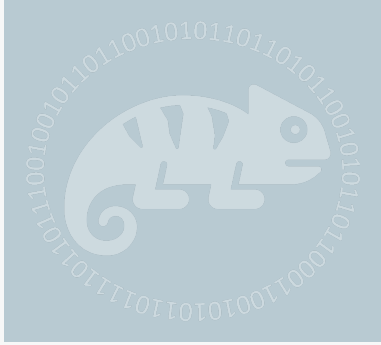

Hybrid Obfuscated Key Exchange and KEMs

Felix Günther
IBM Research – Zurich

Michael Rosenberg
Cloudflare

Douglas Stebila
University of Waterloo

Shannon Veitch
ETH Zurich

CRYPTO 2025. Santa Barbara, CA, United States.

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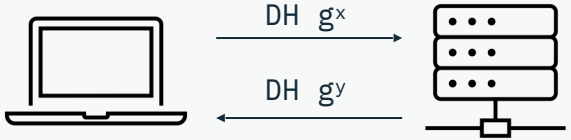

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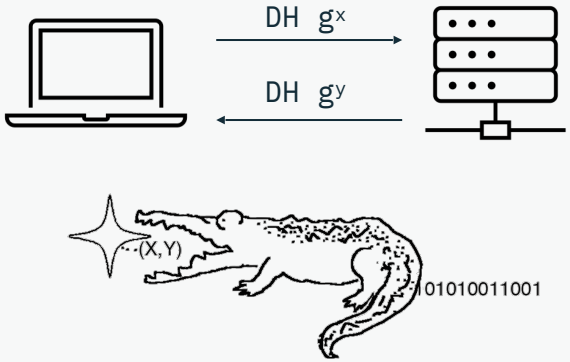

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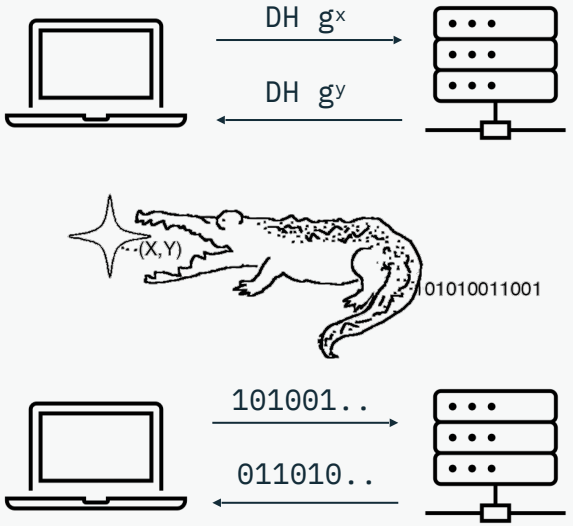

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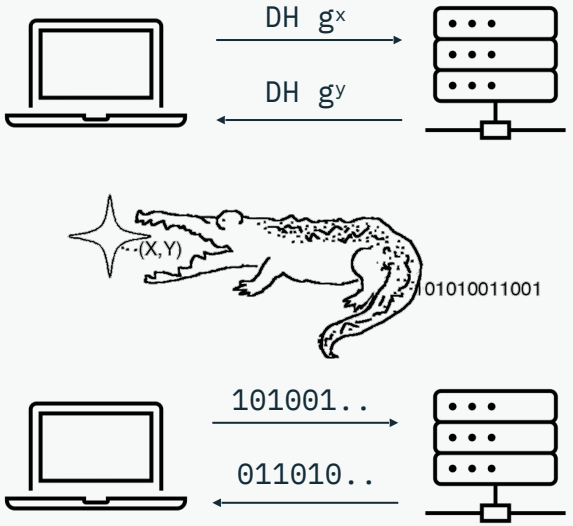

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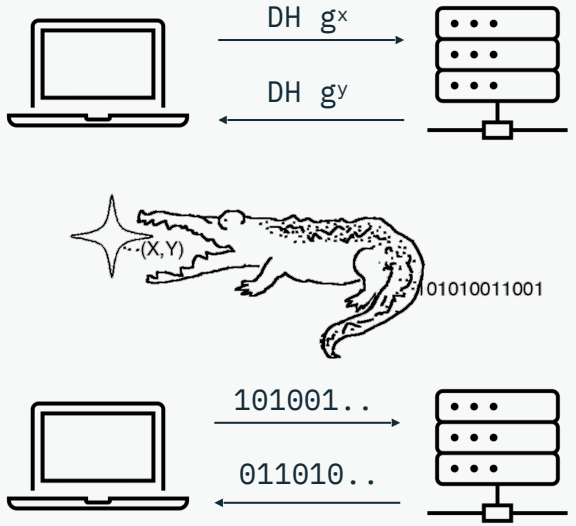
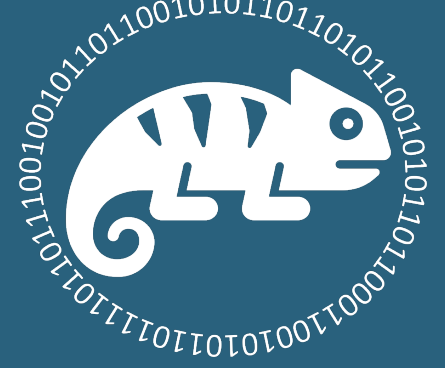


But what about hybrid?

Our contributions



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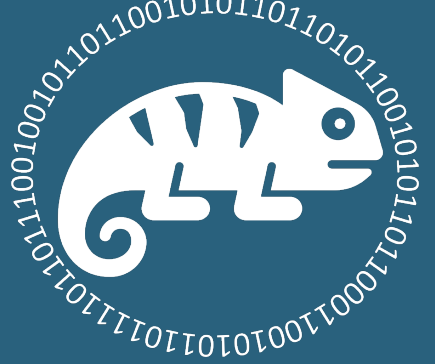

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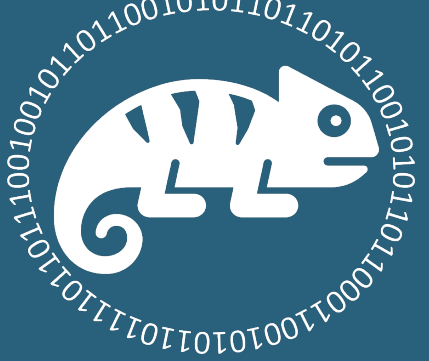

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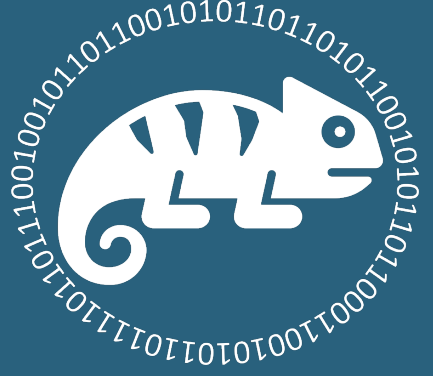

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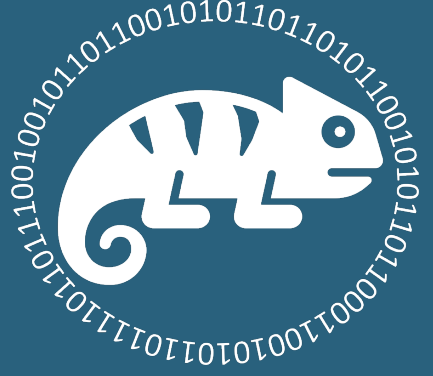

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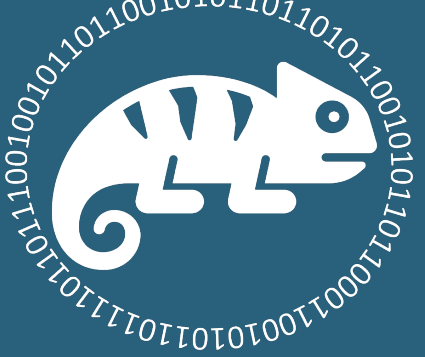

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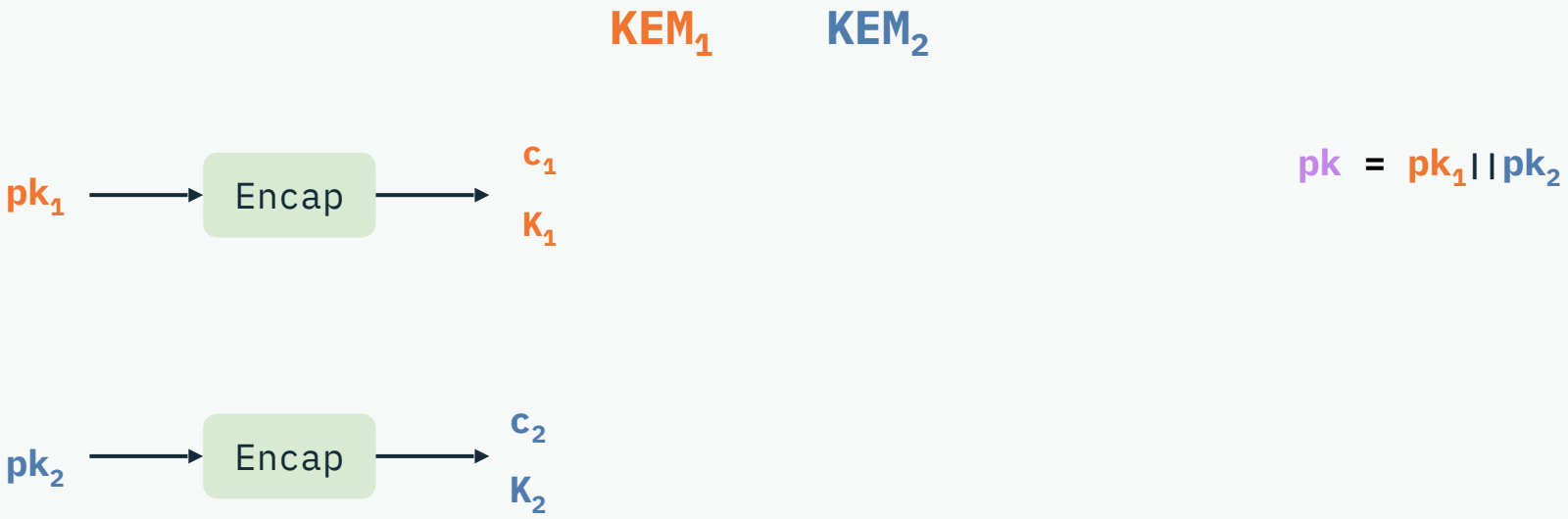

