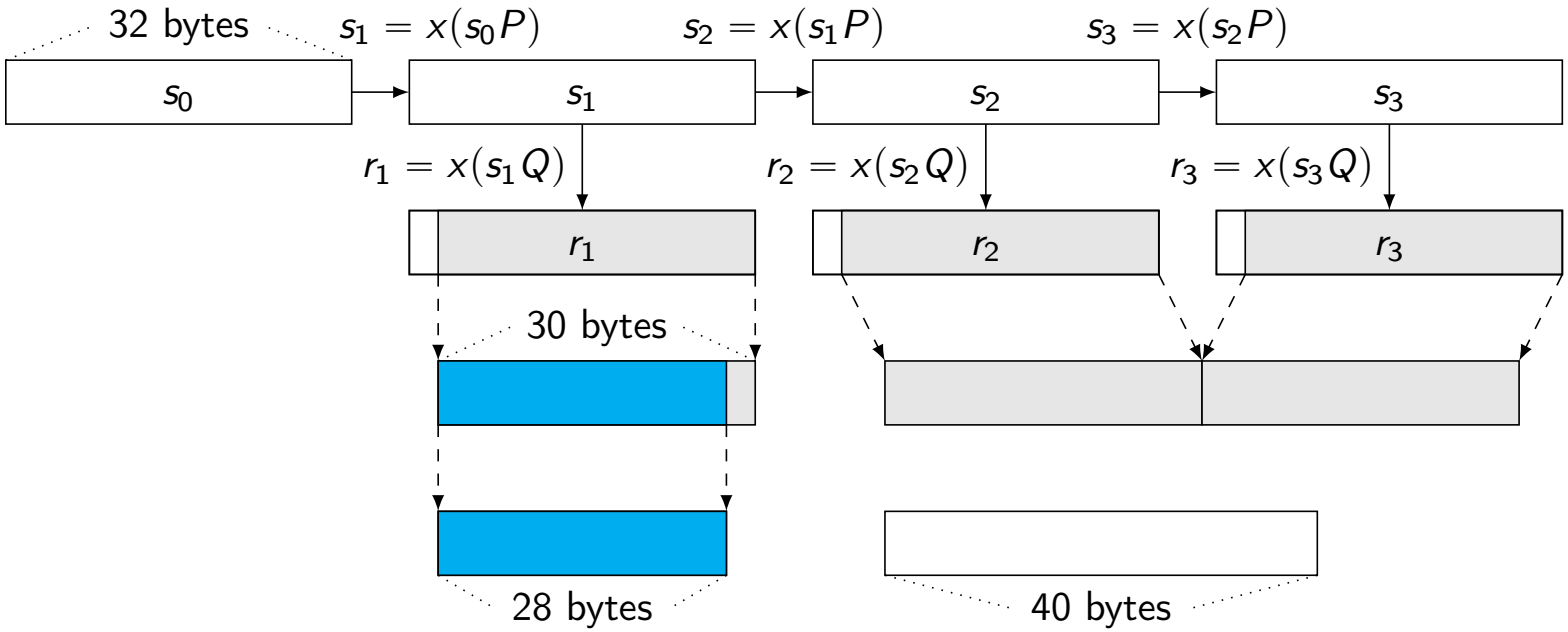

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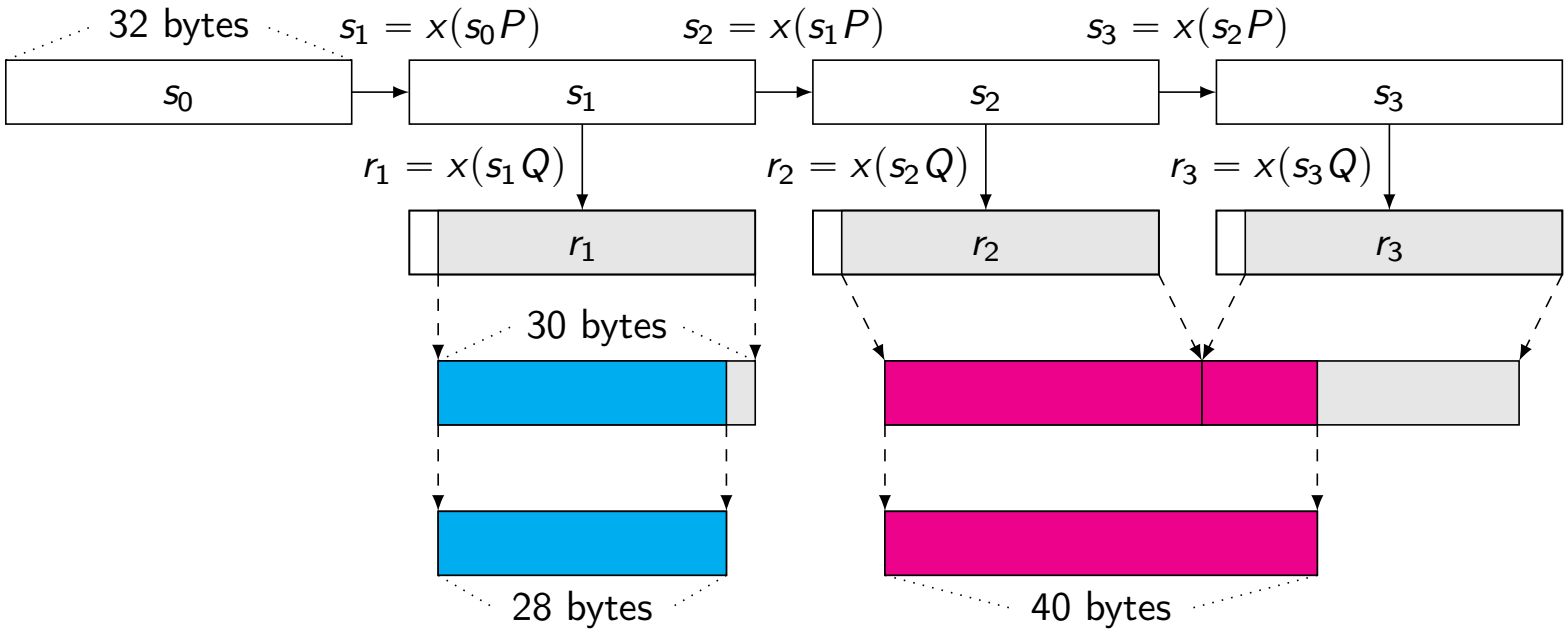

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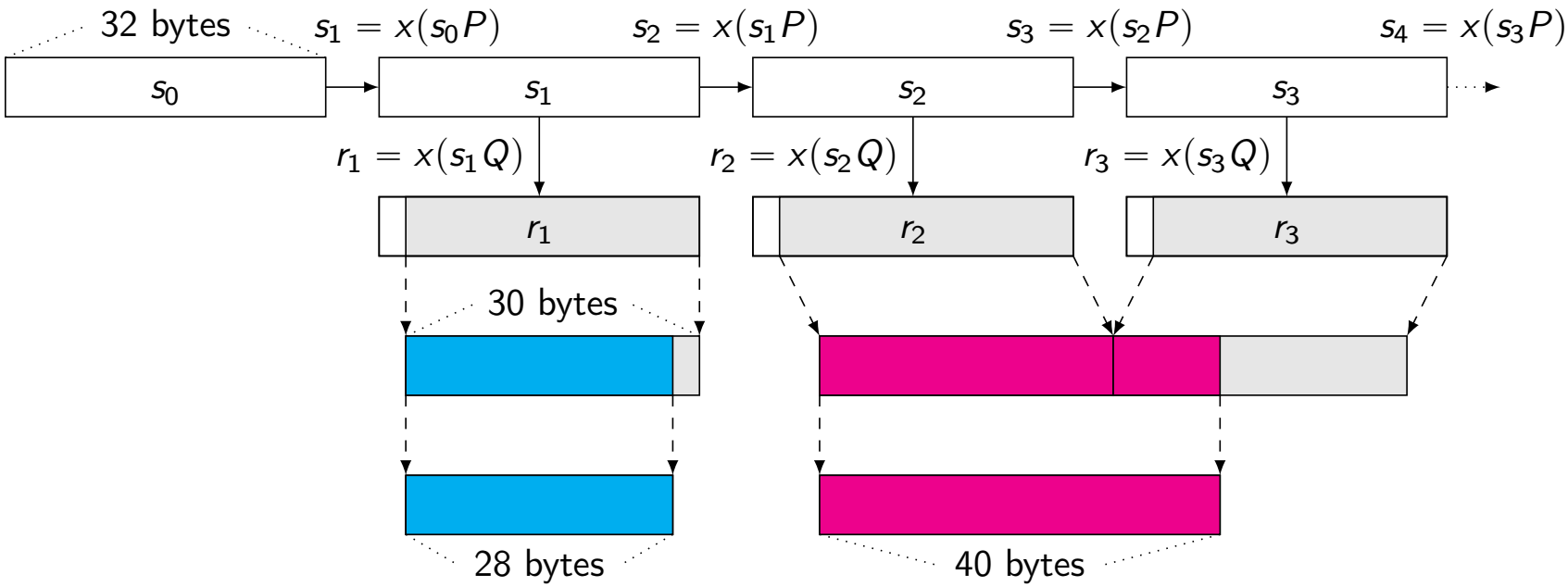

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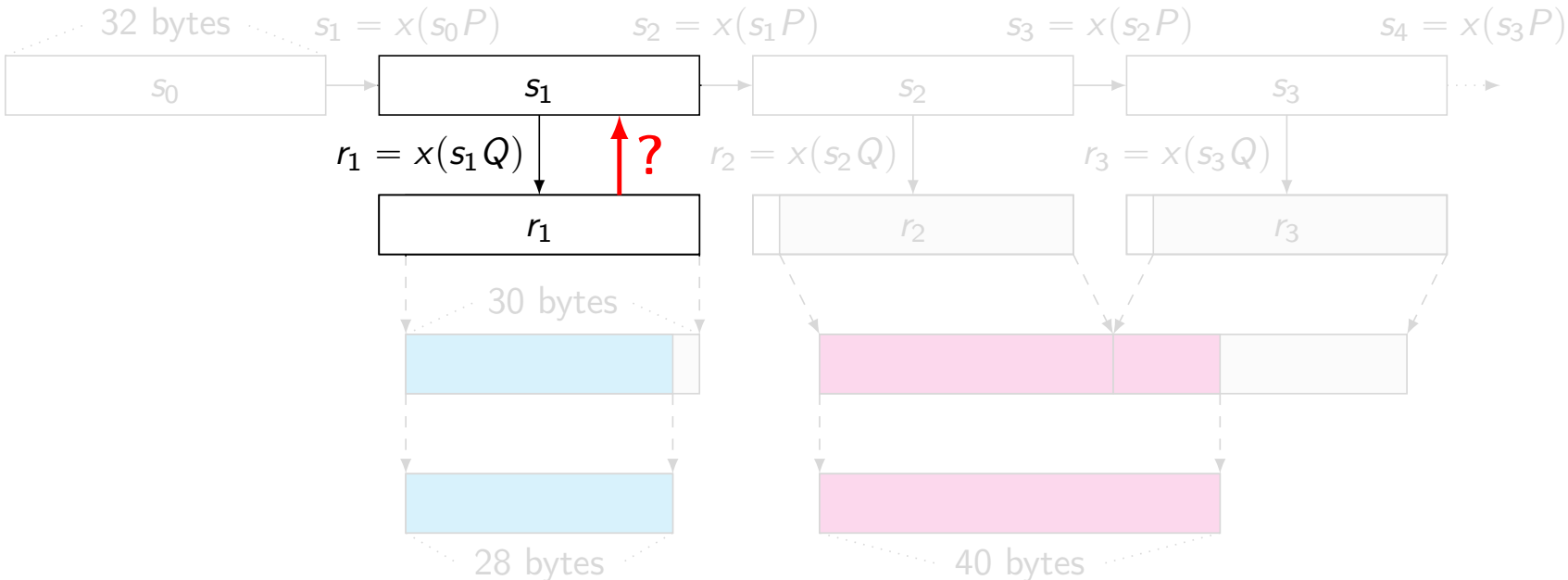

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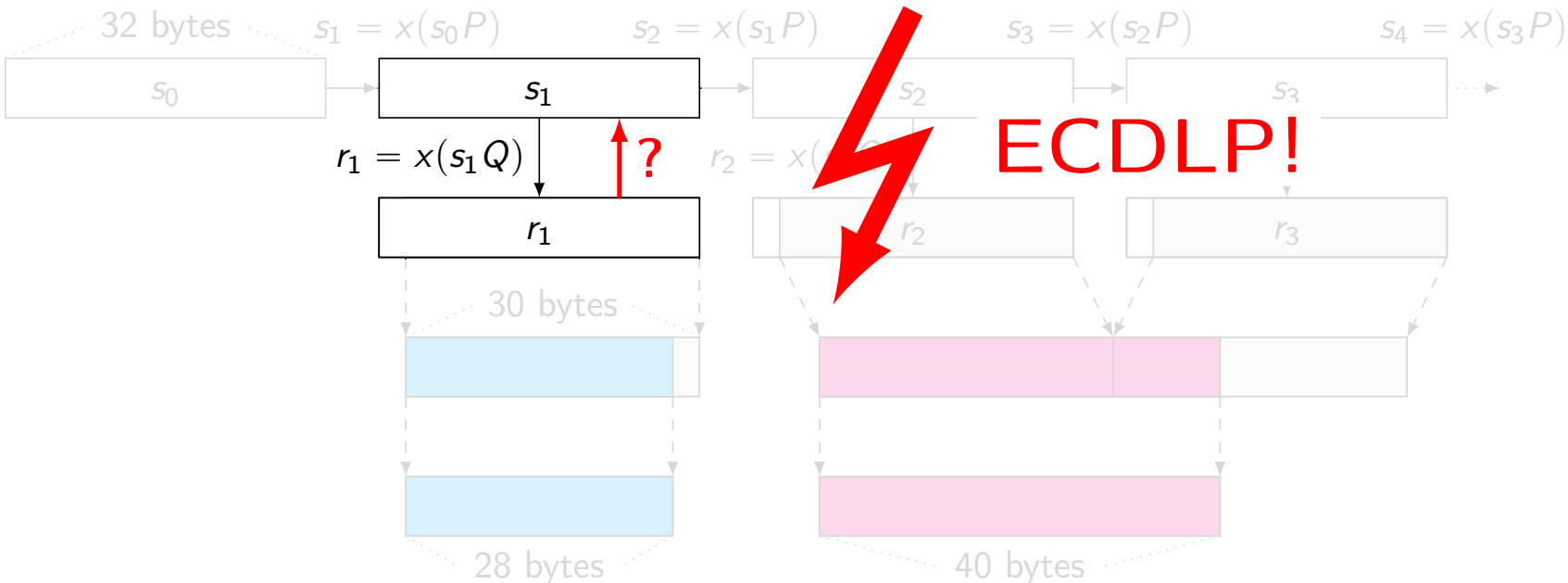

Shumow and Ferguson – the Basic Attack

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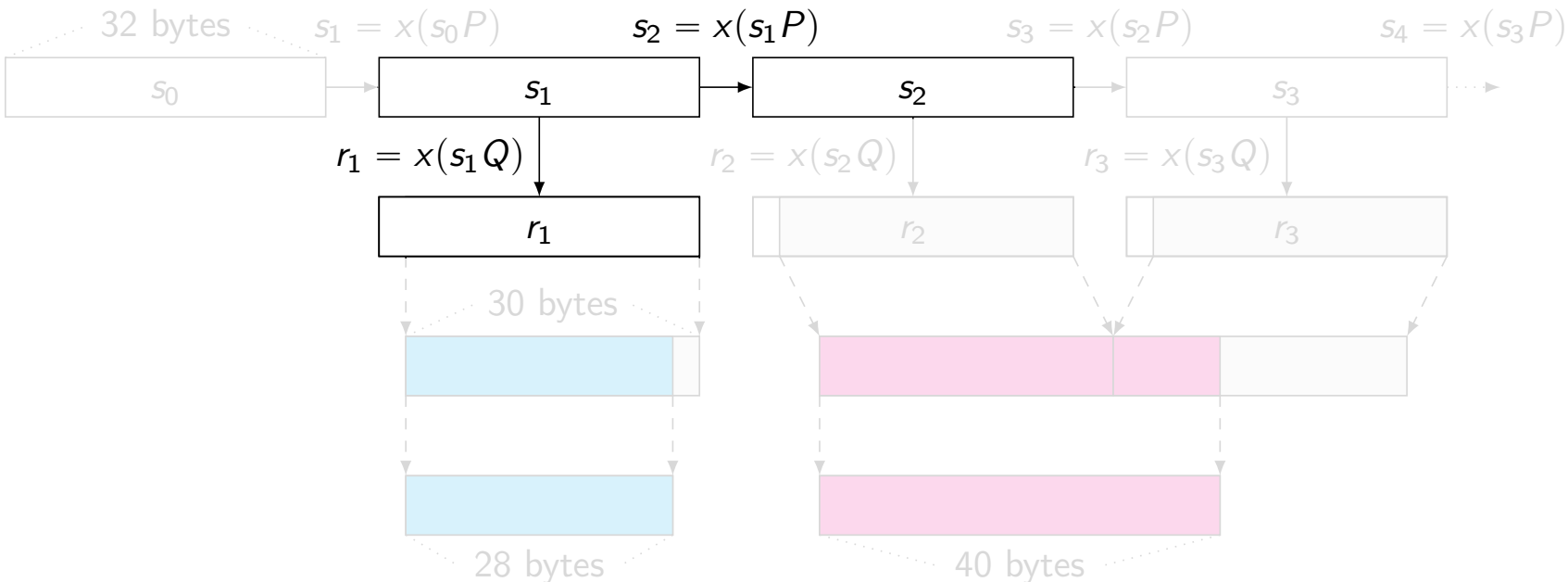

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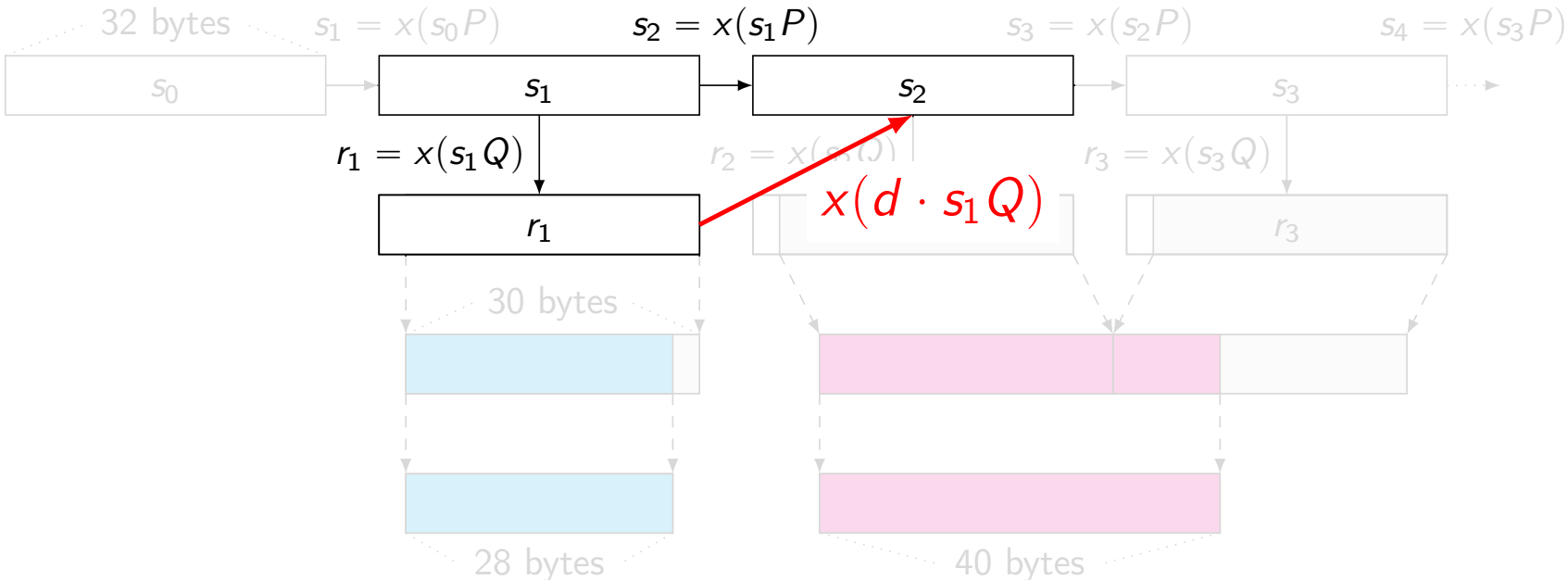

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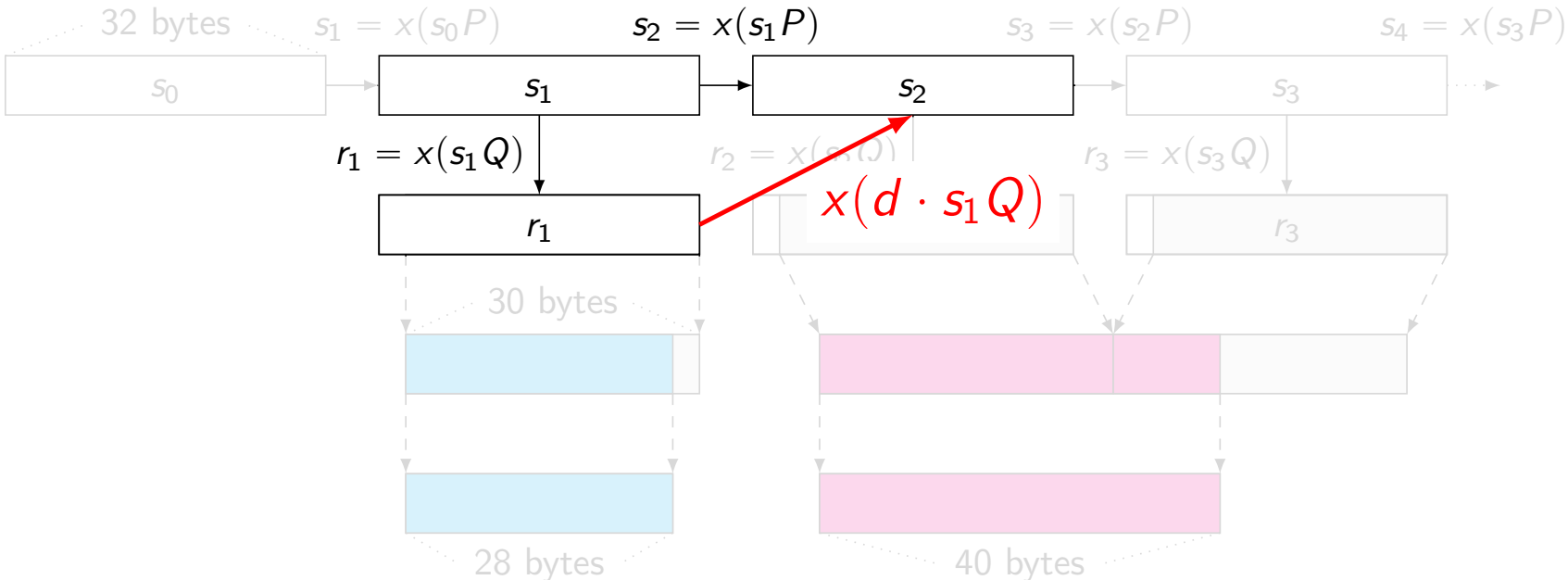

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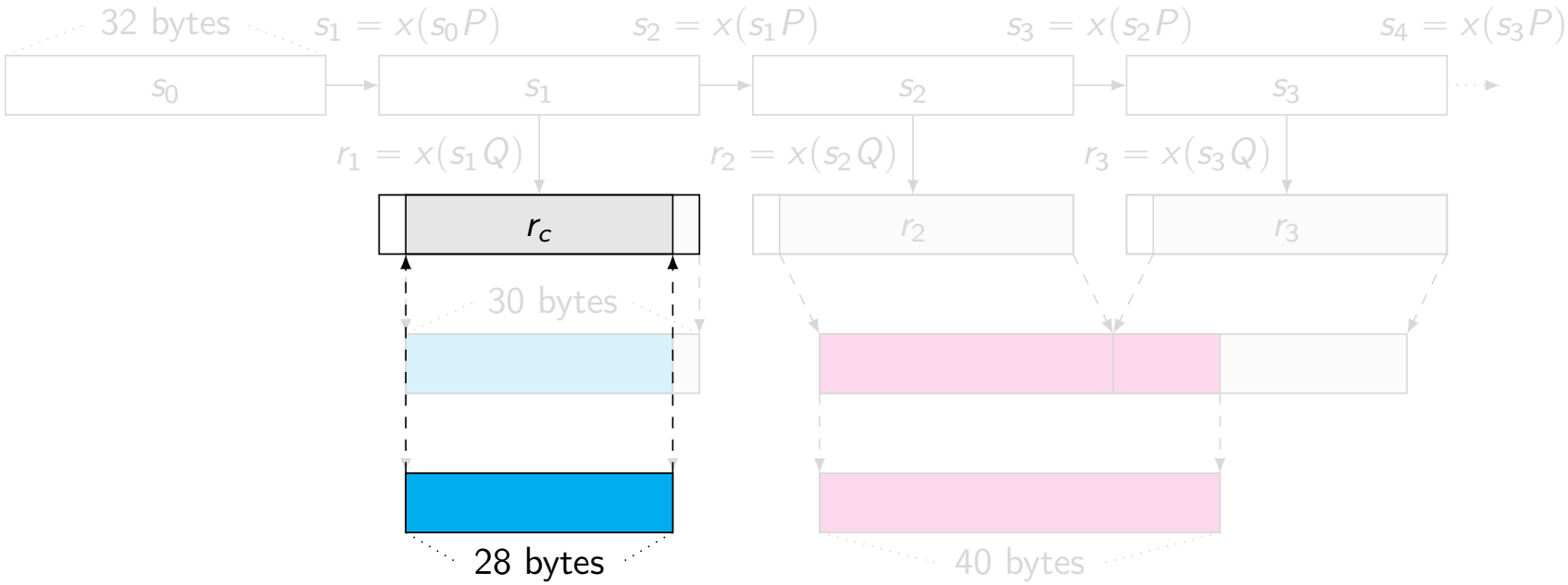

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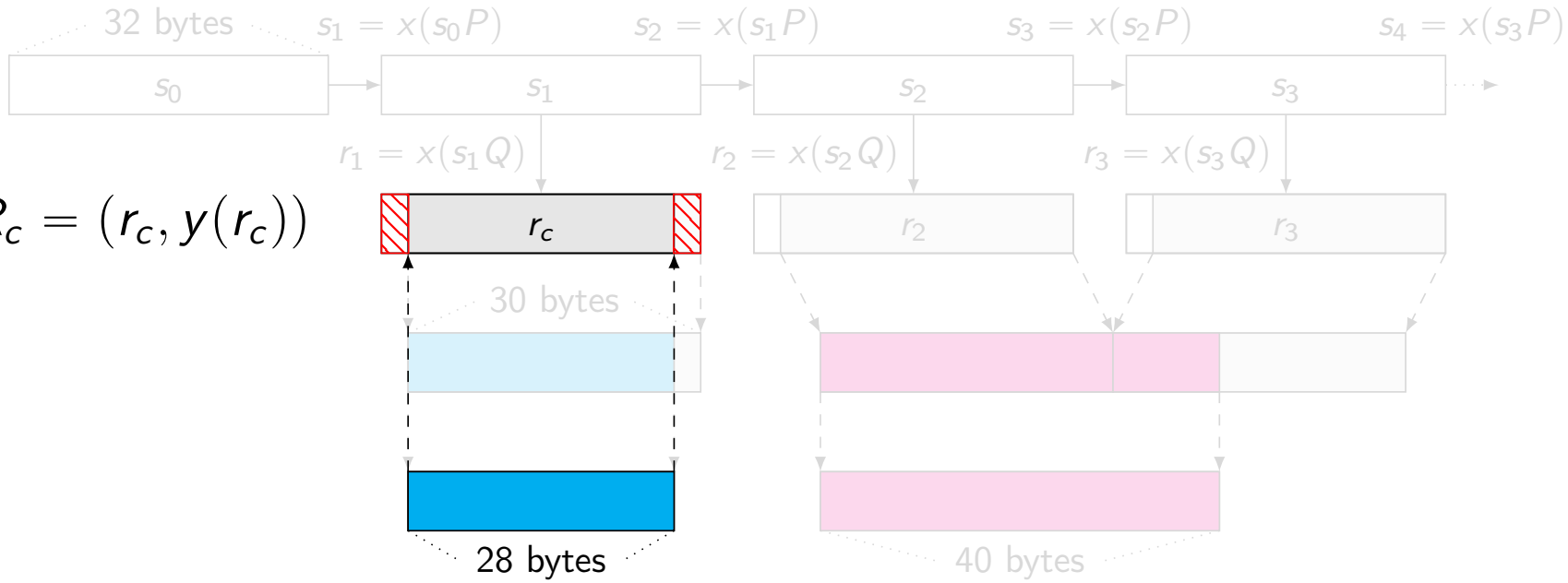

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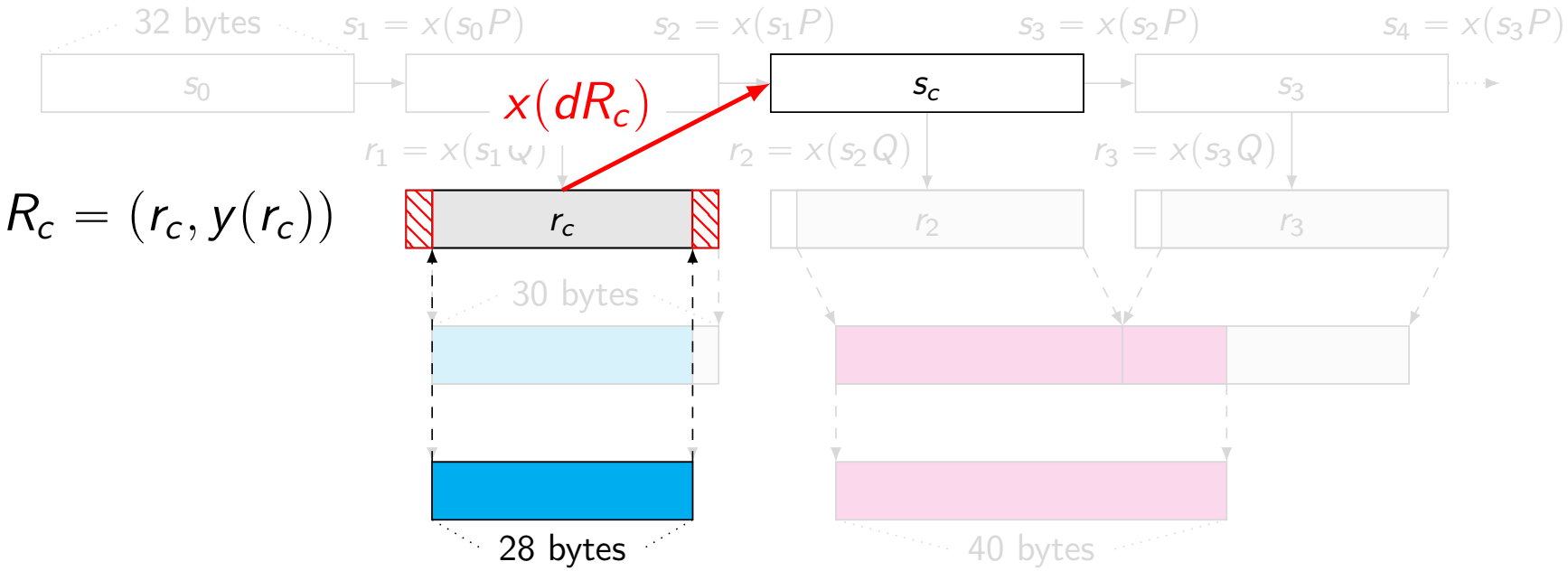

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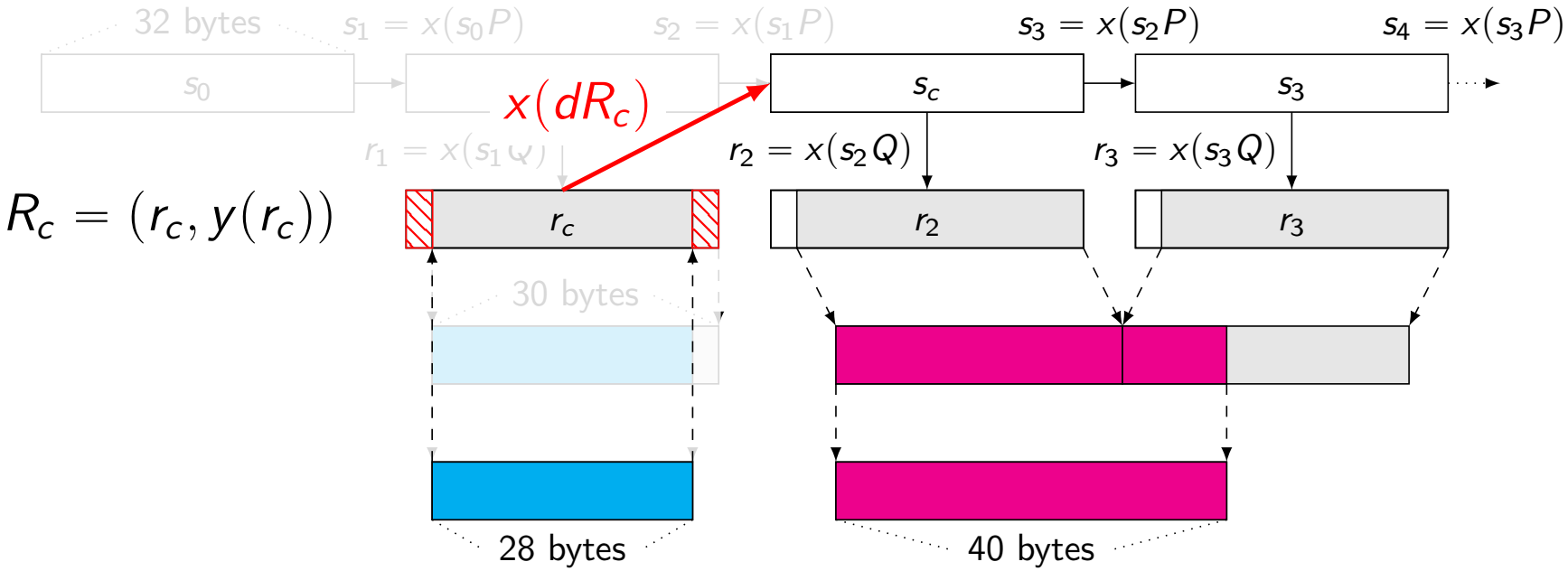