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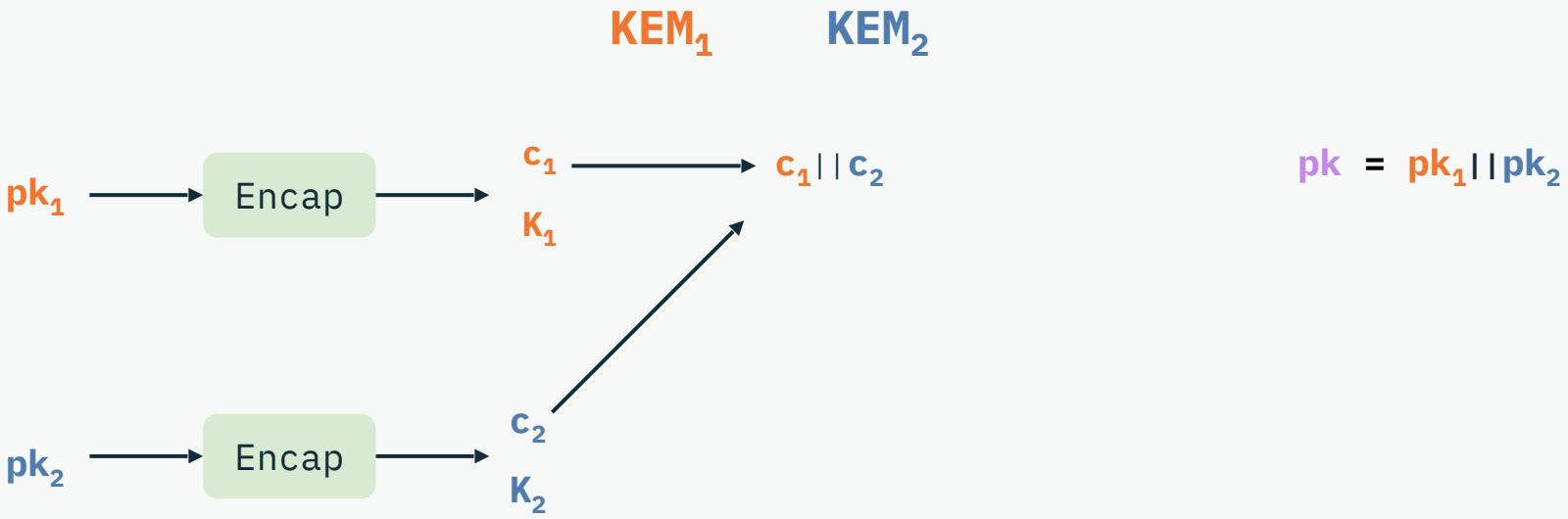

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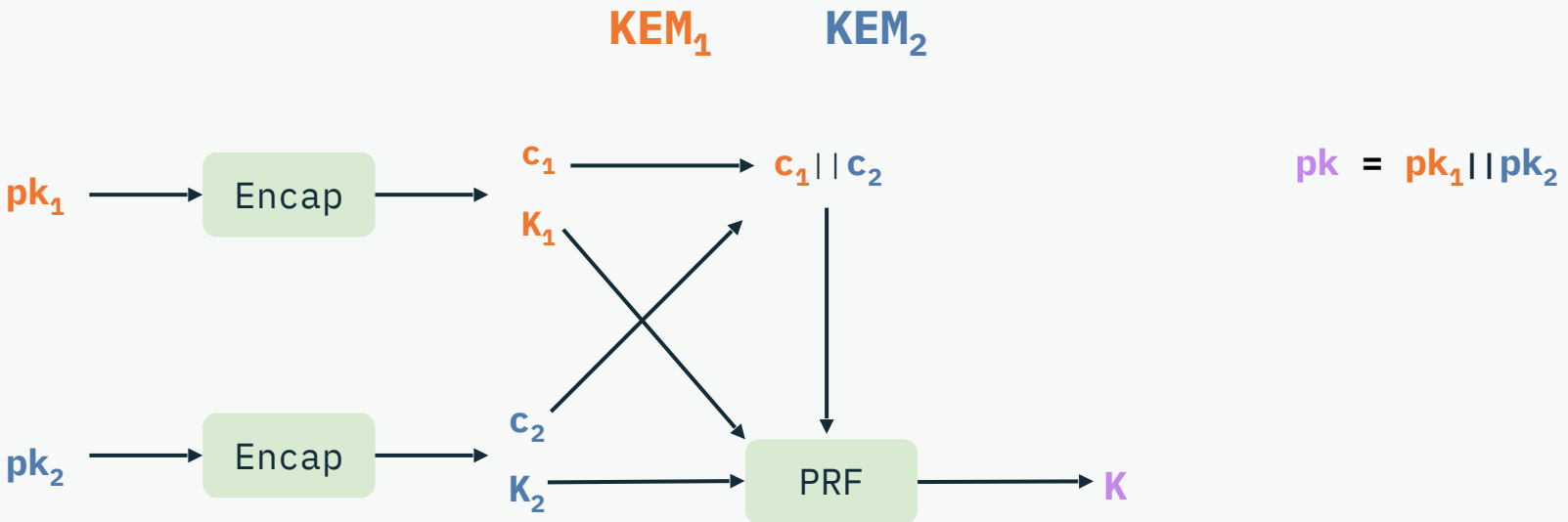

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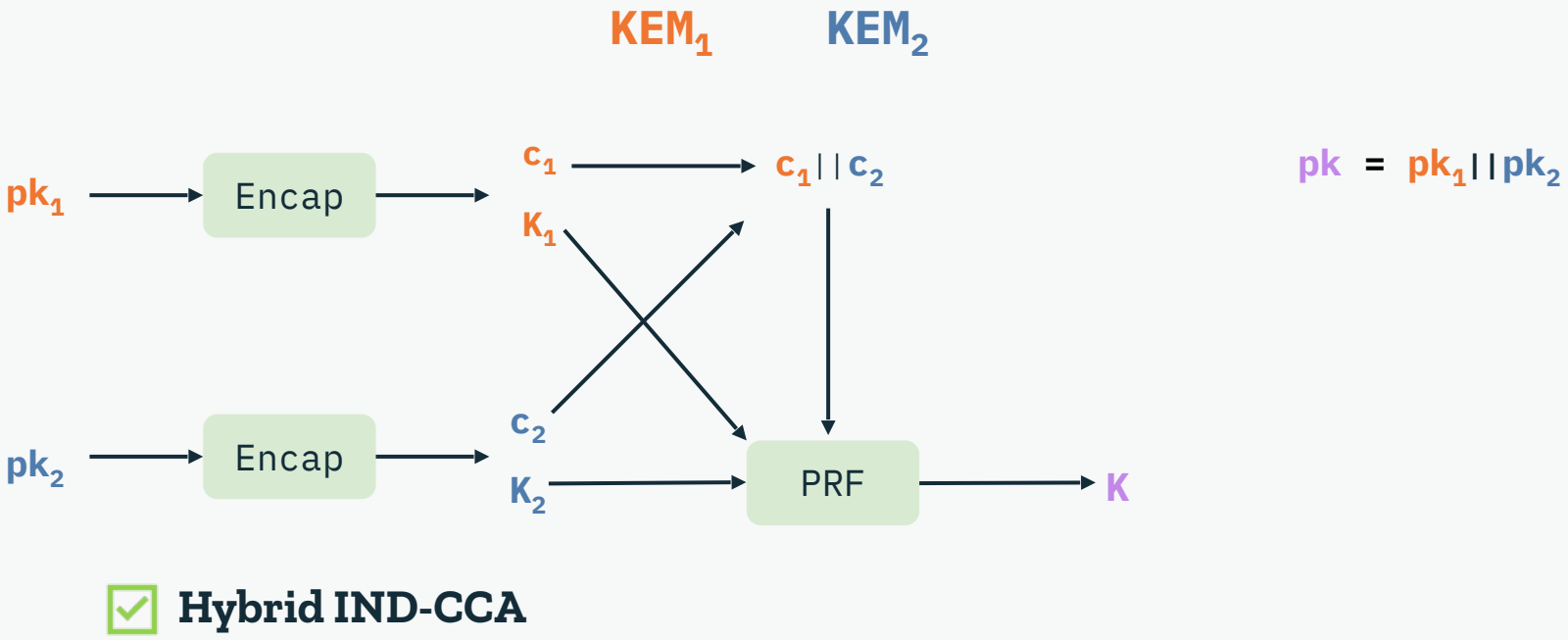

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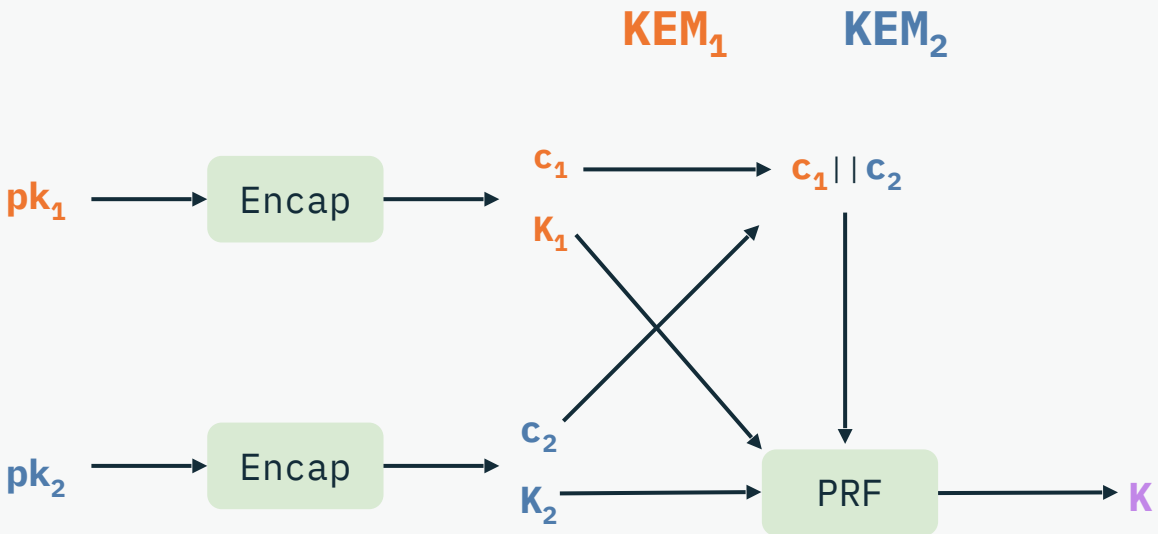

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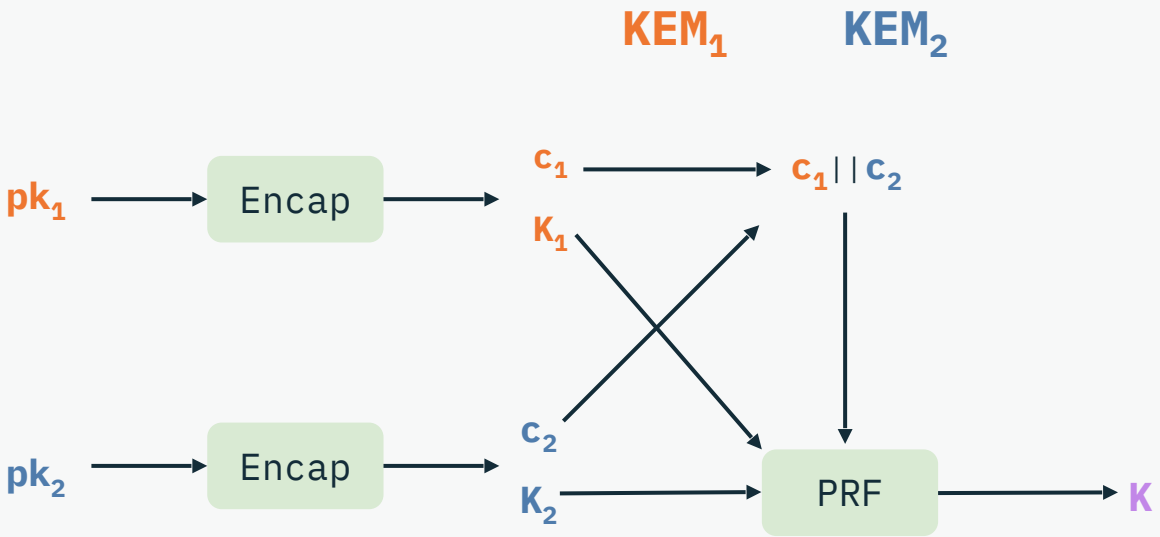

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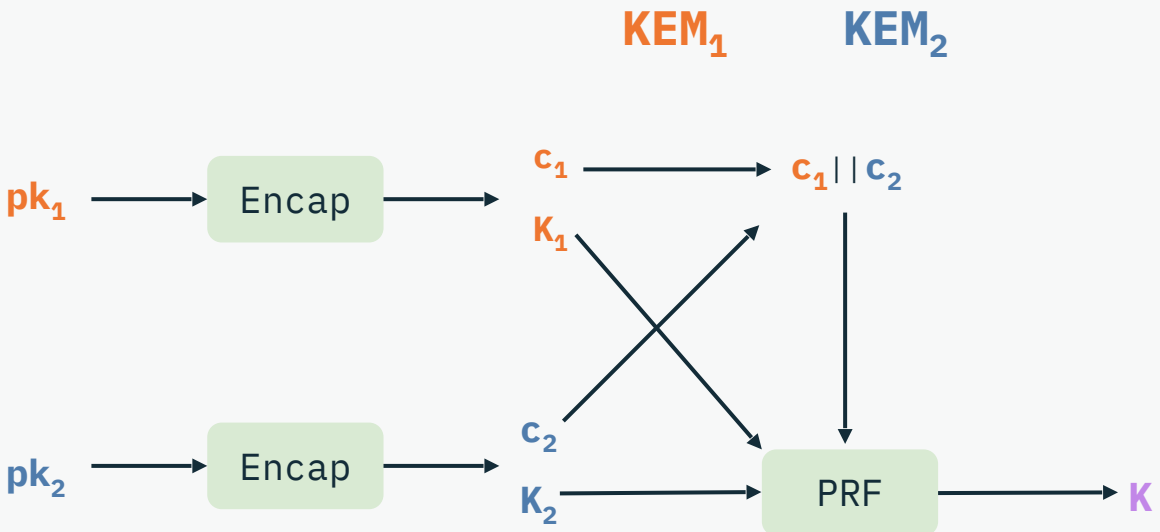

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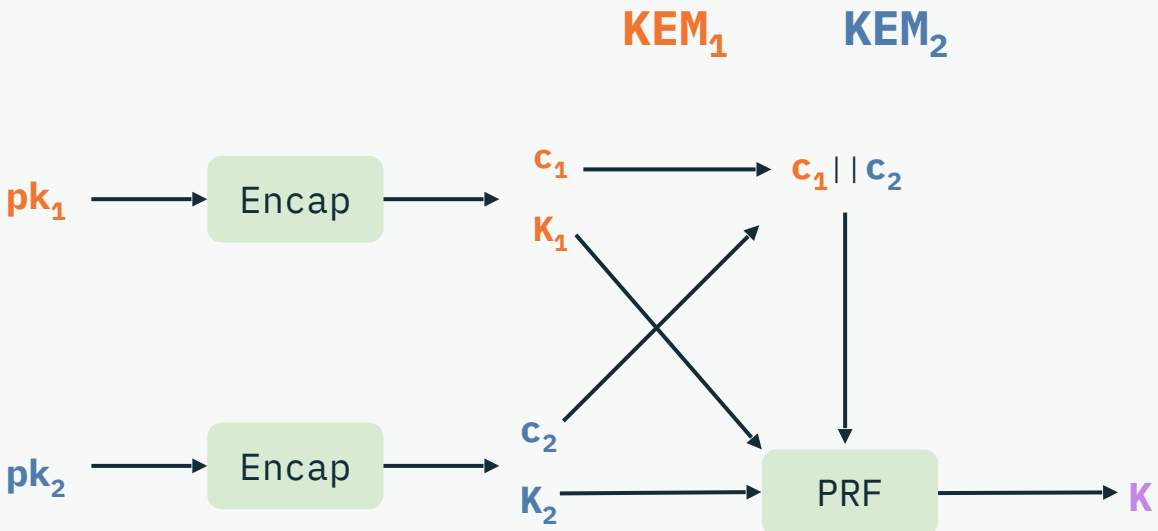

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Sometimes c_1 is **unconditionally uniform**

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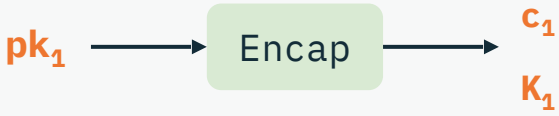

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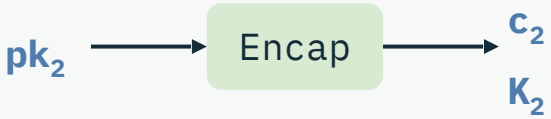