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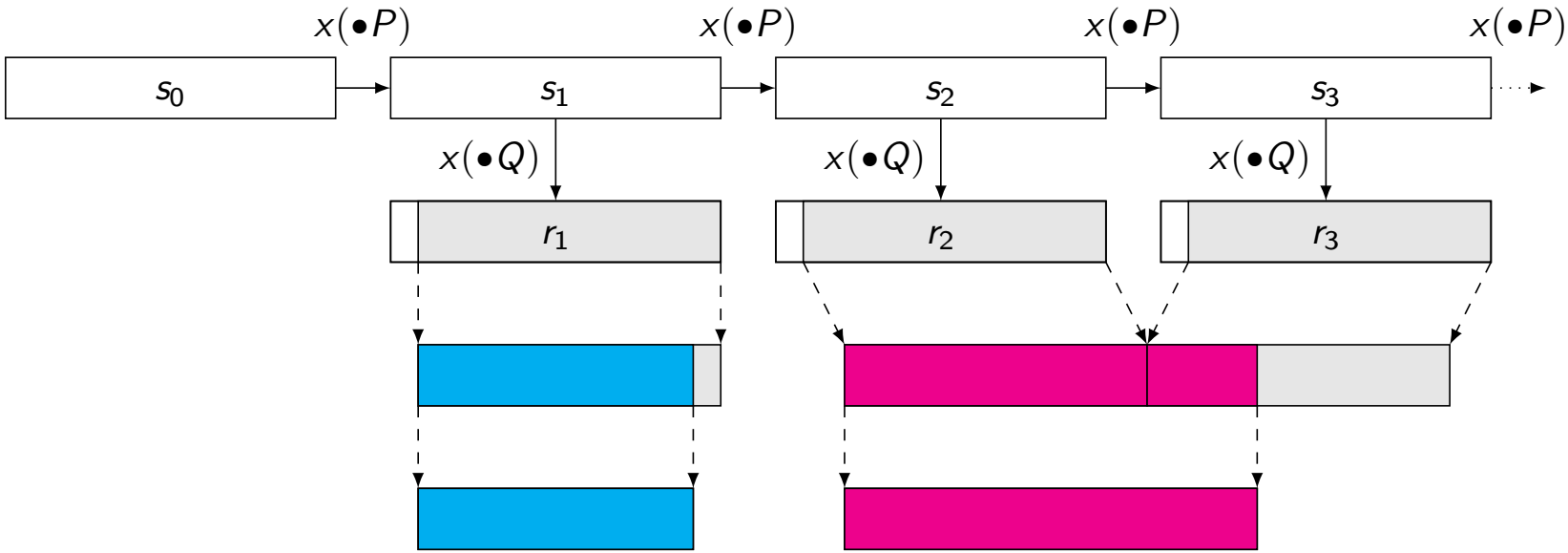
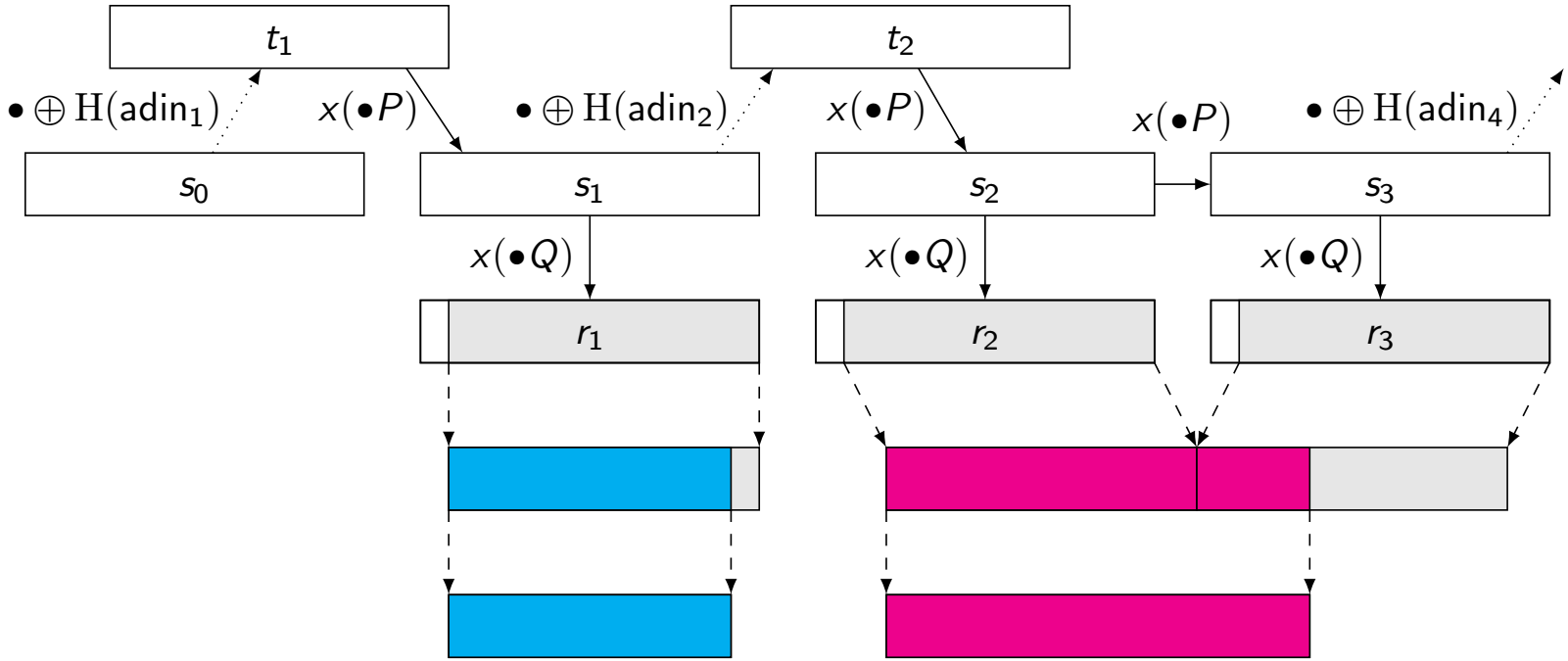


Dual EC — NIST SP800-9 in June 2006



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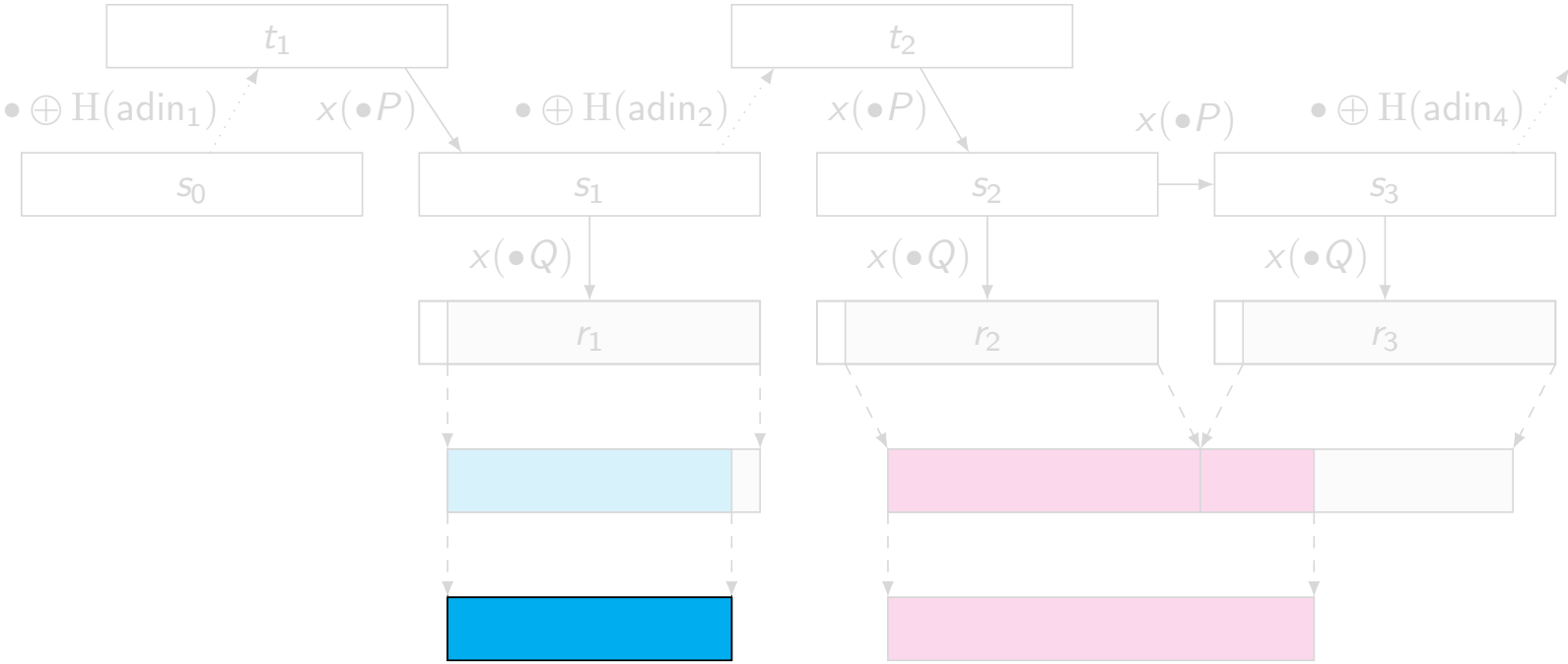

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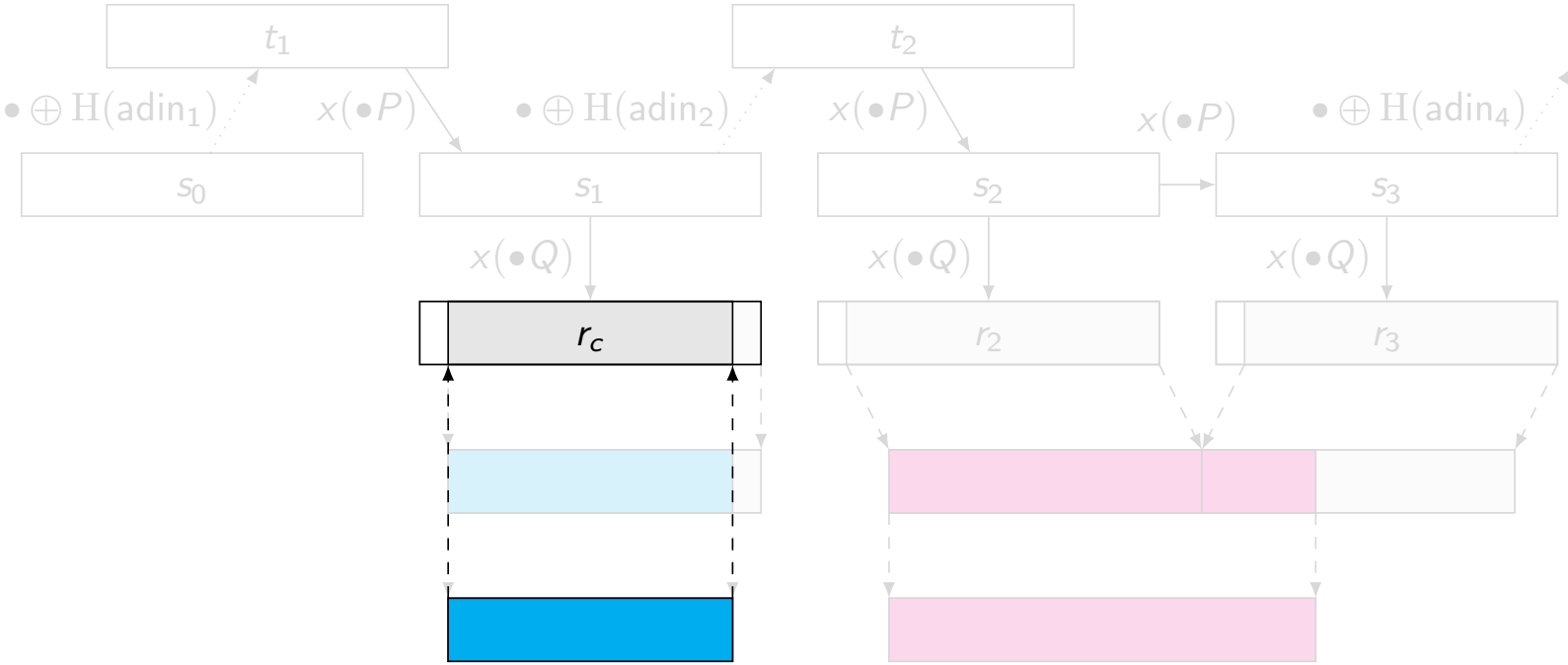

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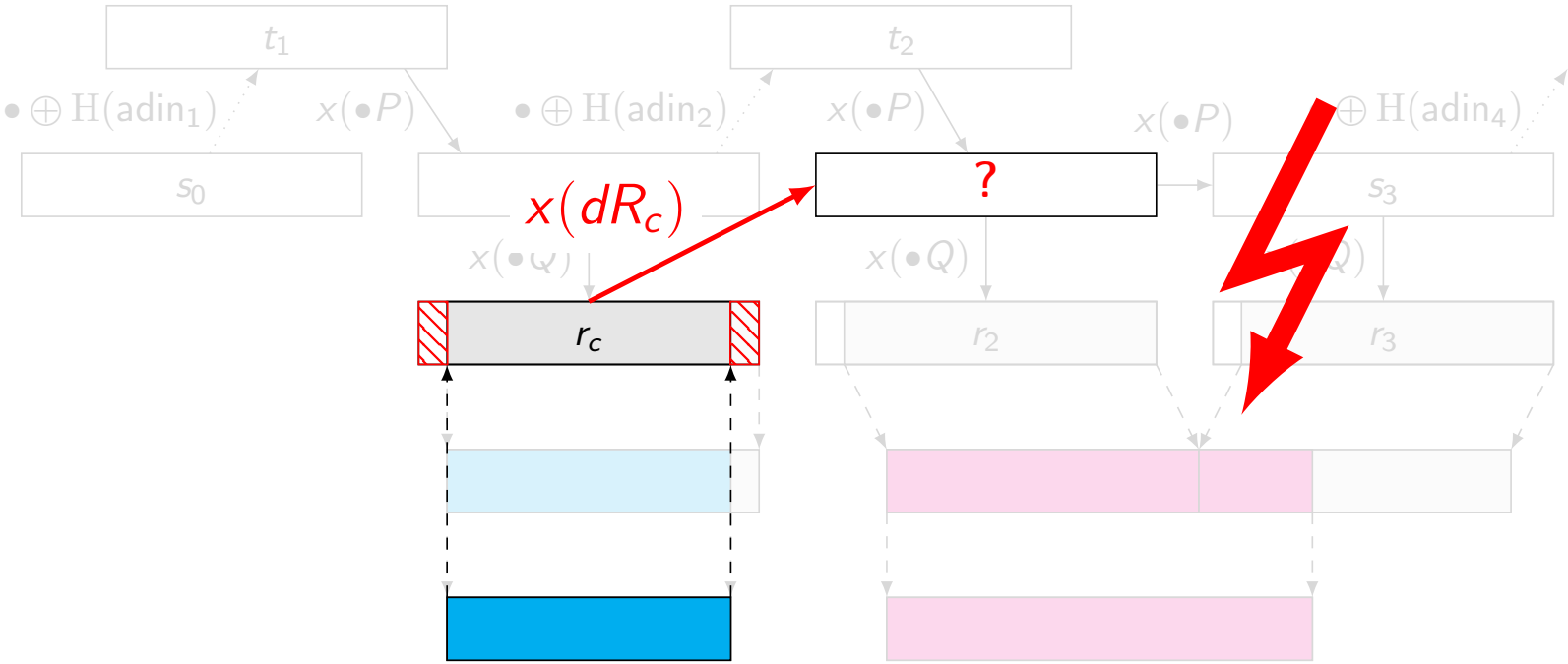