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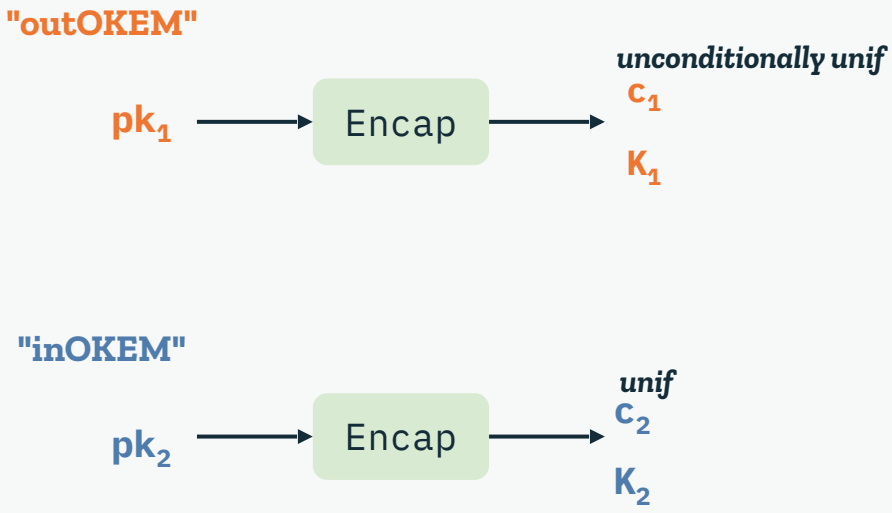

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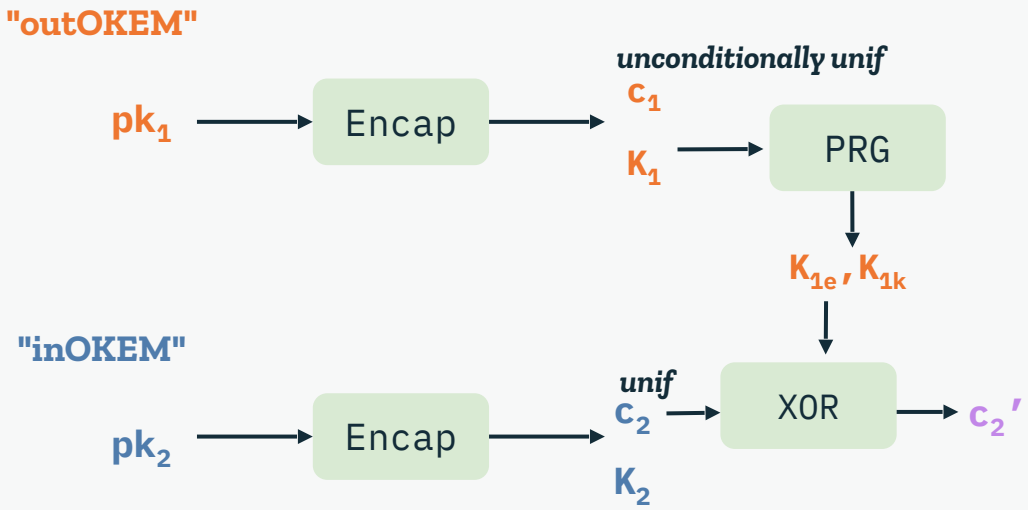

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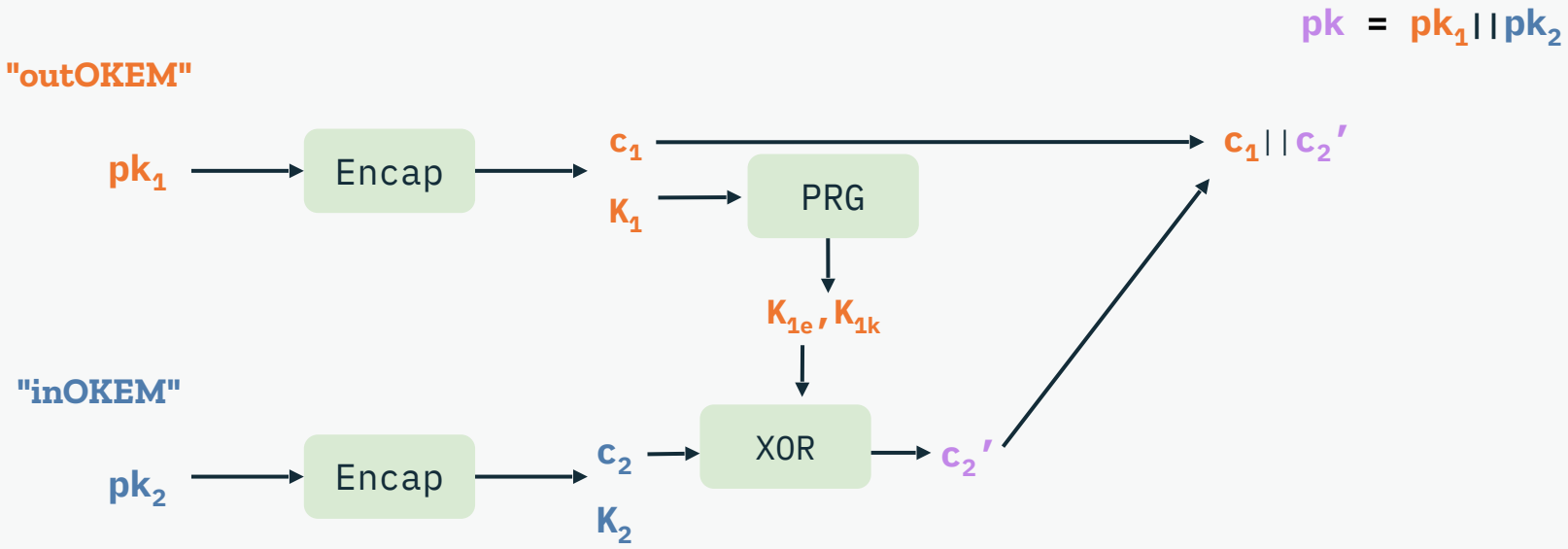

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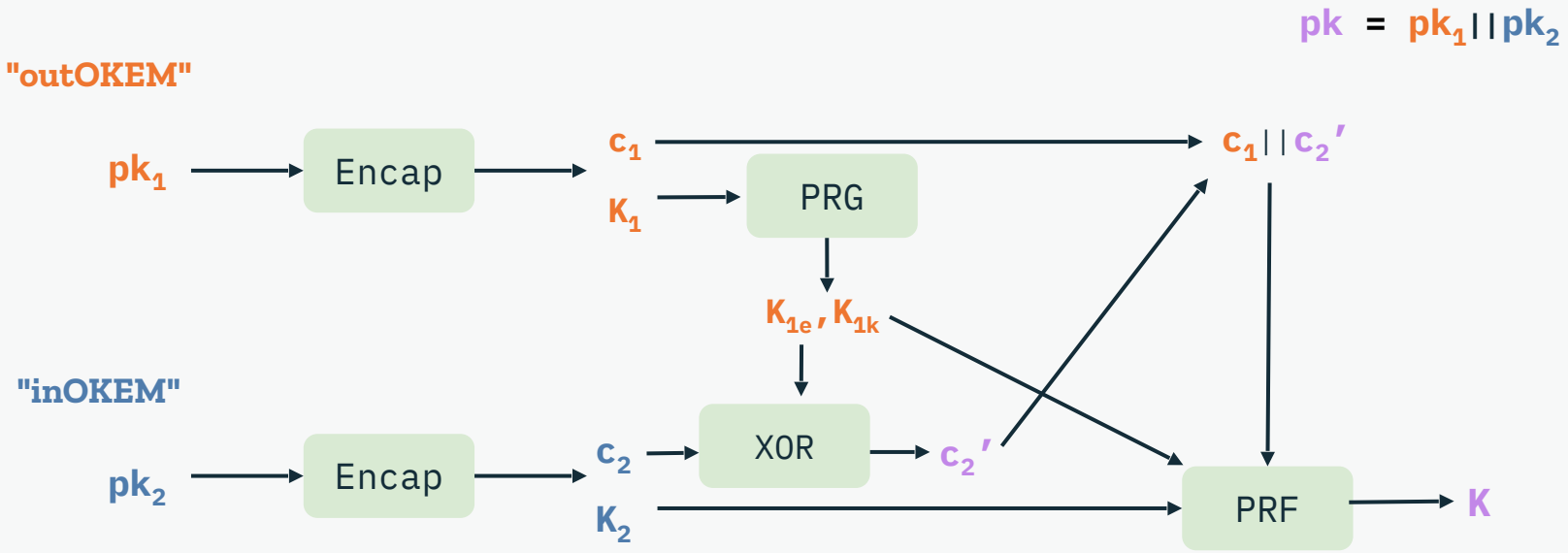