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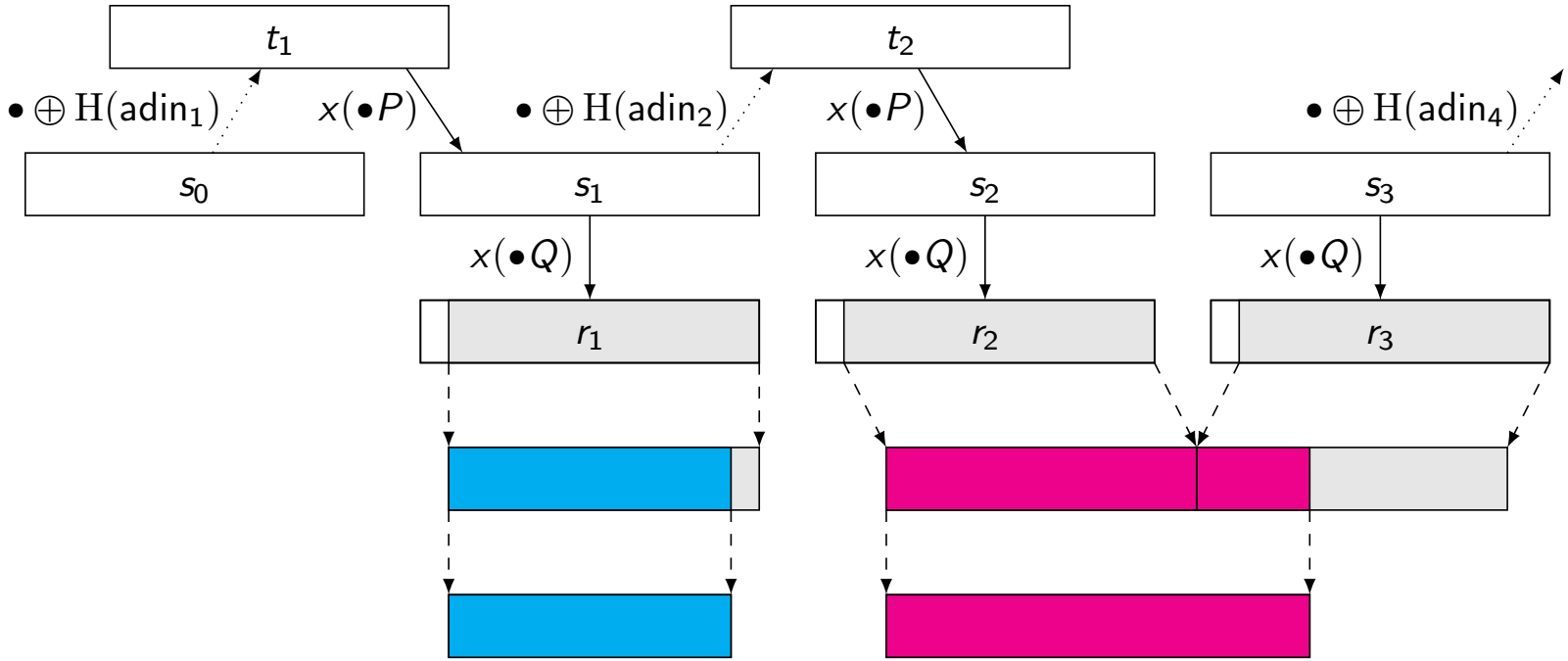
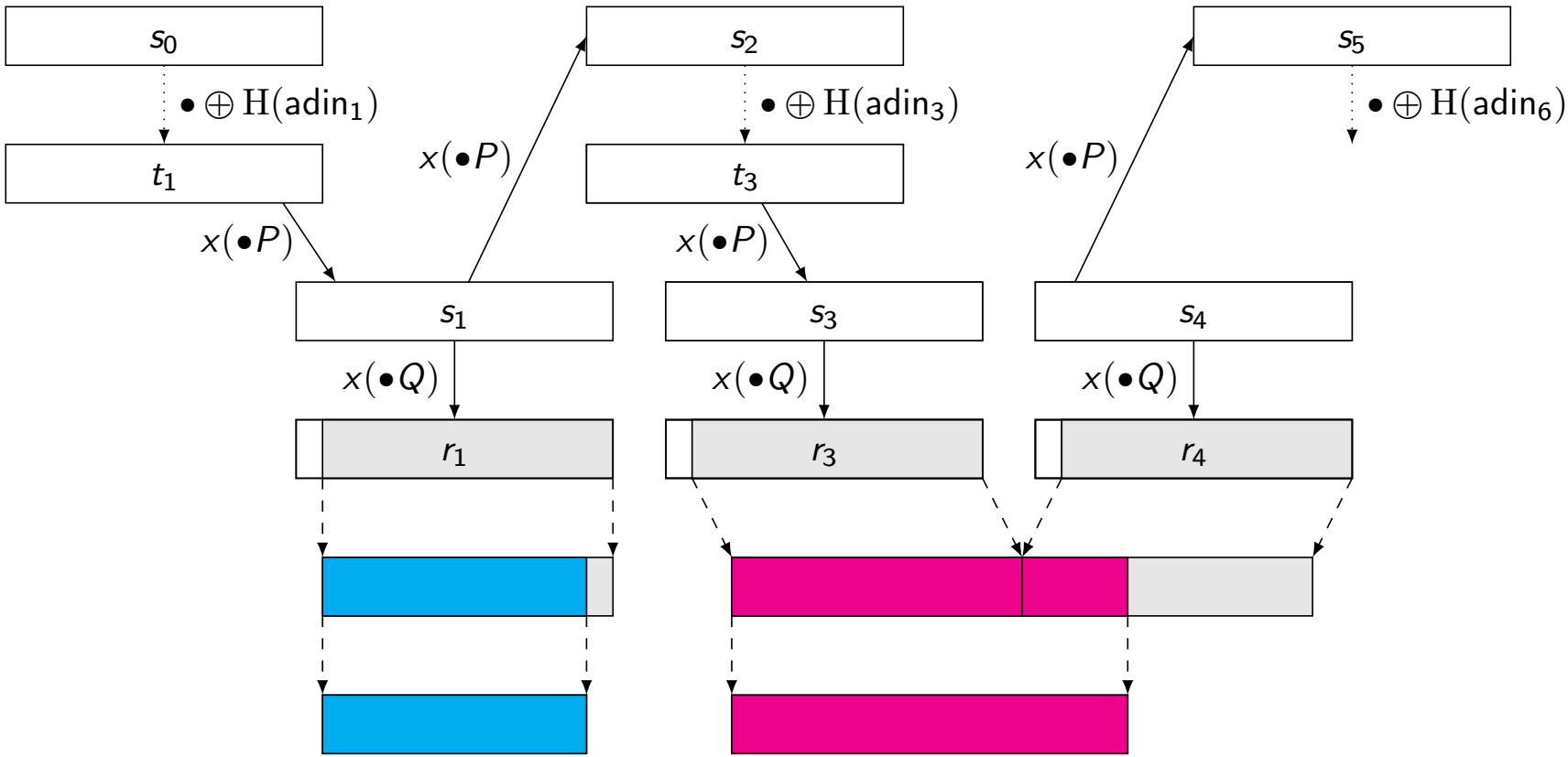


Dual EC — NIST SP800-90 in March 2007



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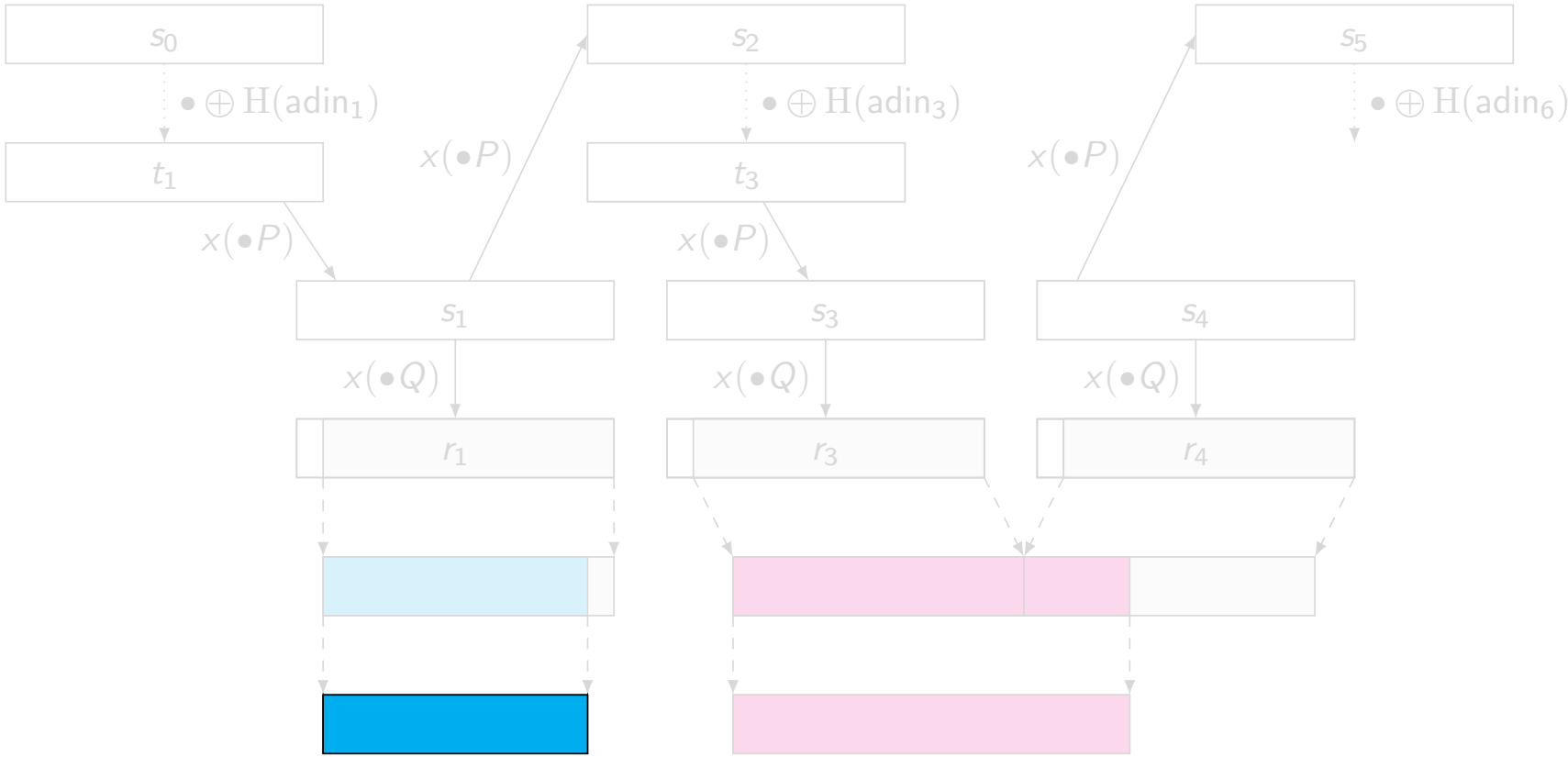

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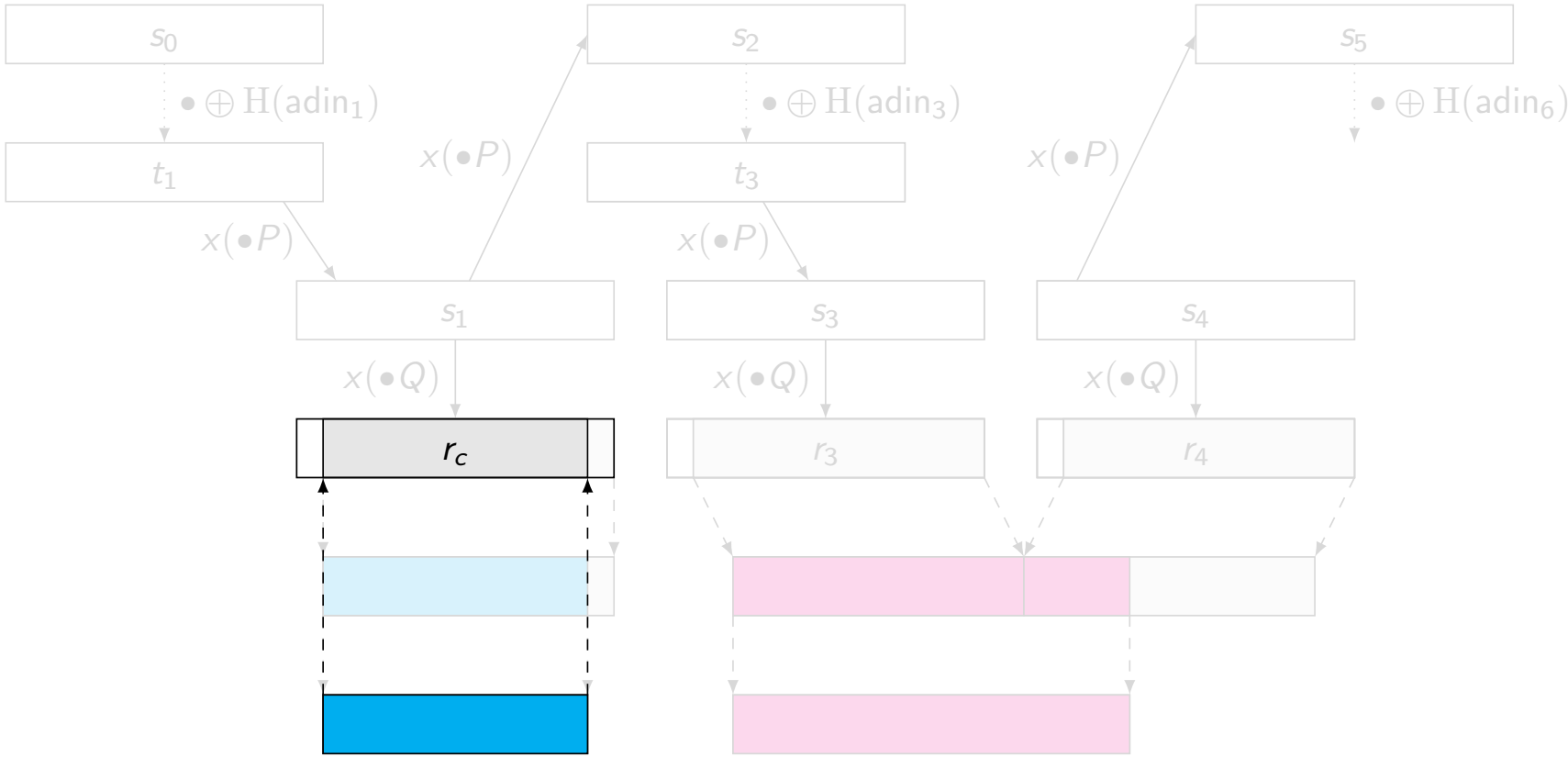

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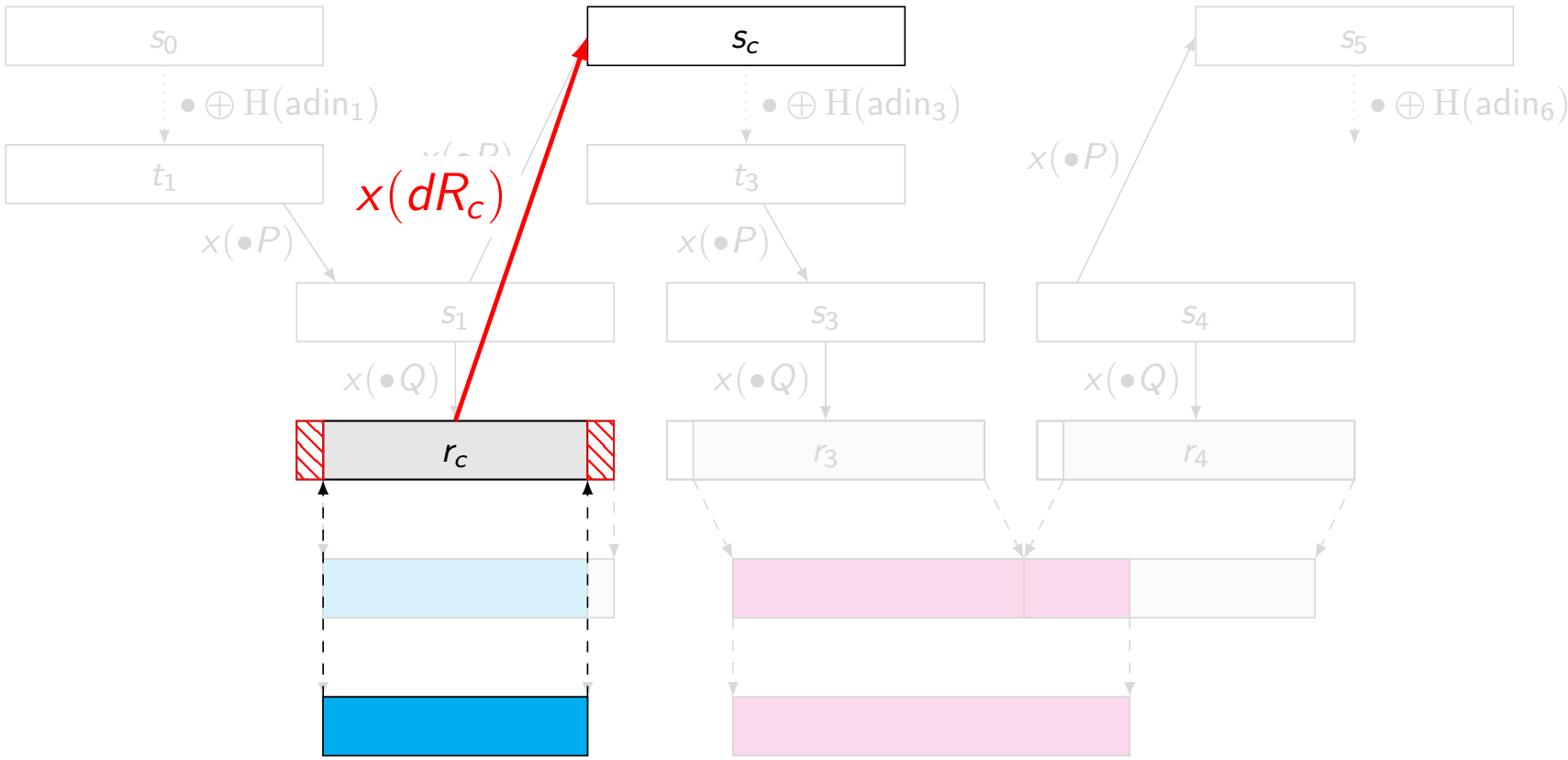

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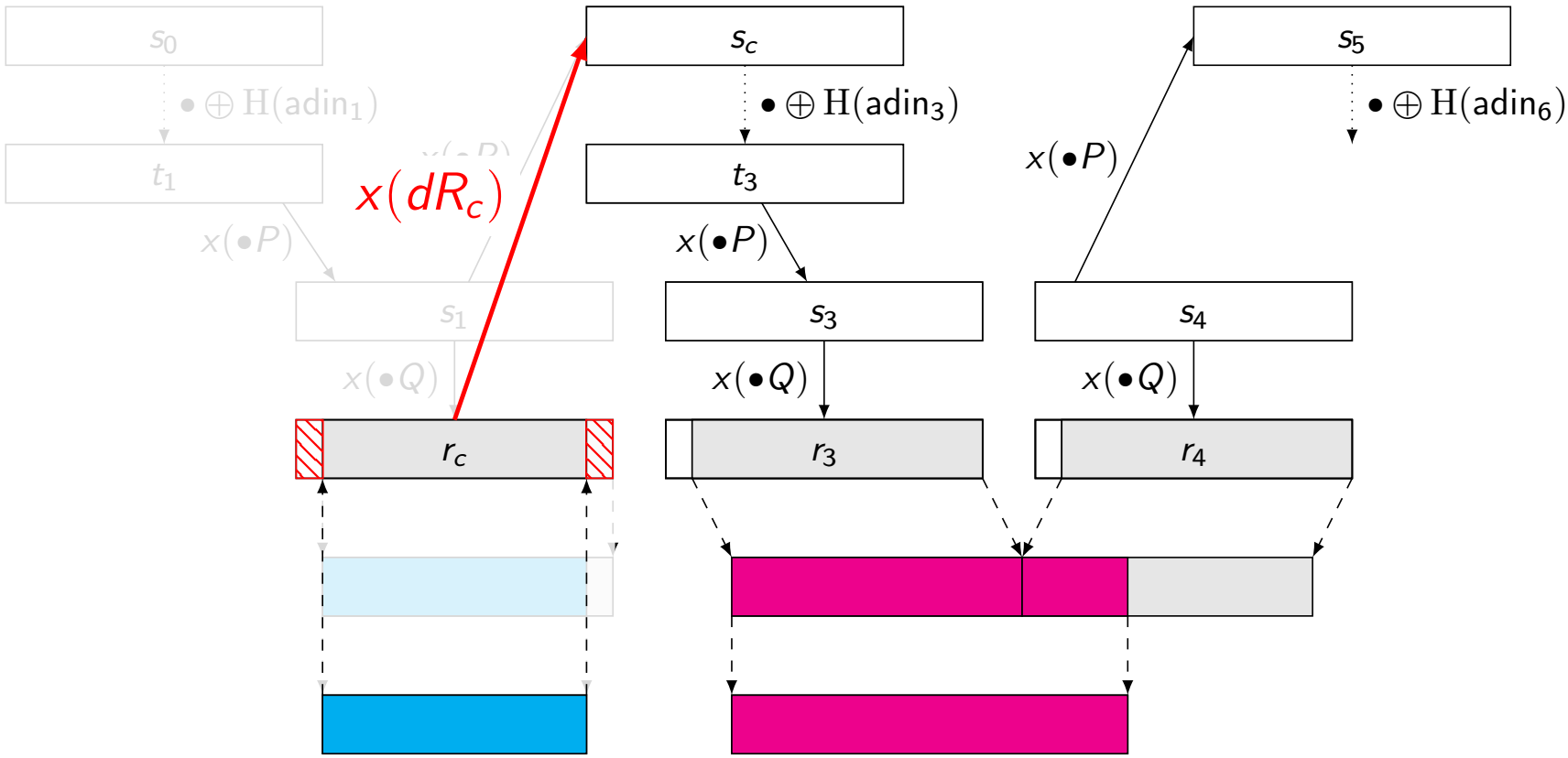

Attack

Attack targets in our analysis:

- RSA's BSAFE
  - RSA BSAFE Share for Java (BSAFE Java)
  - RSA BSAFE Share for C and C++ (BSAFE C)
- Microsoft's SChannel
- OpenSSL

We replaced the points P and Q with points where we know the back-door computation.

Attack — Example: BSAFE-Java

server random

ECDHE priv. key

ECDSA nonce

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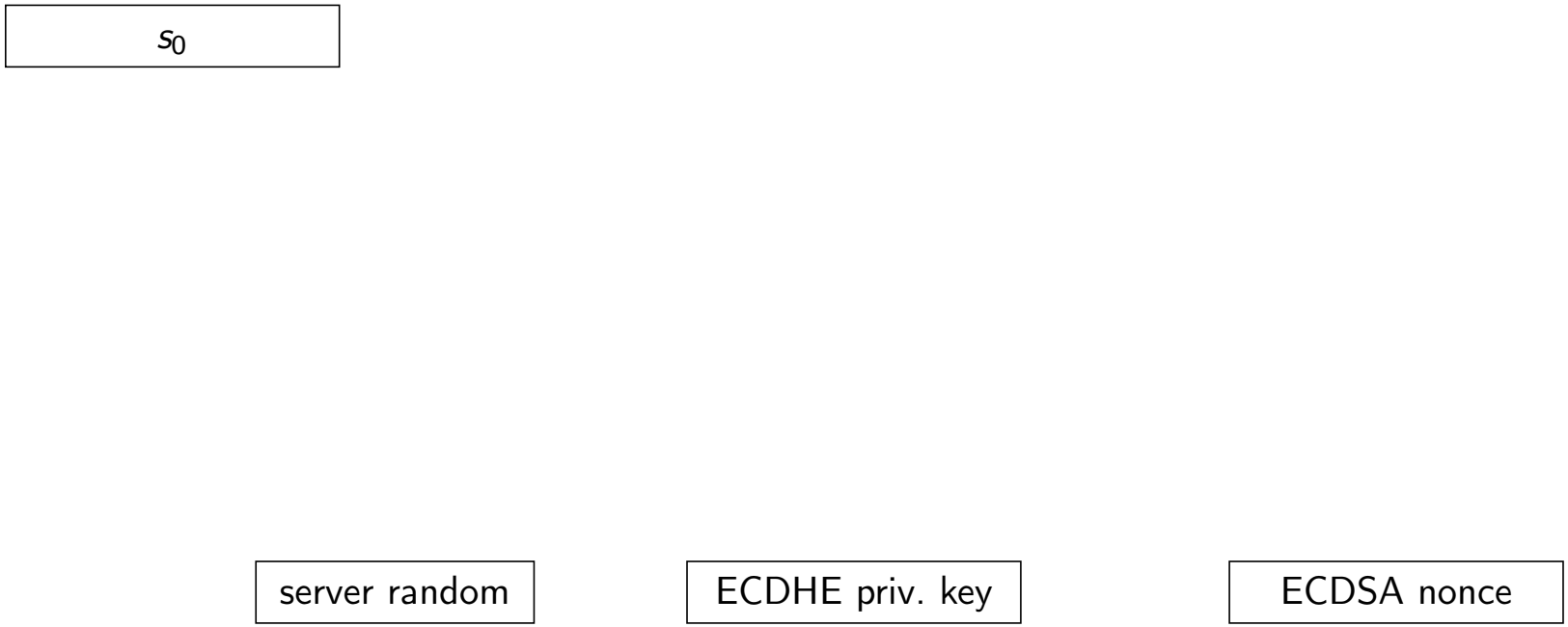

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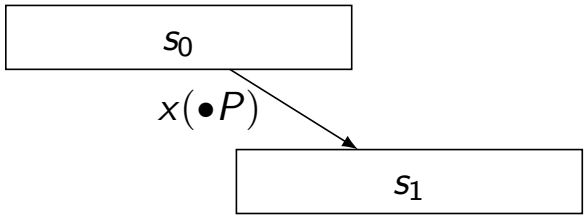

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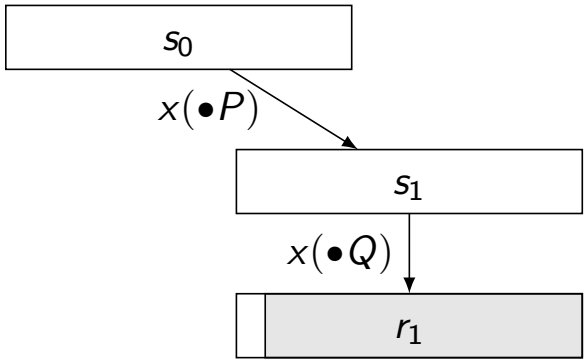

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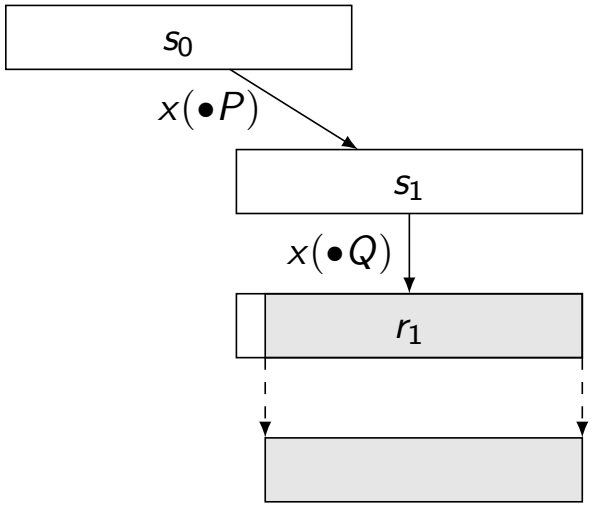

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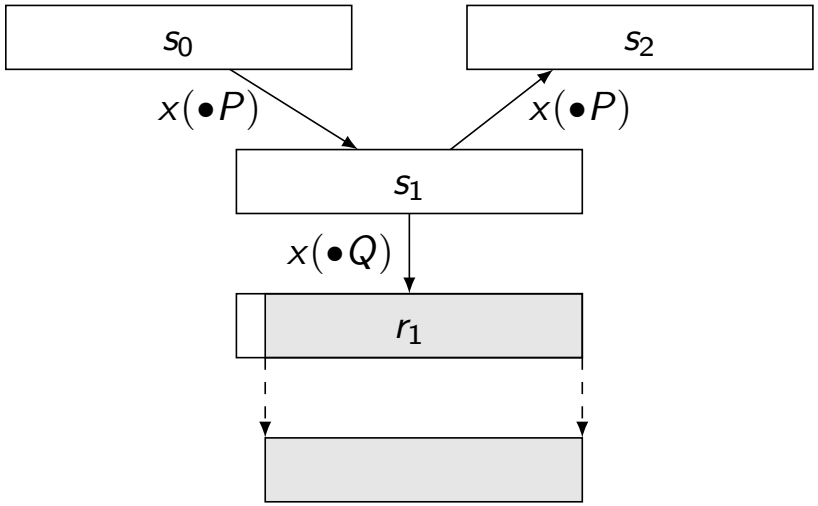

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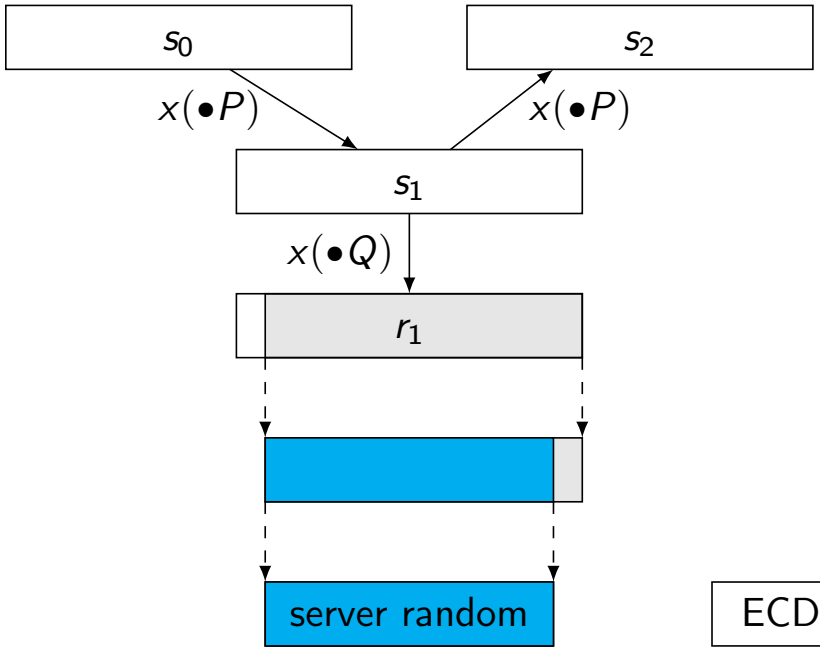

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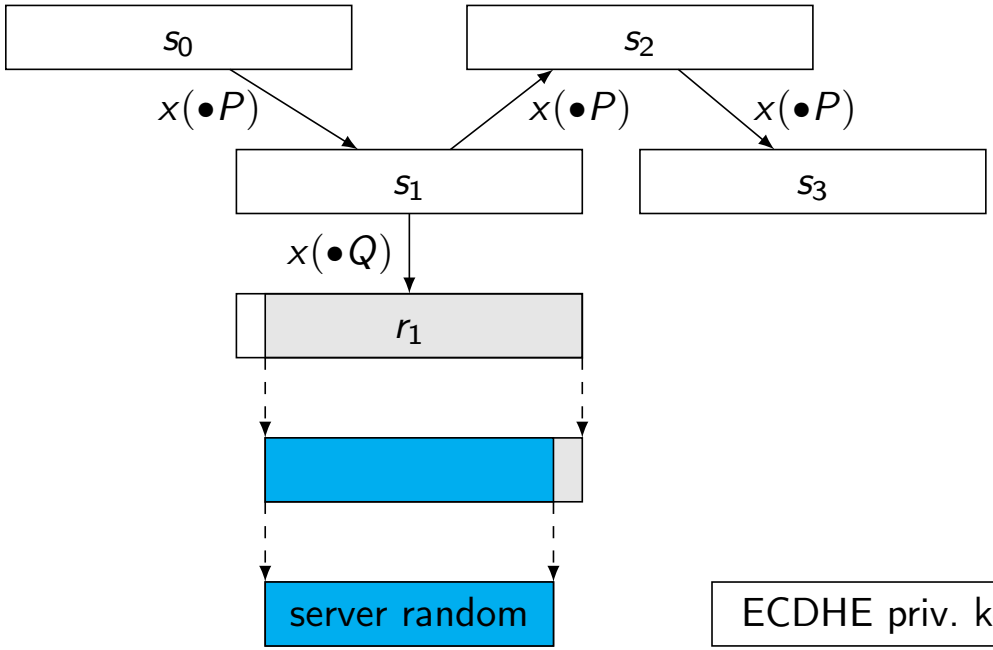

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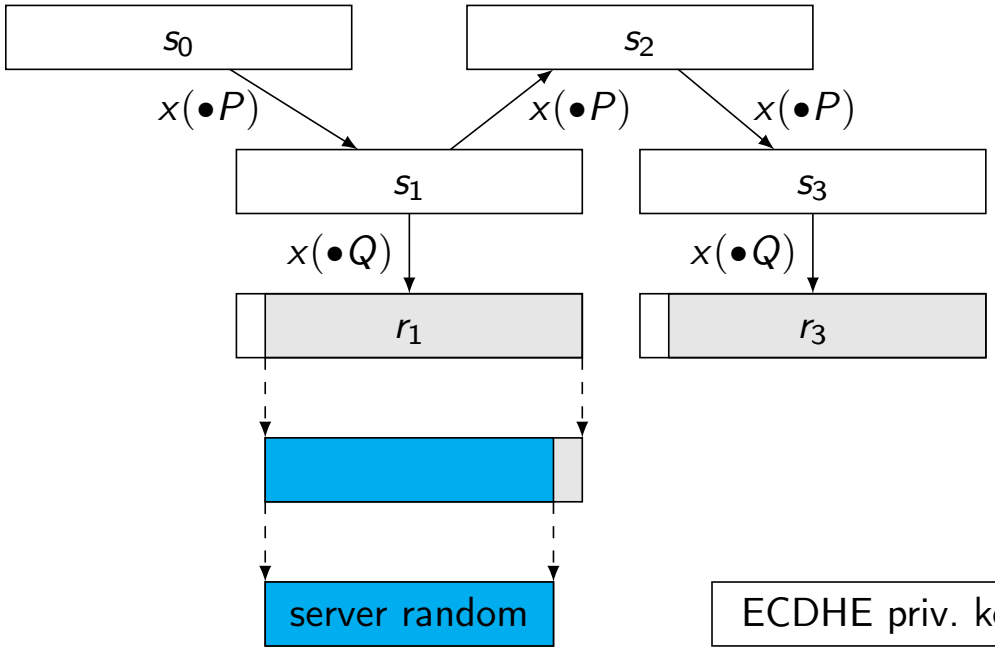

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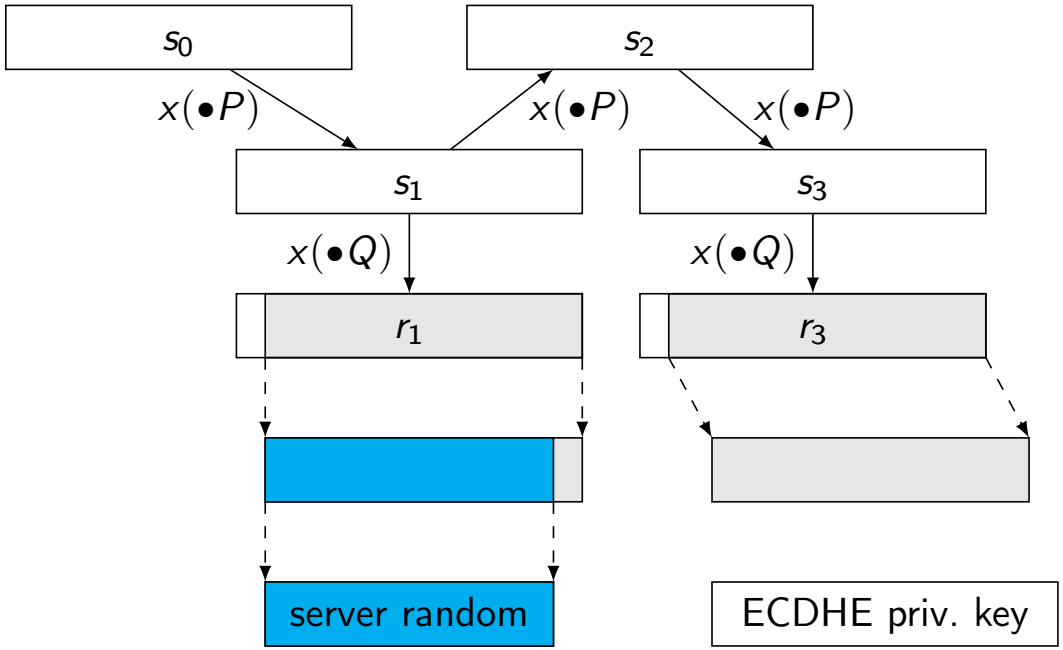