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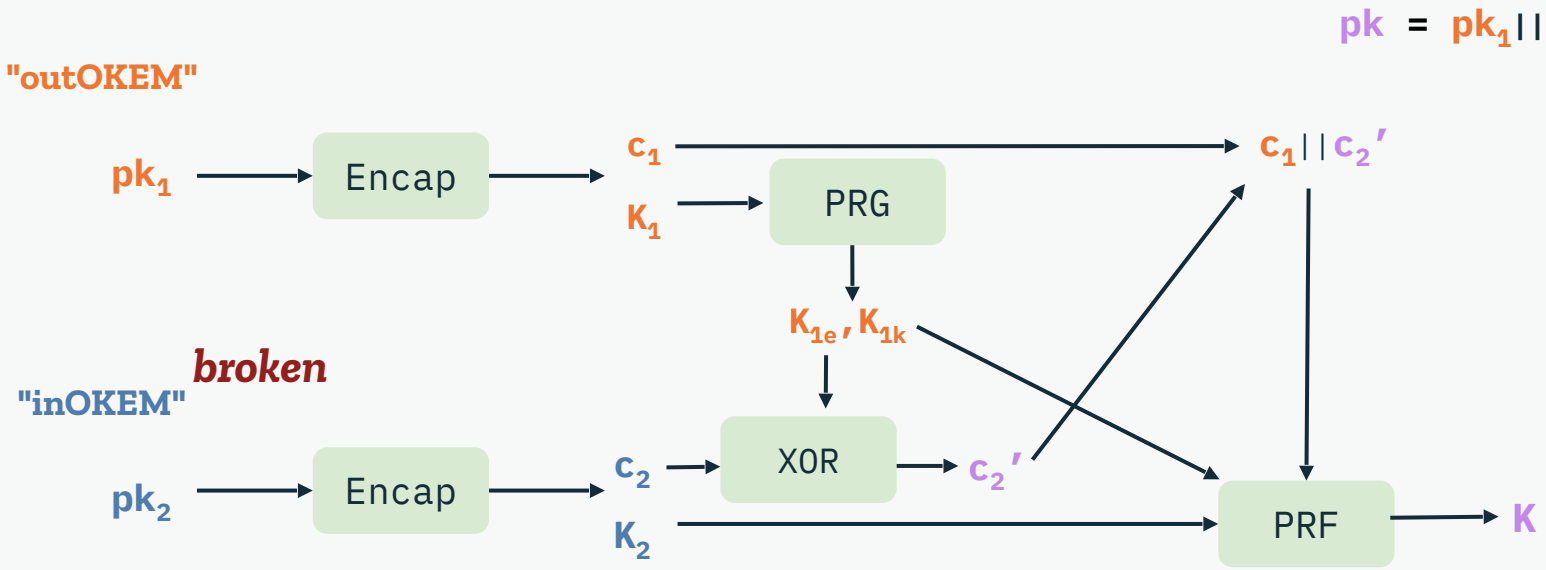

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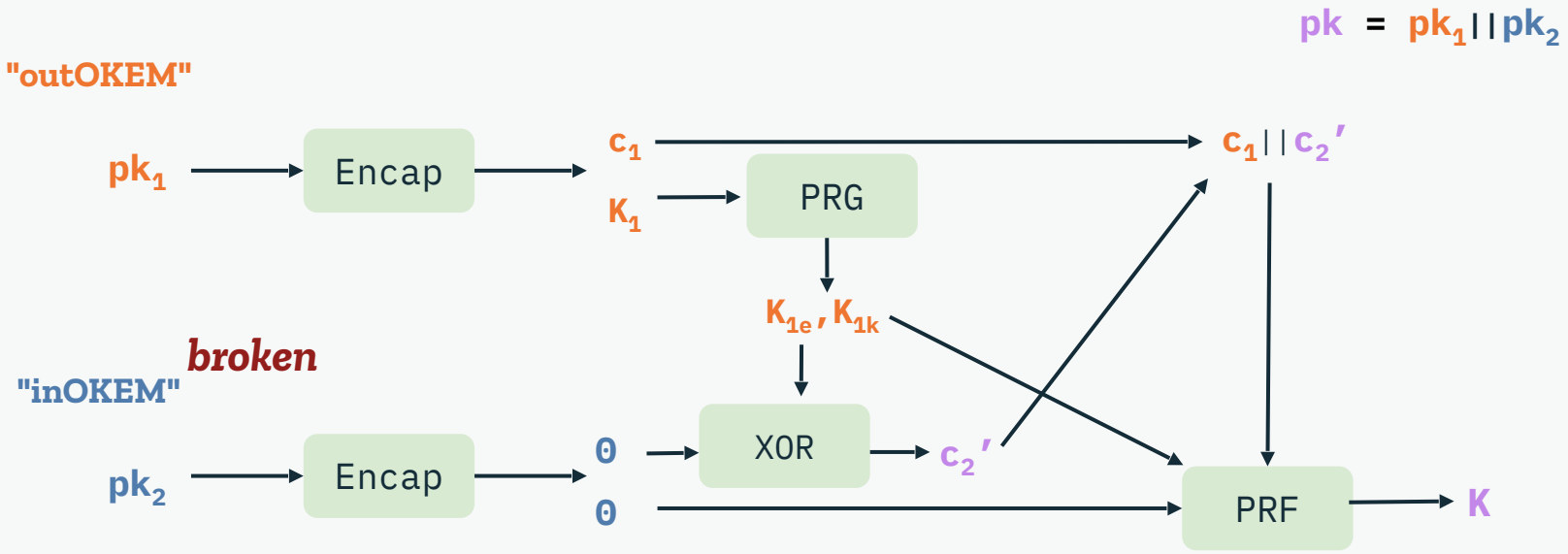

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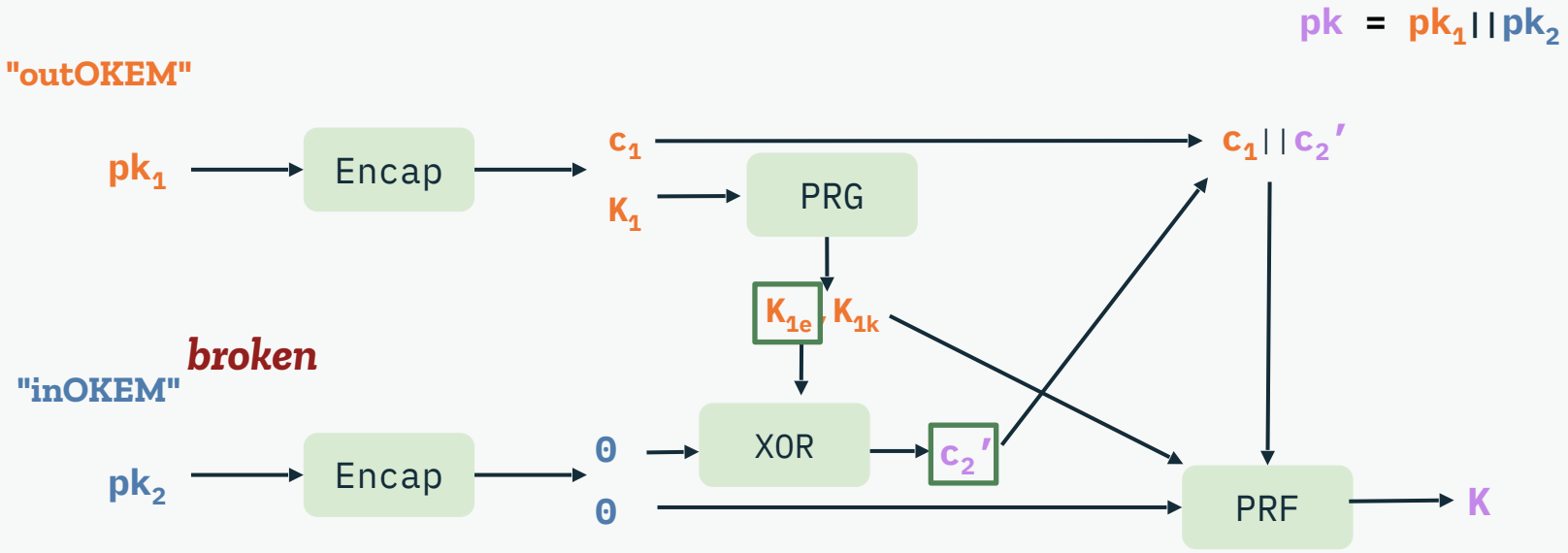

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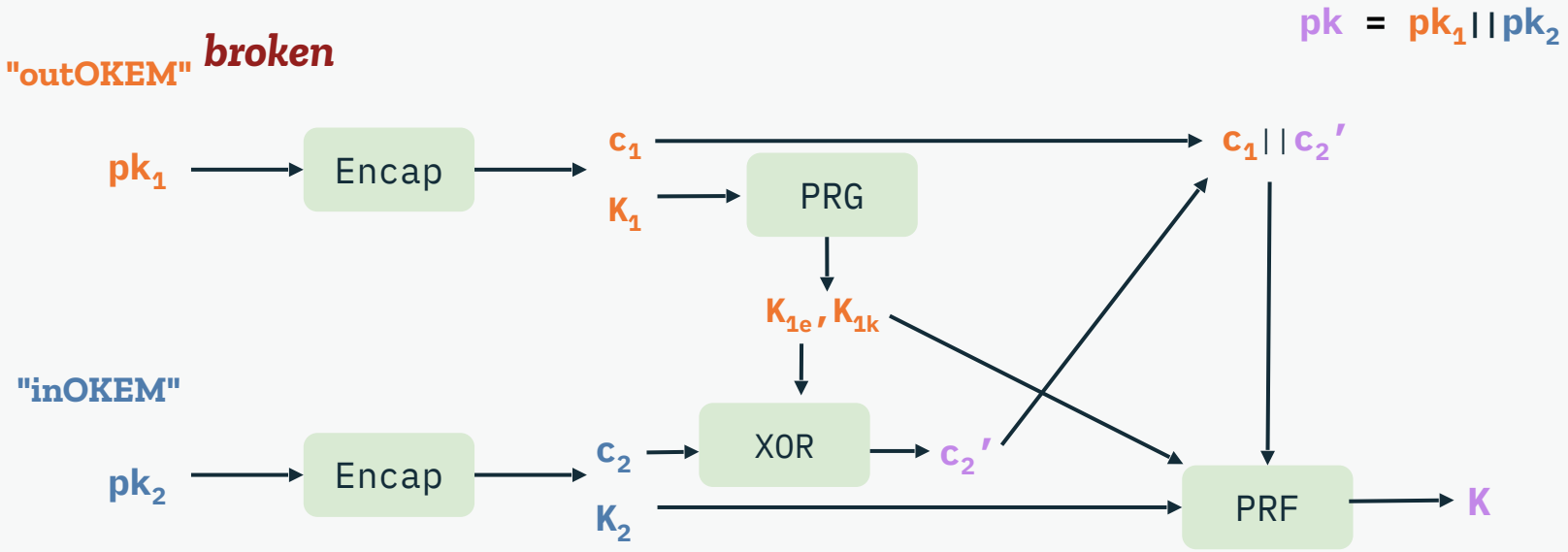