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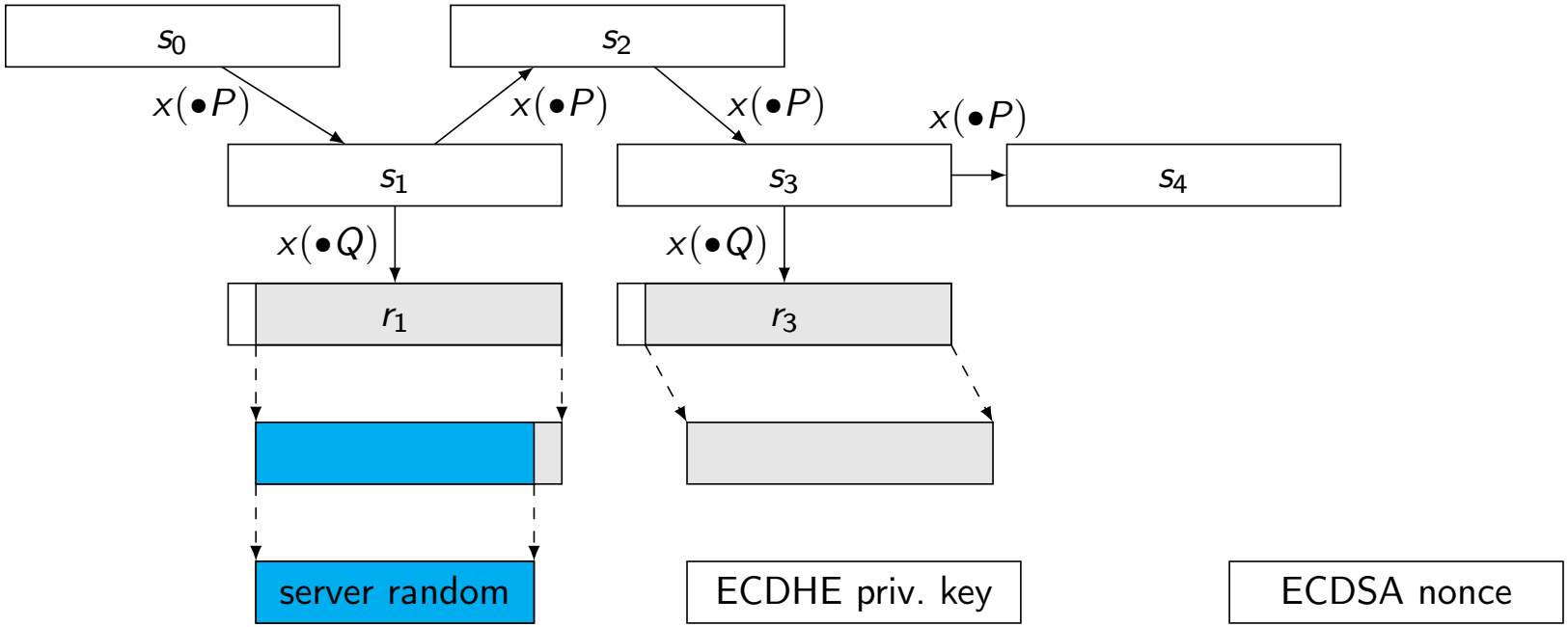

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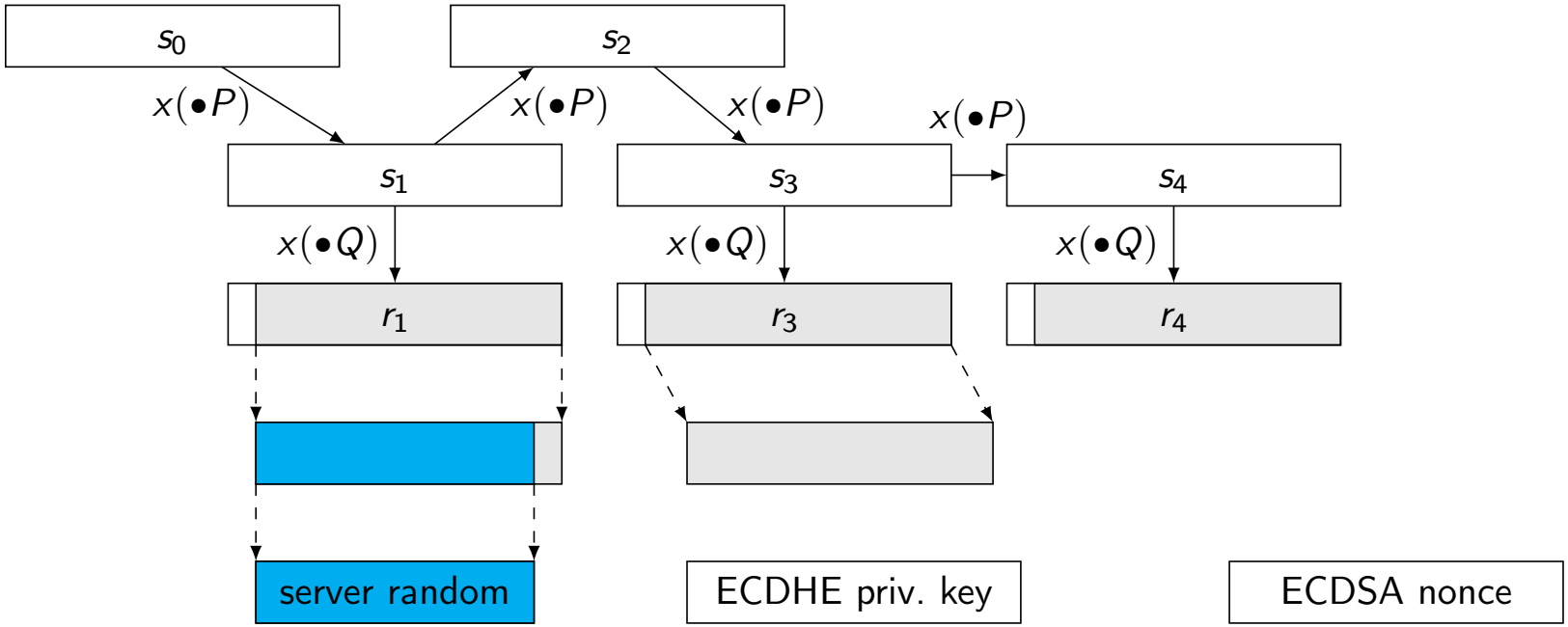

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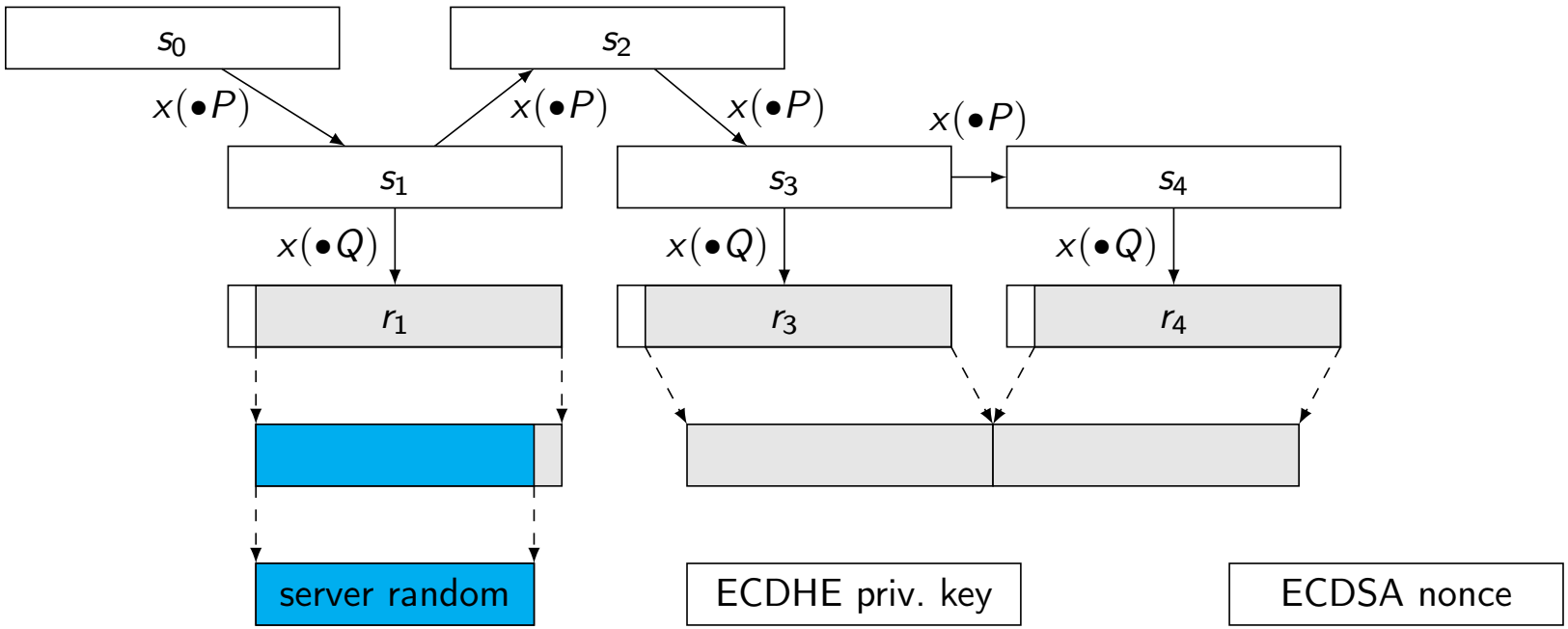

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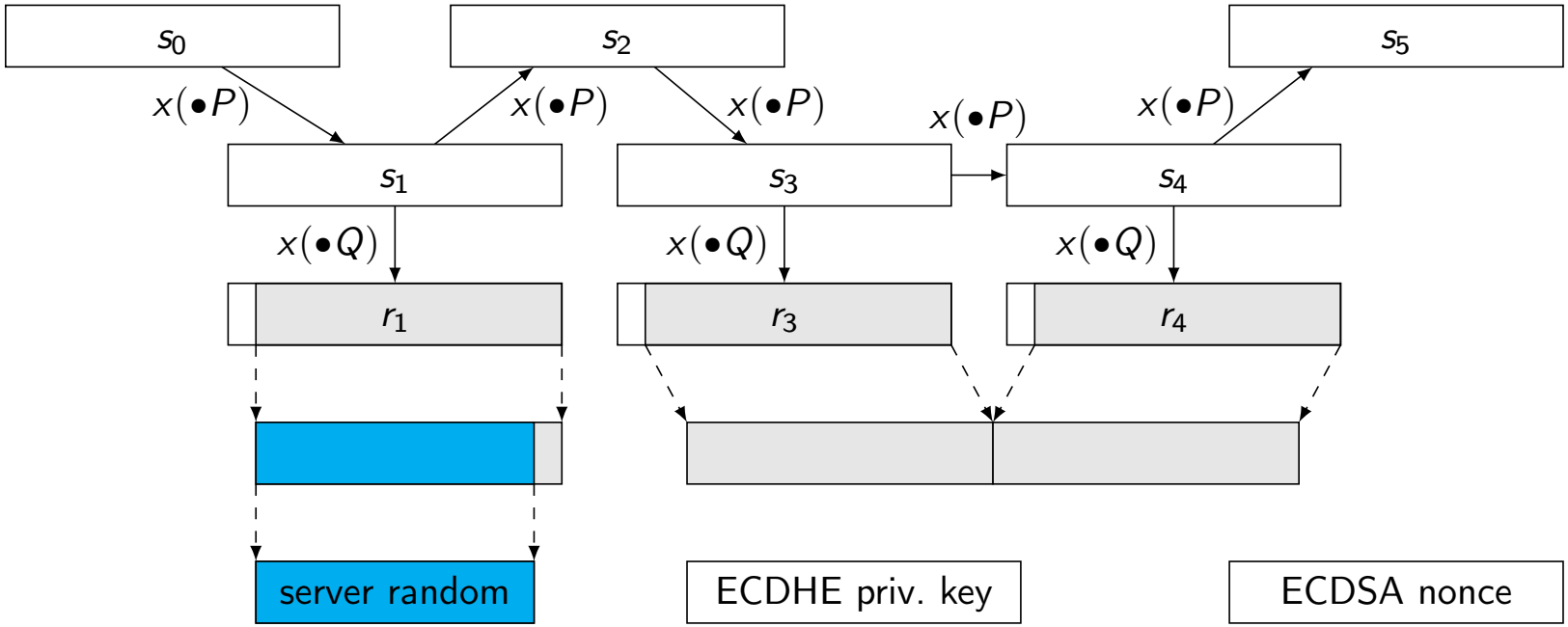

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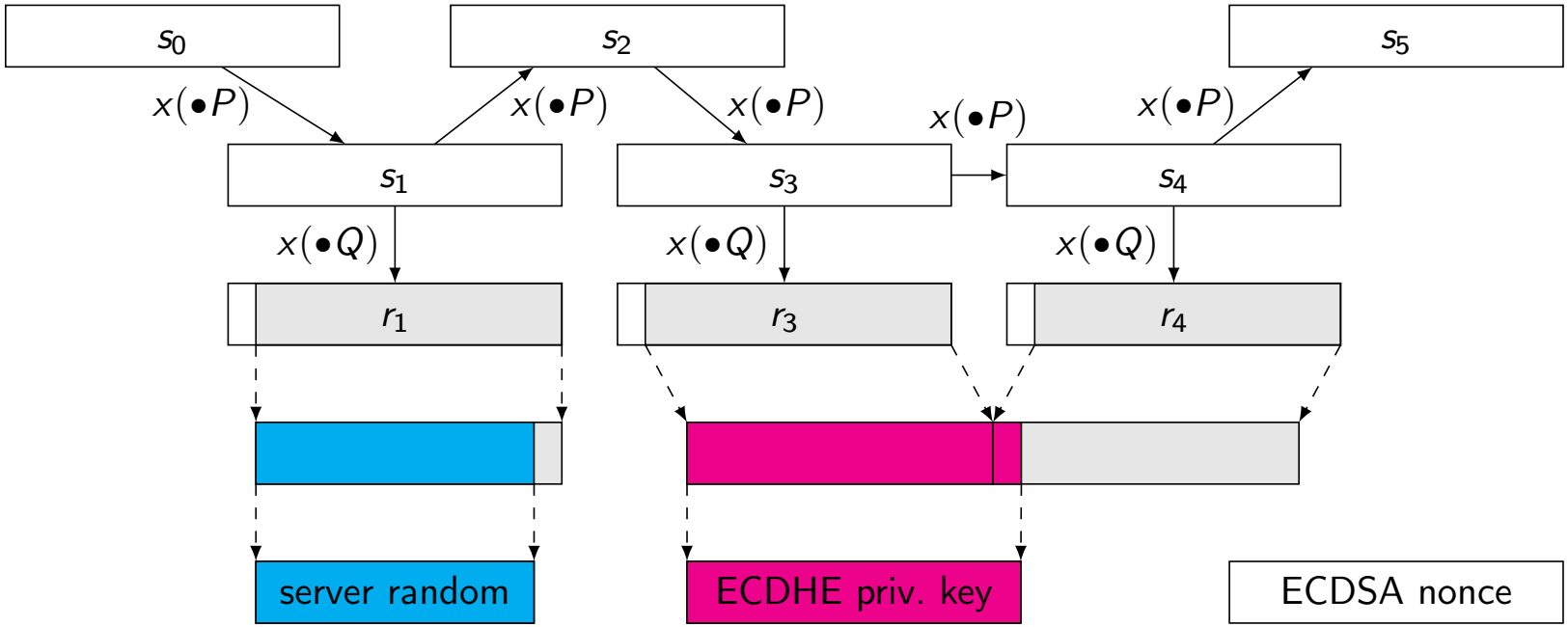

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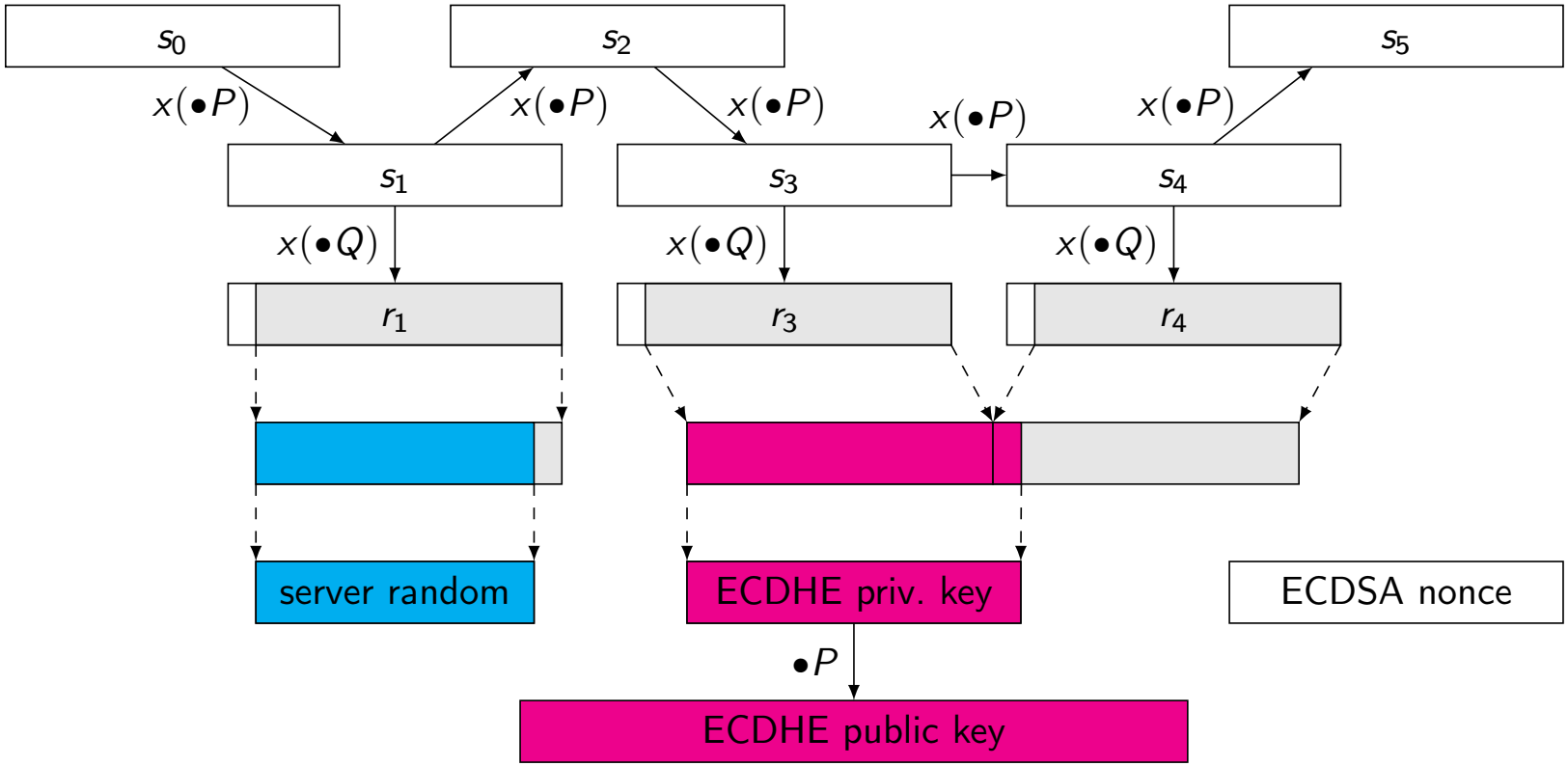

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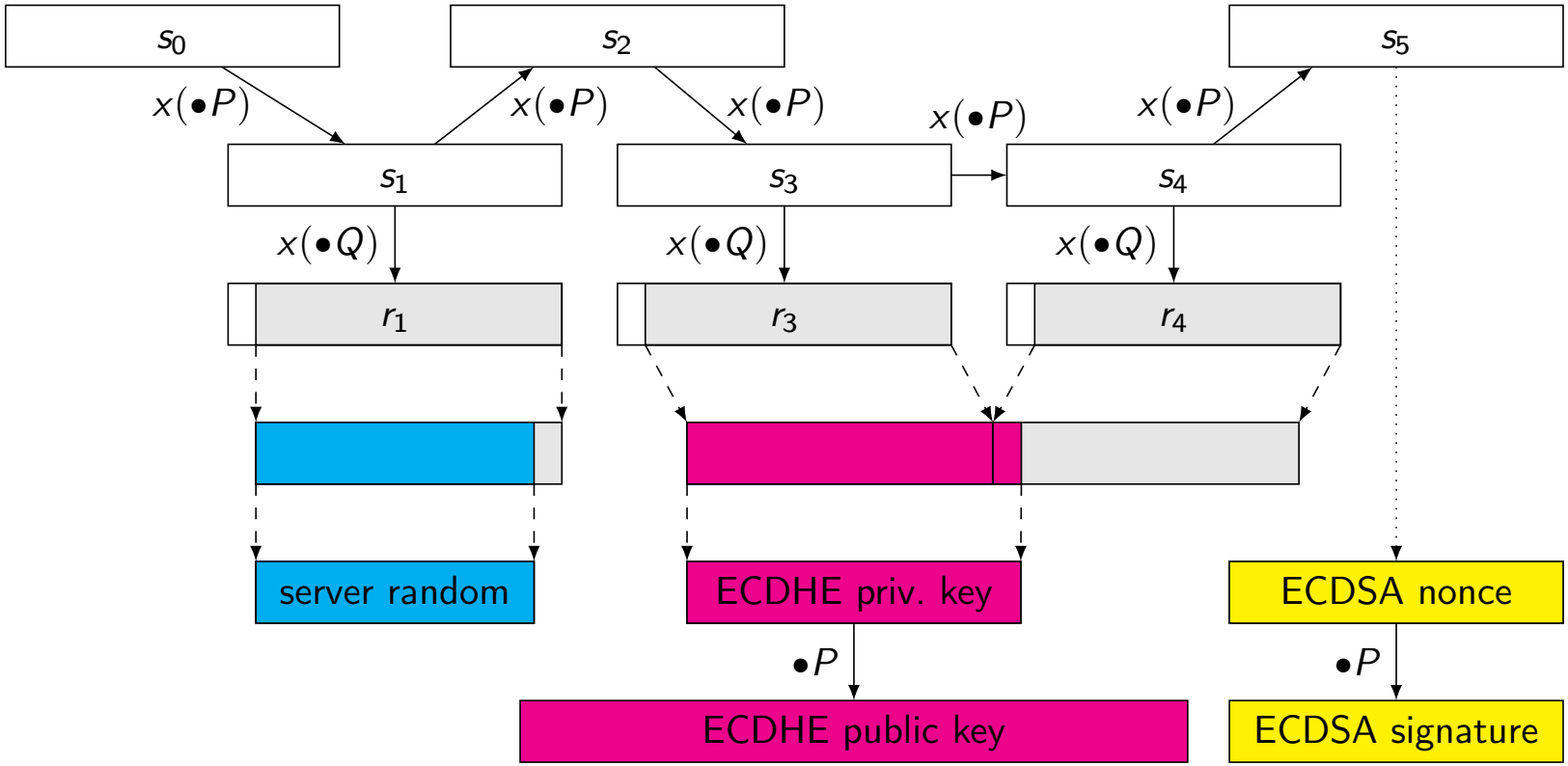

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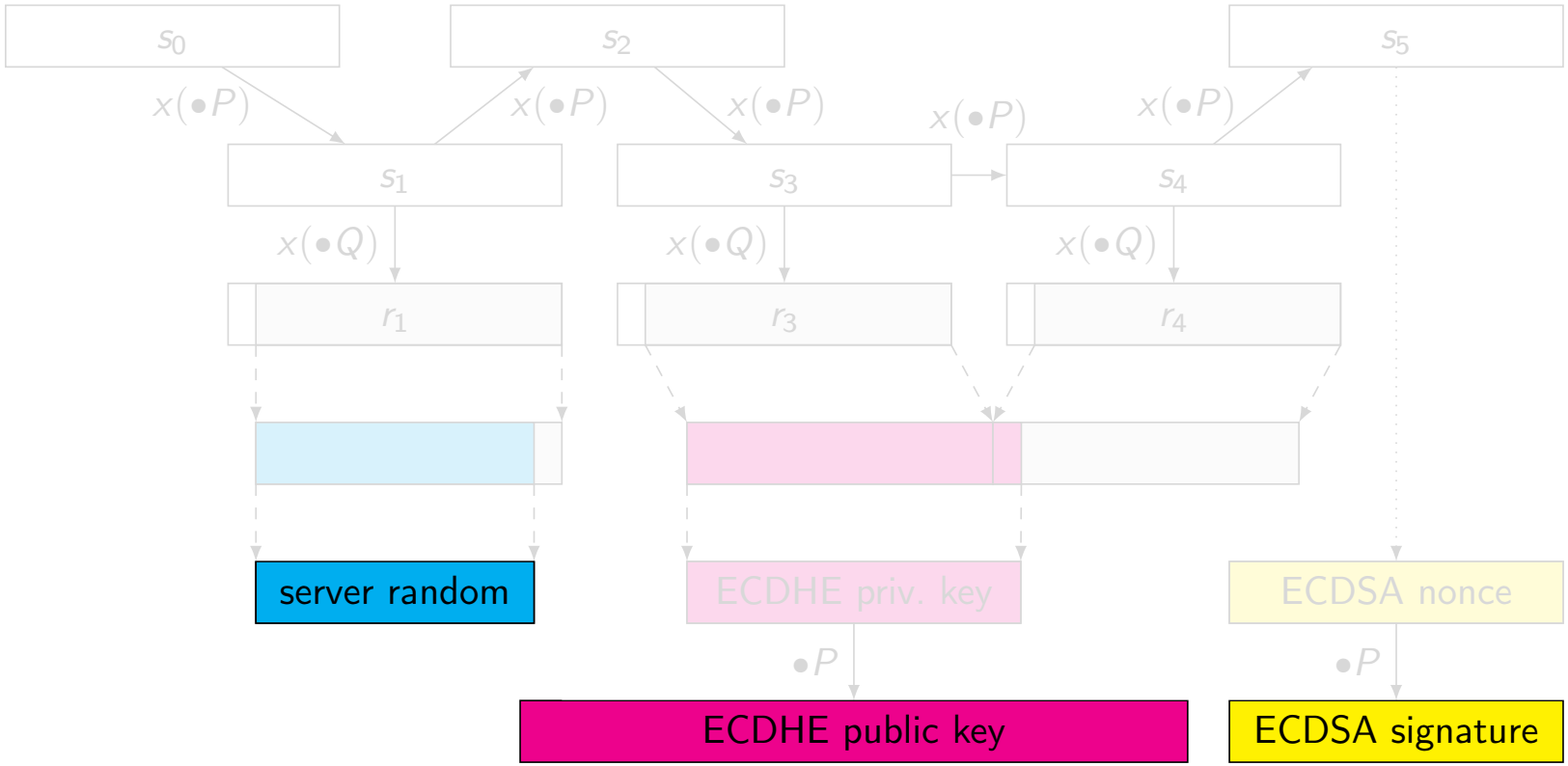

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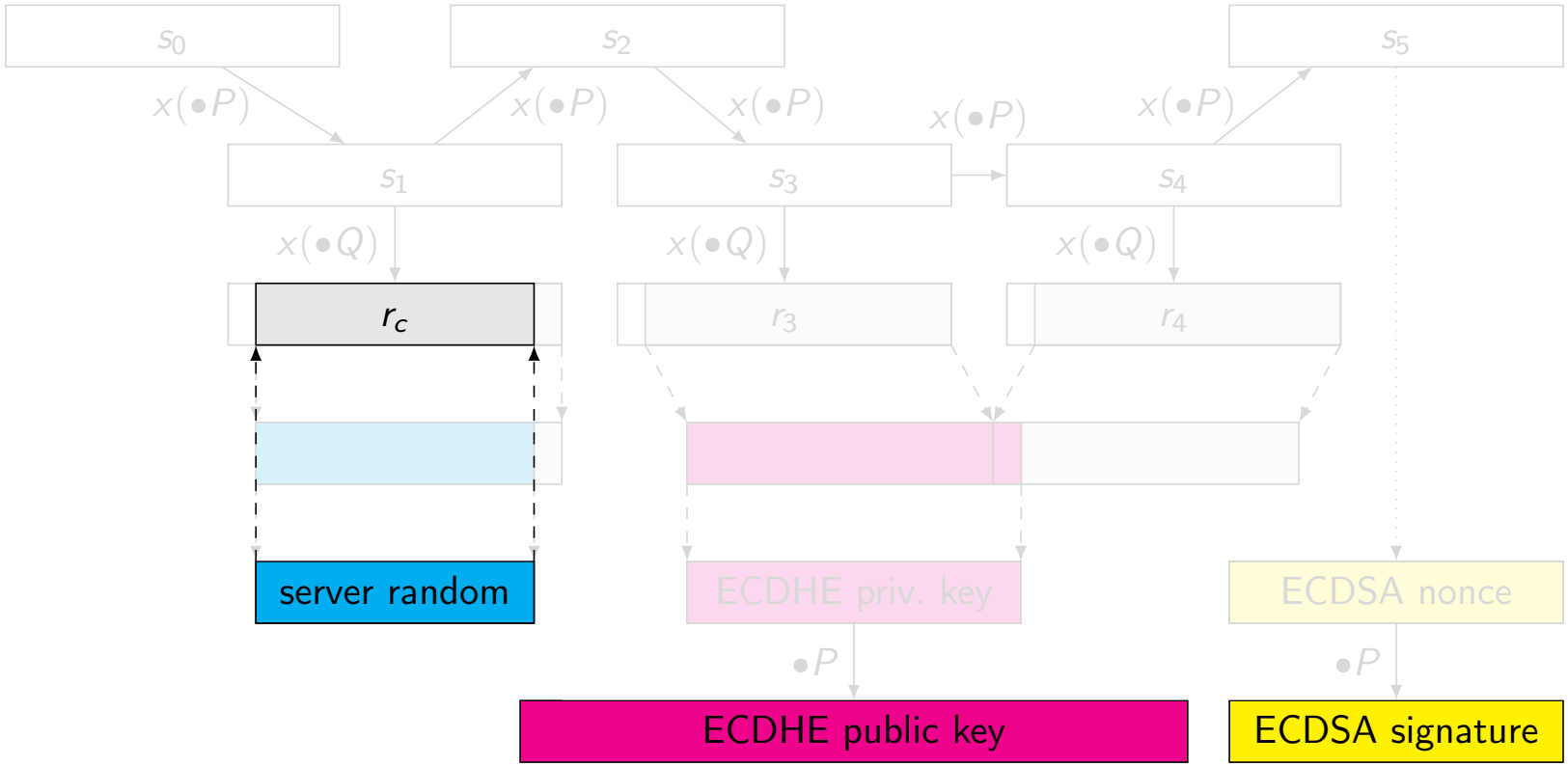

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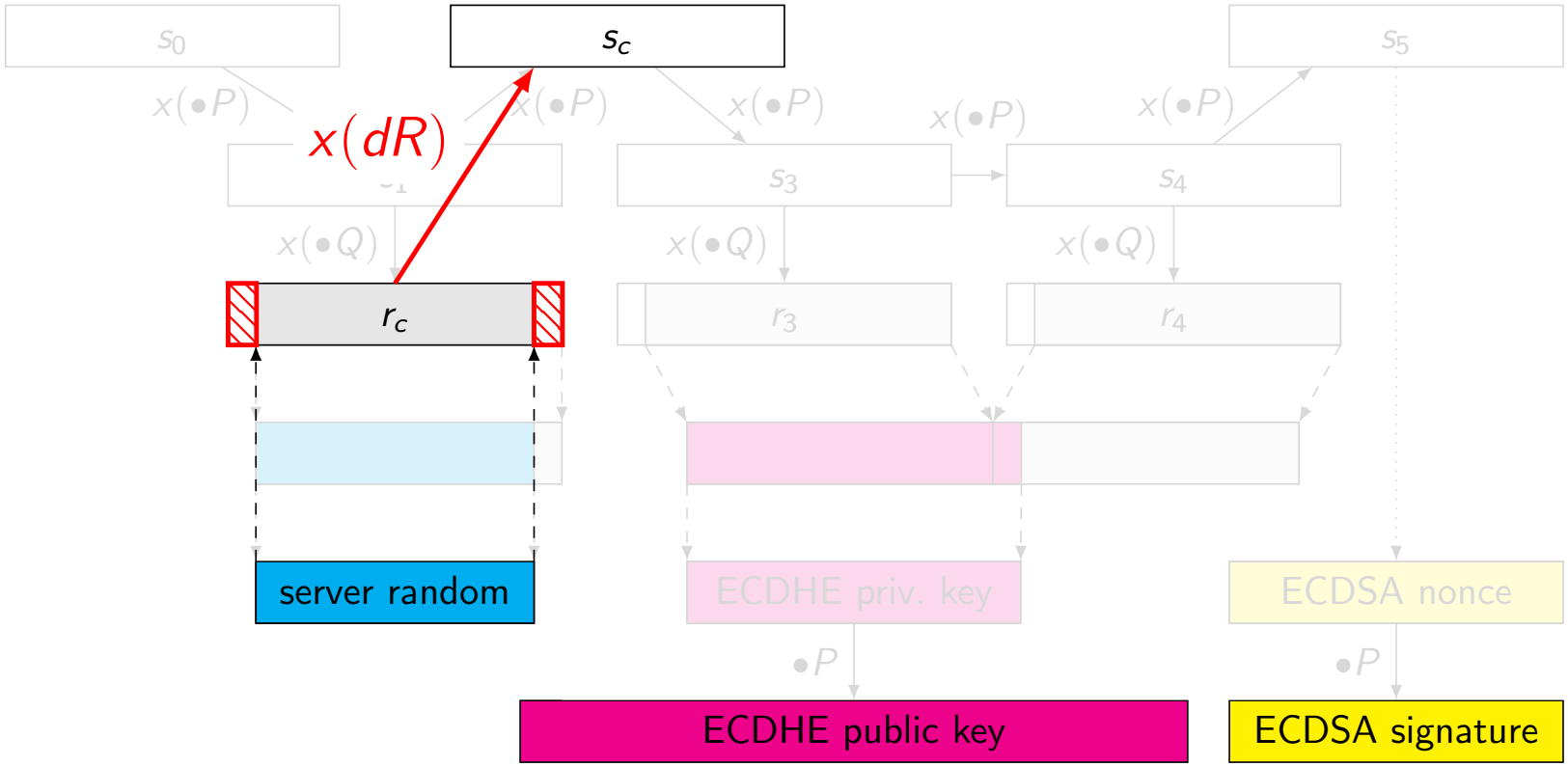