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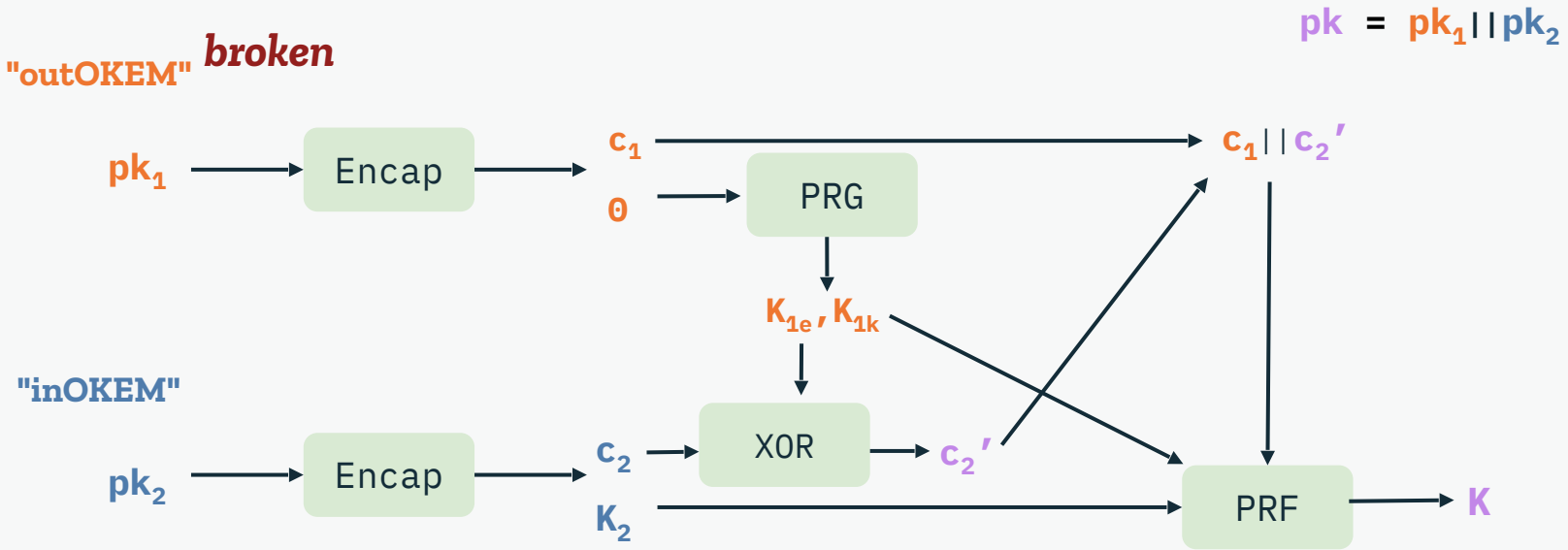

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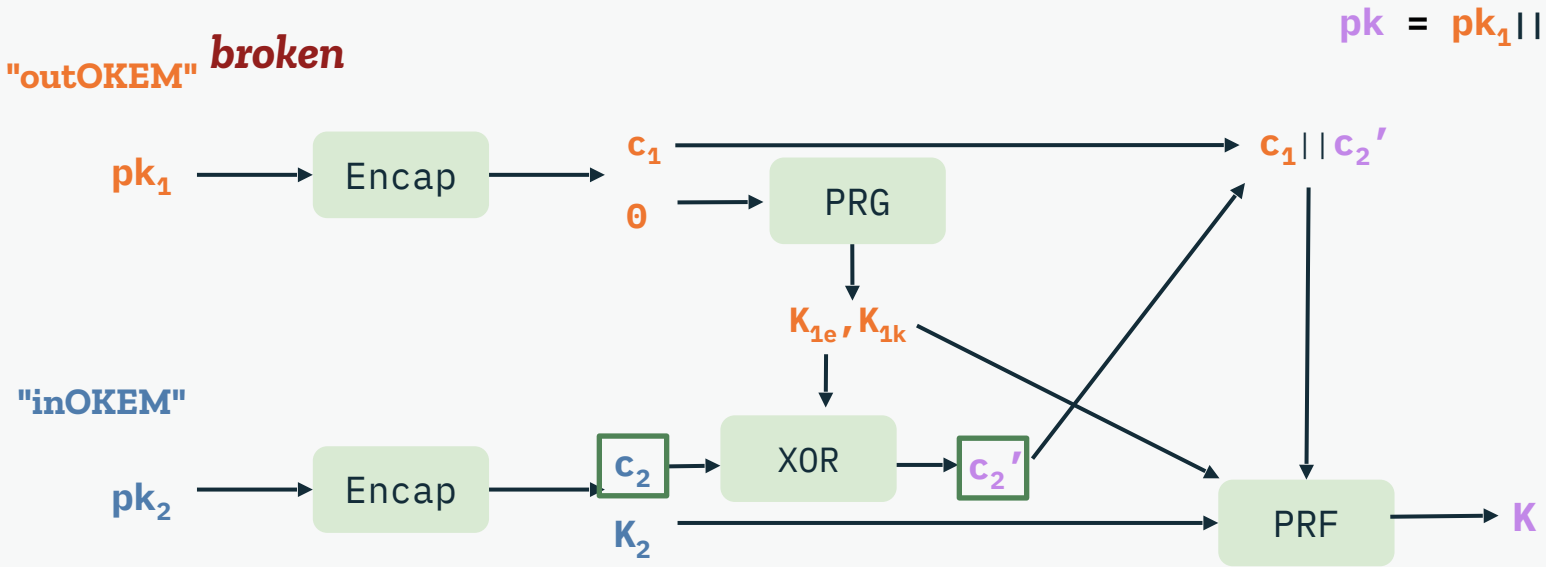

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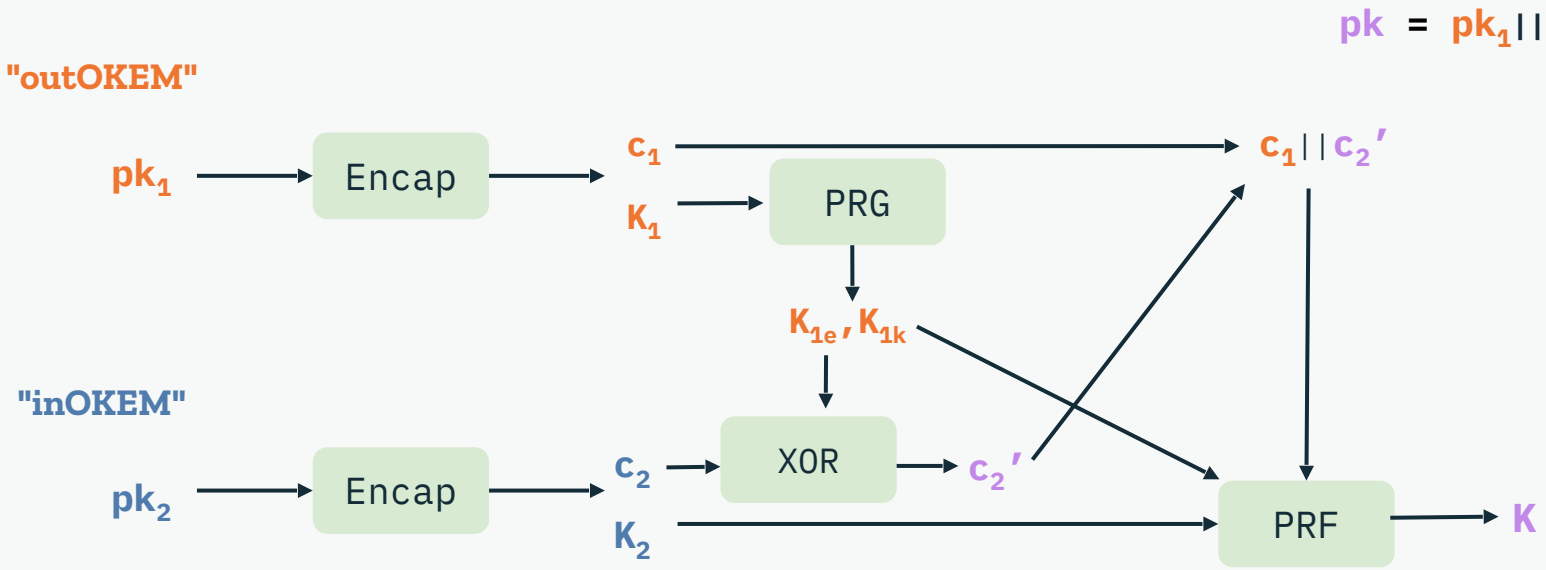

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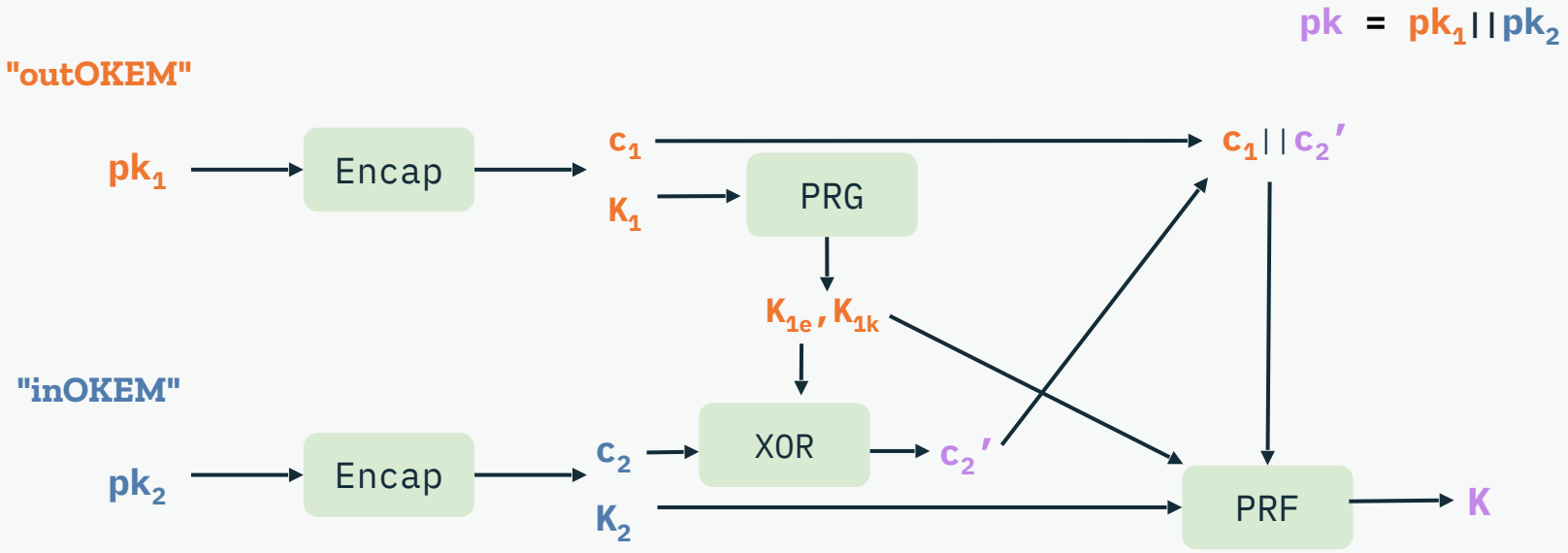

Similar trick in: **PAKE combiner** [HR24,LL24], **deniable AKEM combiner** [GHJ25], **OPRF combiner** [FH25]

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Hybrid pk-unif ⇒ both must be unconditionally pk-unif

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Ciphertext uniformity	outOKEM is SPR-CCA	or	inOKEM is ct-unif
Public key uniformity	outOKEM is pk-unif	**and**	inOKEM is pk-unif

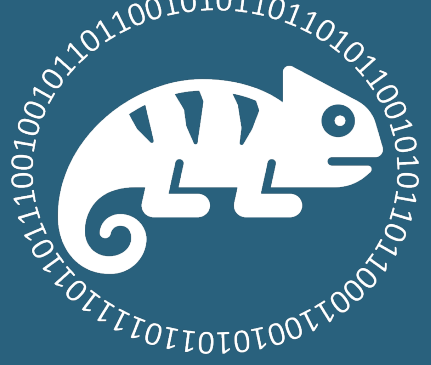
Hybrid pk-unif ⇒ both must be unconditionally pk-unif

We don't always need pk-unif

Our contributions

We build **hybrid obfuscated key exchange**

1. Define an obfuscated KEM (OKEM) combiner
2. Define Drivel, a new KEX protocol
3. Bonus: Hybrid PAKE from OKEM



Obfuscated Key Exchange

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Client does key exchange with a **bridge**

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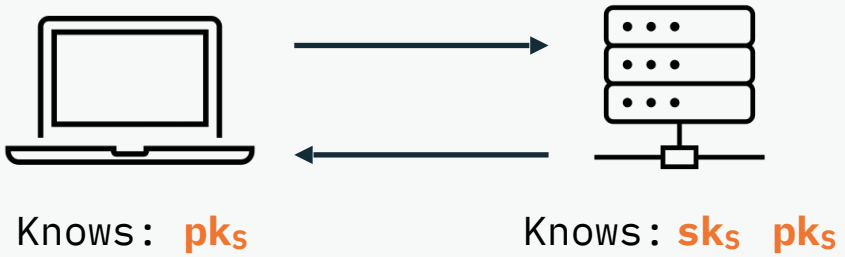
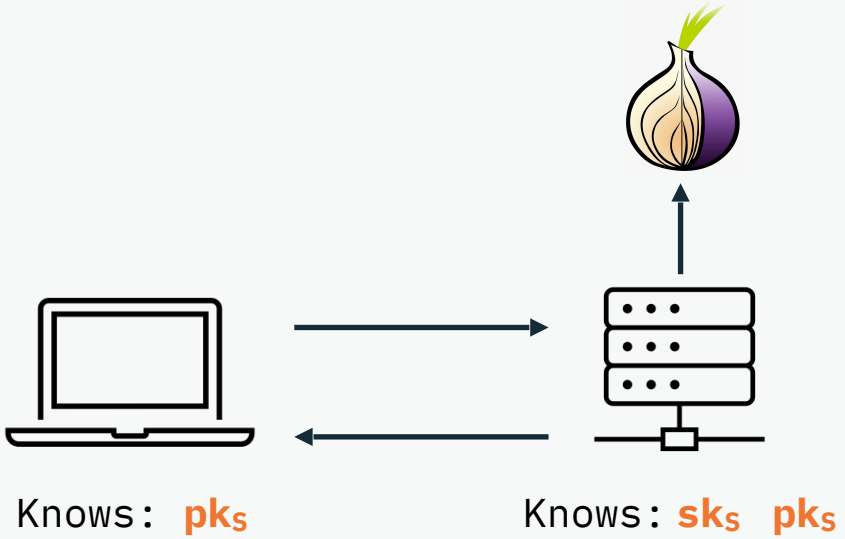


Obfuscated Key Exchange

Client does key exchange with a **bridge**

The bridge relays client traffic to **Tor**

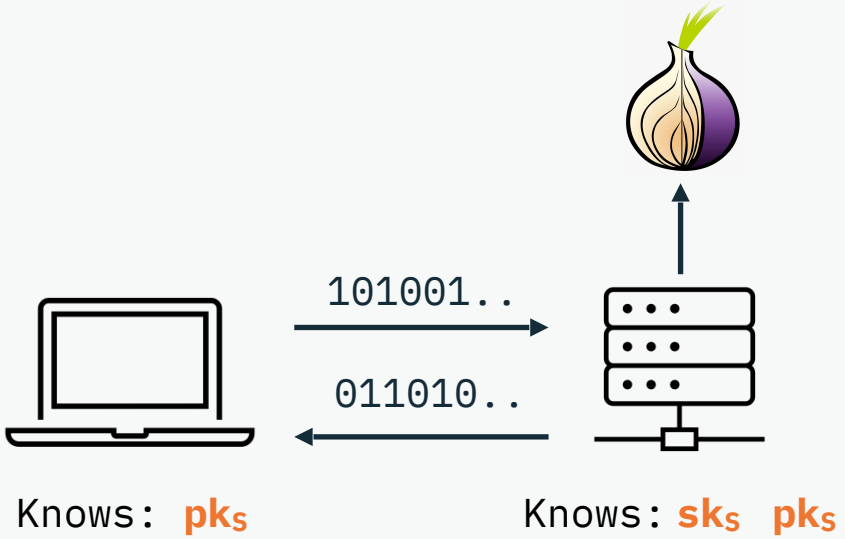


Obfuscated Key Exchange

Client does key exchange with a **bridge**

The bridge relays client traffic to **Tor**

Key exchange has to **appear uniform**



Drivel: Hybrid Obfuscated Key Exchange from OKEM

Drivel: Hybrid Obfuscated Key Exchange from OKEM

Prior work: pqobfs

Drivel: Hybrid Obfuscated Key Exchange from OKEM

pqobfs (simplified)

Client **Server** sk_S pk_S

Drivel: Hybrid Obfuscated Key Exchange from OKEM

pqobfs (simplified)

Client **Server** sk_S pk_S

$(sk_e, pk_e) := \text{OKEM.Keygen}()$

$(c_2, K_2) := \text{OKEM.Encap}(pk_e)$

$K_2 := \text{KEM.Decap}(sk_e, c_2)$

Drivel: Hybrid Obfuscated Key Exchange from OKEM

pqobfs (simplified)

Client

(sk_e, pk_e) := OKEM.Keygen()

(c_1, K_1) := OKEM.Encap(pk_s)

Server sk_s pk_s

K_1 := OKEM.Decap(sk_s, c_1)

(c_2, K_2) := OKEM.Encap(pk_e)