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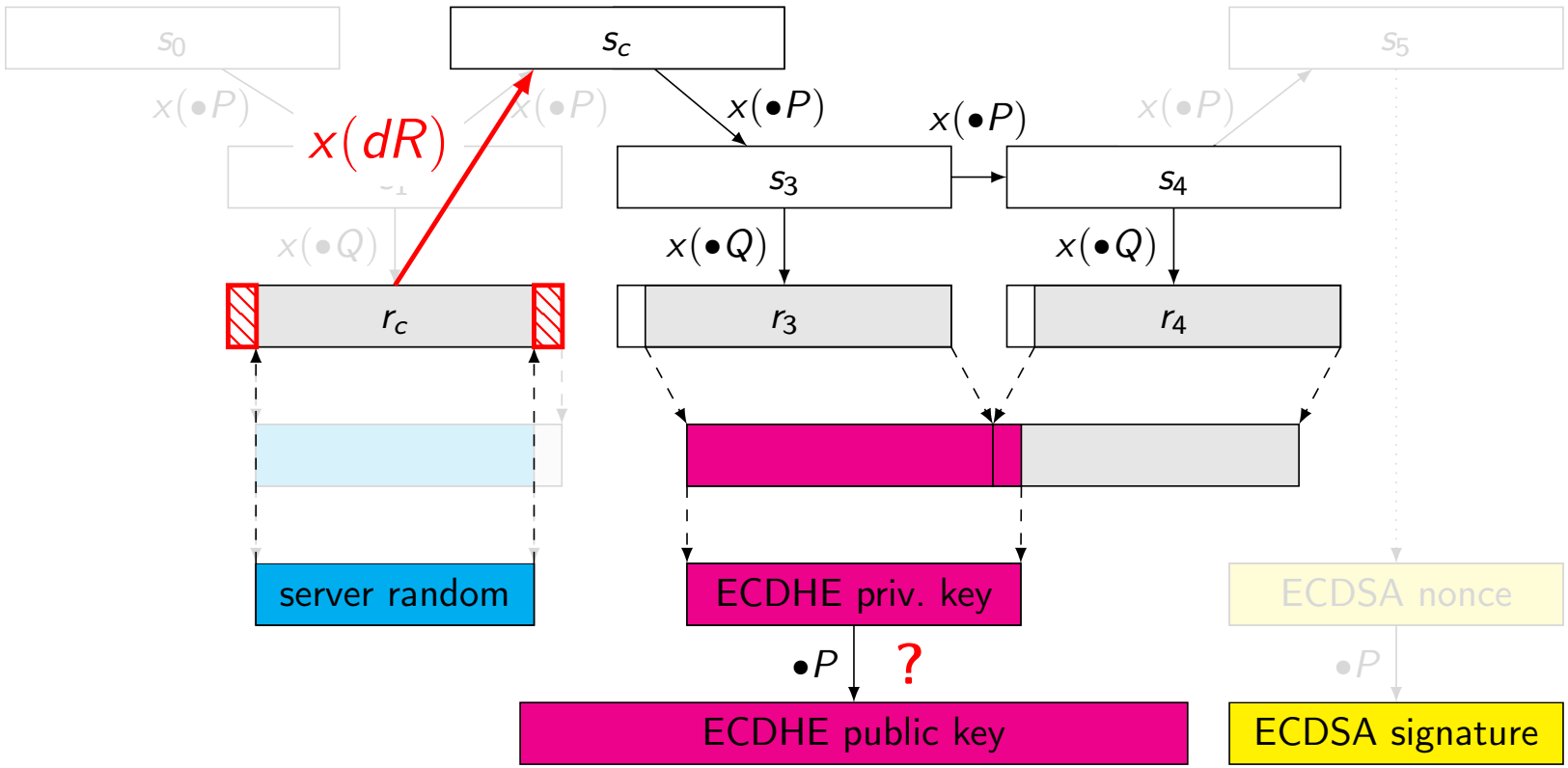

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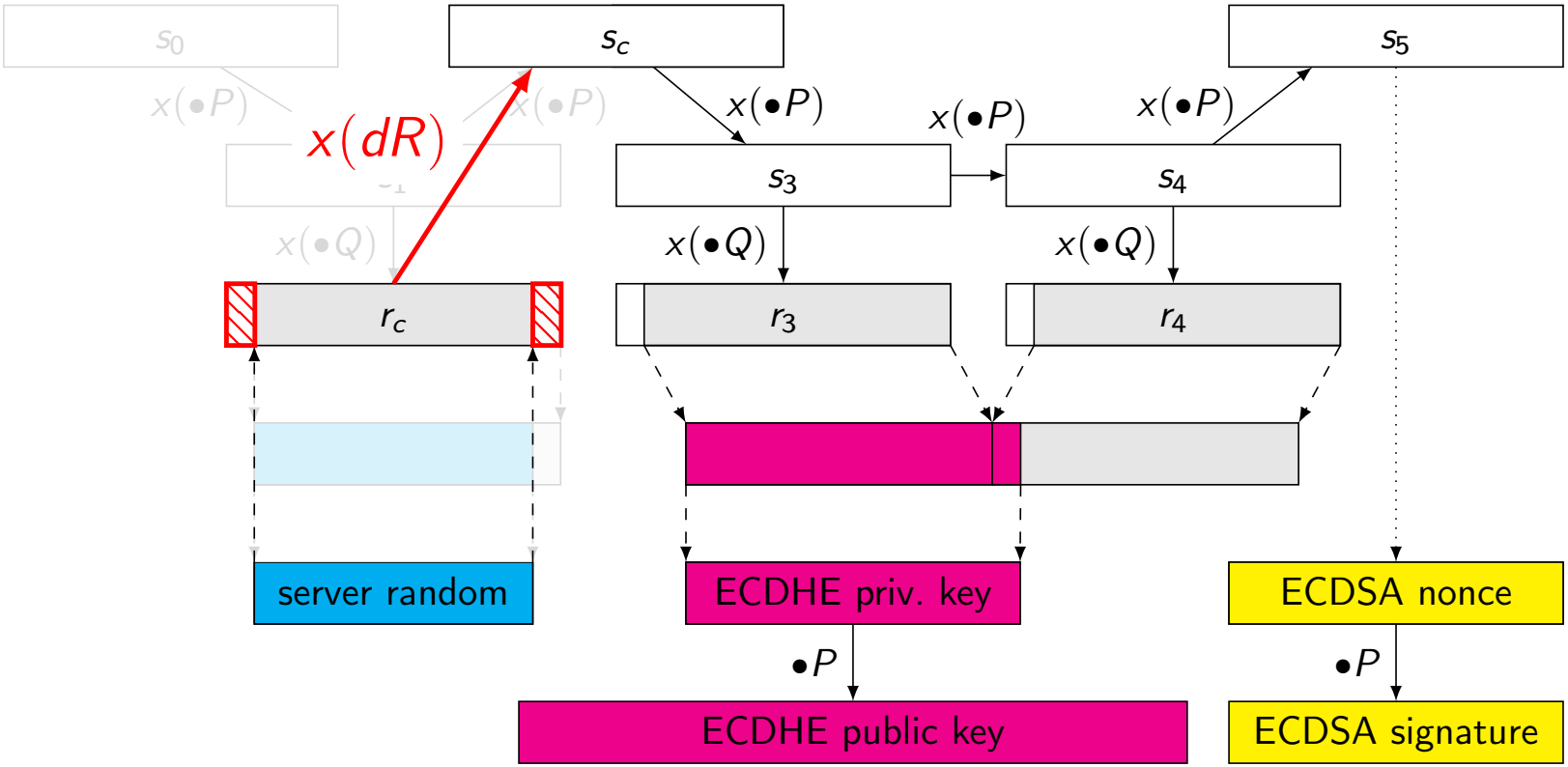

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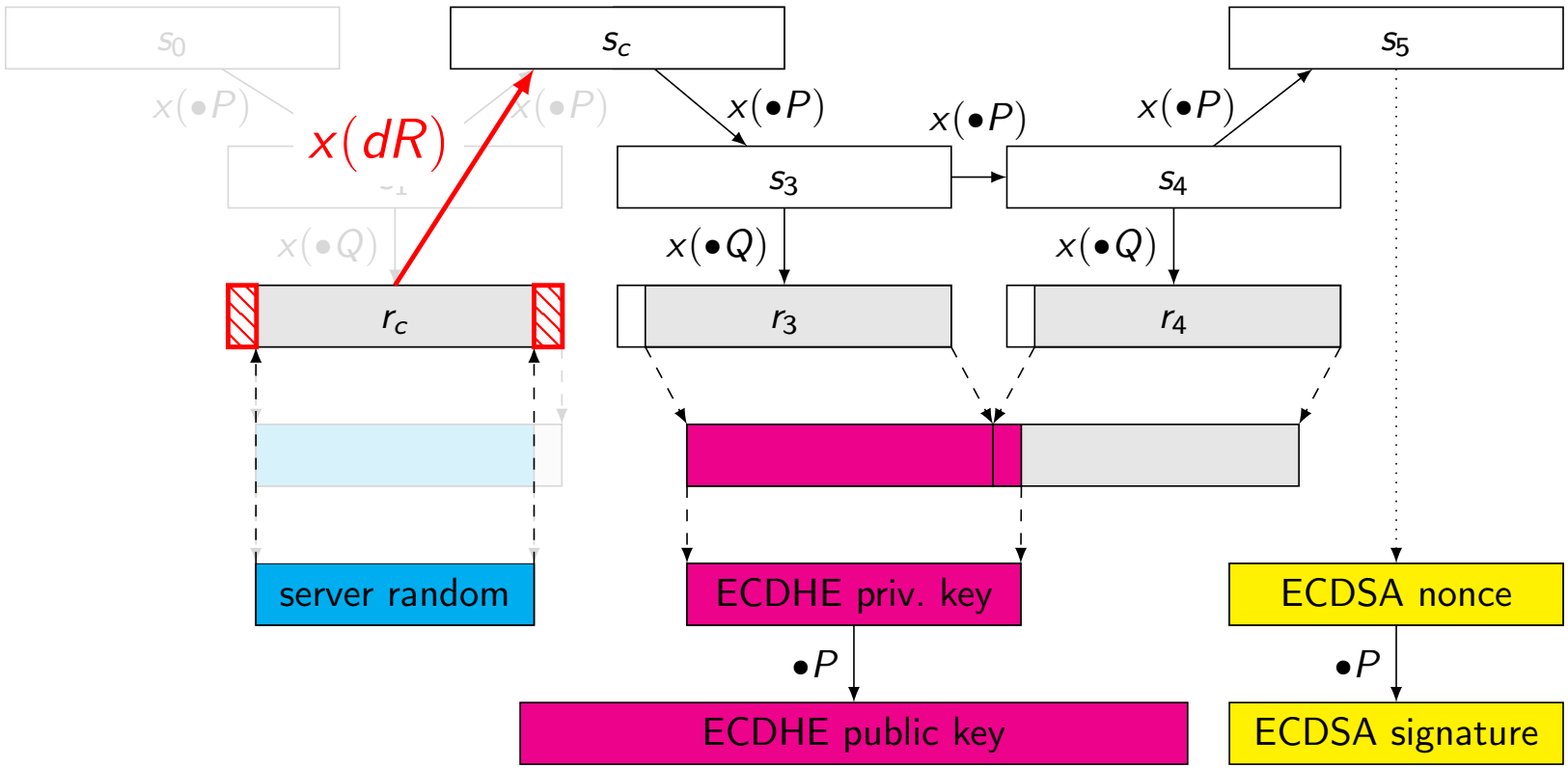

average cost: $2^{31}(C_v + 5C_f)$

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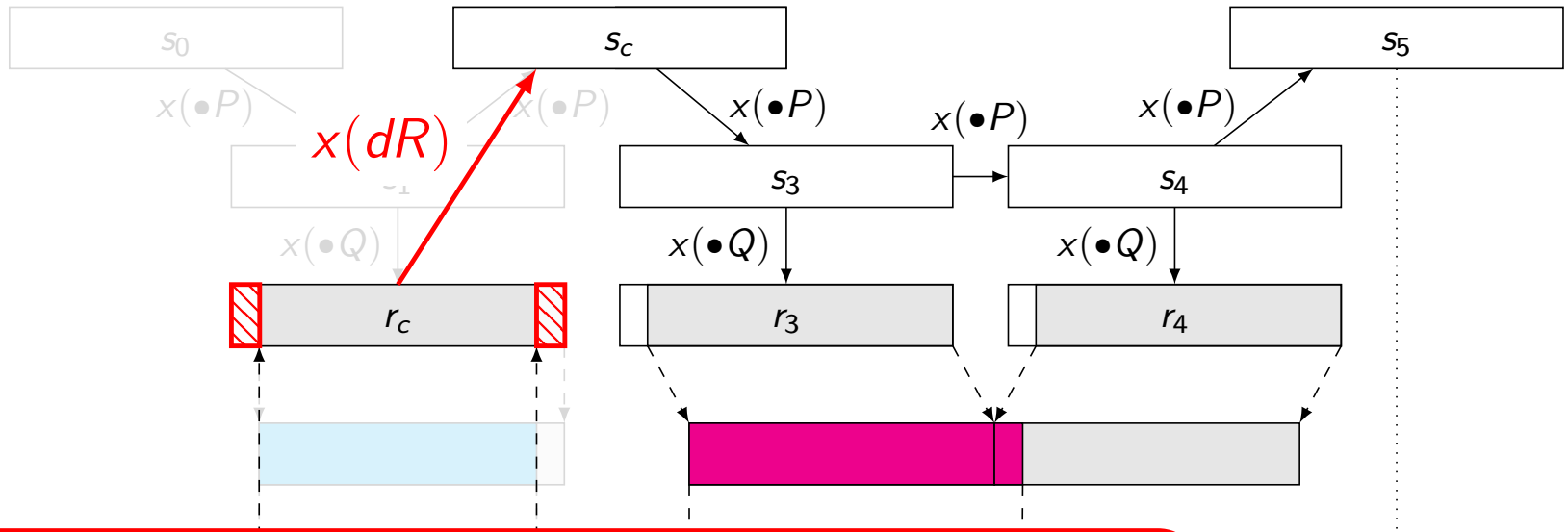
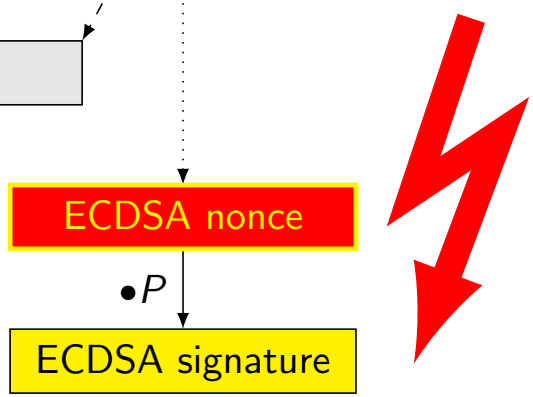


Exposes longterm secret key!
Impersonation attack possible!



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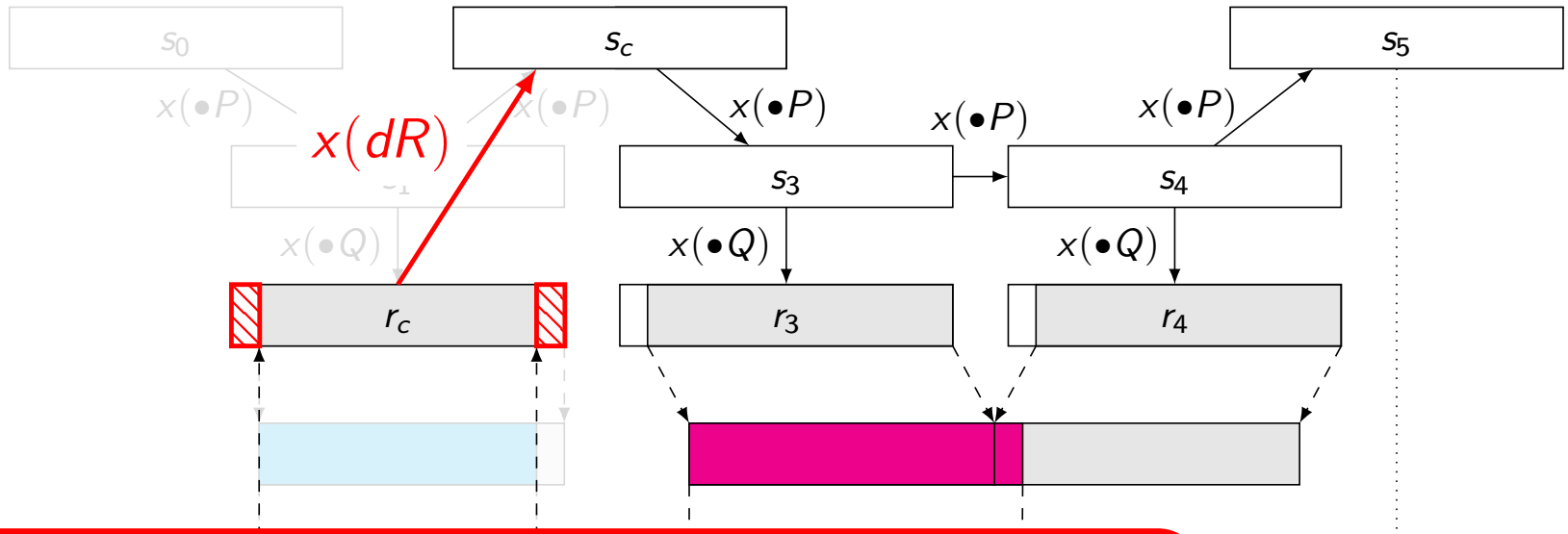

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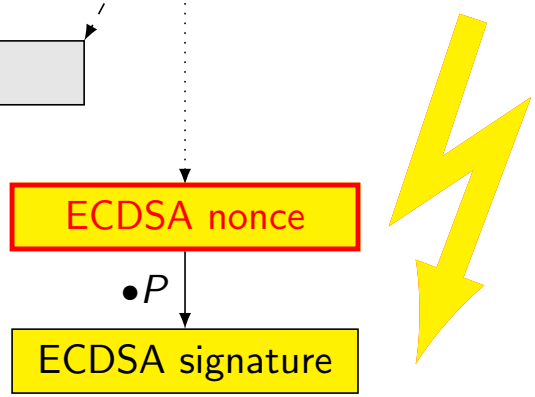

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Attack — Attack Timings

Attack	Intel Xeon CPU		AMD Cluster
	Avg. Time (min)	# for 1s	Tot. Time (min)
BSAFE-C v1.1	0.26	16	0.04
BSAFE-Java v1.1	641	38,500	63.96
SChannel I	619	37,100	62.97
SChannel II	1,760	106,000	182.64
OpenSSL-fixed I	0.04	3	0.02
OpenSSL-fixed II	707	44,200	83.32
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Draft Proposal – Extended Random

Draft for a proposed TLS extension named “Extended Random”:

- allows client to request up to 2^{16} random bytes
- has a weak motivation:
  `The rationale for this as stated by DoD is that the public randomness for each side should be at least twice as long as the security level for cryptographic parity, which makes the 224 bits of randomness provided by the current TLS random values insufficient.`
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Makes Dual EC even more vulnerable!

Summary

Dual EC — a standardized back door:

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How to fix it?

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Don't use Dual EC!

Summary

Additional information:

https://projectbullrun.org/dual-ec/