K_2 := KEM.Decap(sk_e, c_2)

Drivel: Hybrid Obfuscated Key Exchange from OKEM

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(sk_e, pk_e) := OKEM.Keygen()

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Server sk_S pk_S

K_1 := OKEM.Decap(sk_S, c_1)

(c_2, K_2) := OKEM.Encap(pk_e)

K_2 := KEM.Decap(sk_e, c_2)

return H(K_1, K_2)

return H(K_1, K_2)

Drivel: Hybrid Obfuscated Key Exchange from OKEM

pqobfs (simplified)

Client

$(sk_e, pk_e) := \text{OKEM.Keygen}()$

$(c_1, K_1) := \text{OKEM.Encap}(pk_s)$

Requires pk-unif

c_1 pk_e

Server sk_s pk_s

$K_1 := \text{OKEM.Decap}(sk_s, c_1)$

$(c_2, K_2) := \text{OKEM.Encap}(pk_e)$

c_2

$K_2 := \text{KEM.Decap}(sk_e, c_2)$

return $H(K_1, K_2)$

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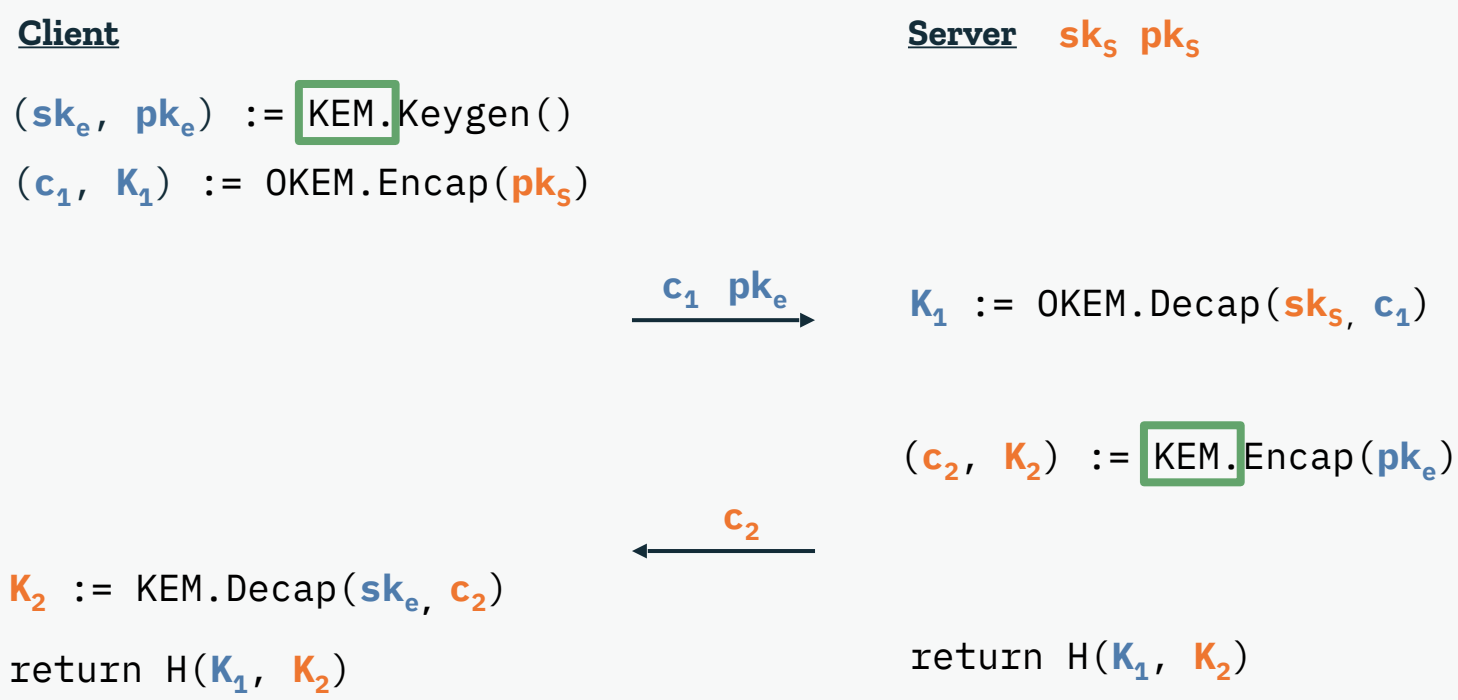

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return H(K_1, K_2)

Server sk_s pk_s

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(c_2, K_2) := KEM.Encap(pk_e)

return H(K_1, K_2)

Drivel: Hybrid Obfuscated Key Exchange from OKEM

Client

(sk_e, pk_e) := KEM.Keygen()

(c_1, K_1) := OKEM.Encap(pk_S)

epk_e := $SE.Enc_{K1}(pk_e)$

Server sk_S pk_S

K_1 := OKEM.Decap(sk_S, c_1)

pk_e := $SE.Dec_{K1}(epk_e)$

(c_2, K_2) := KEM.Encap(pk_e)

K_2 := KEM.Decap(sk_e, c_2)

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$c_1\ epk_e$ →

$c_2 := SE.Dec_{K1}(ec_2)$

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$pk_e := SE.Dec_{K1}(epk_e)$

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← ec_2

$ec_2 := SE.Enc_{K1}(c_2)$

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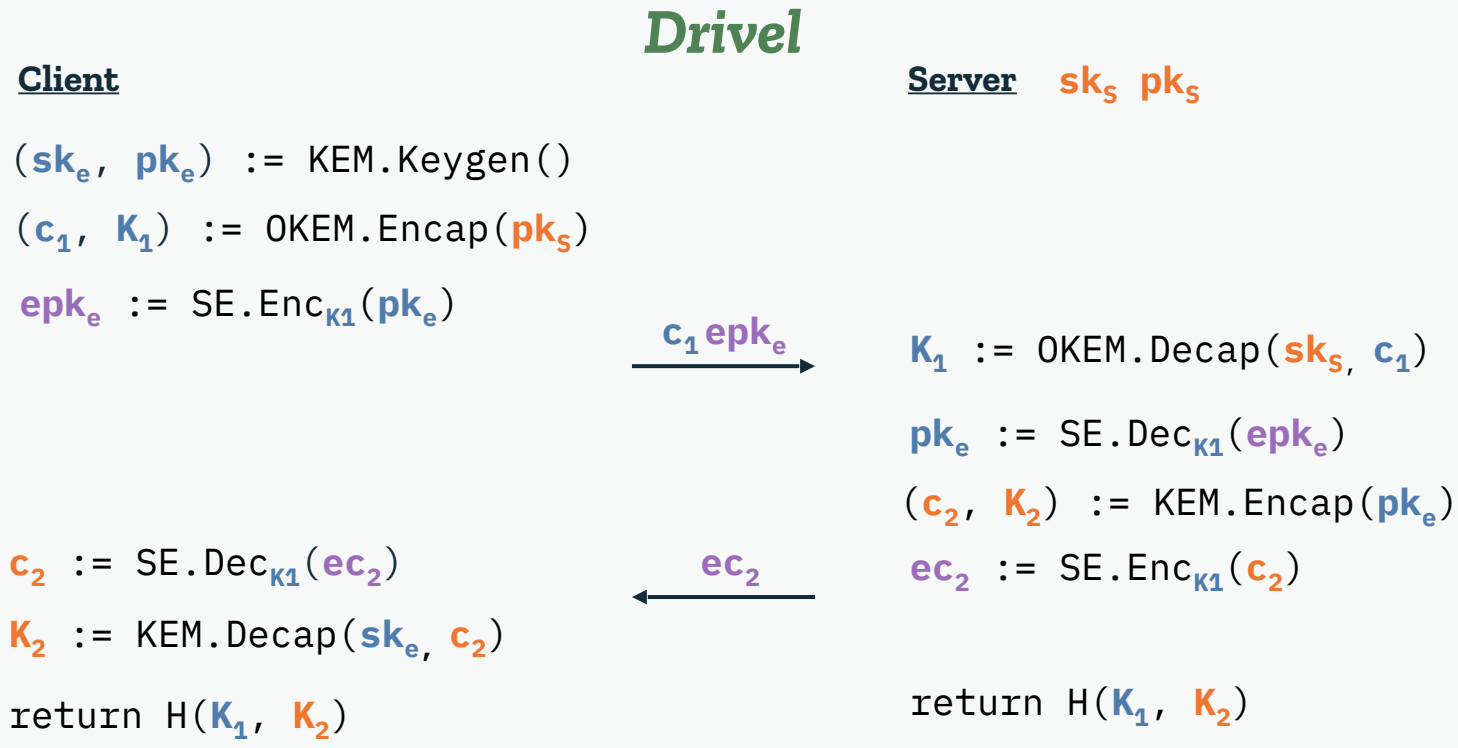
Drivel: Hybrid Obfuscated Key Exchange from OKEM



Drivel: Hybrid Obfuscated Key Exchange from OKEM

Drivel

No pk-unif requirement anymore

Client

$(sk_e, pk_e) := KEM.Keygen()$

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$K_1 := OKEM.Decap(sk_S, c_1)$

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$(c_2, K_2) := KEM.Encap(pk_e)$

$ec_2 := SE.Enc_{K1}(c_2)$

← ec_2

$c_2 := SE.Dec_{K1}(ec_2)$

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return $H(K_1, K_2)$

Server sk_S pk_S

return $H(K_1, K_2)$

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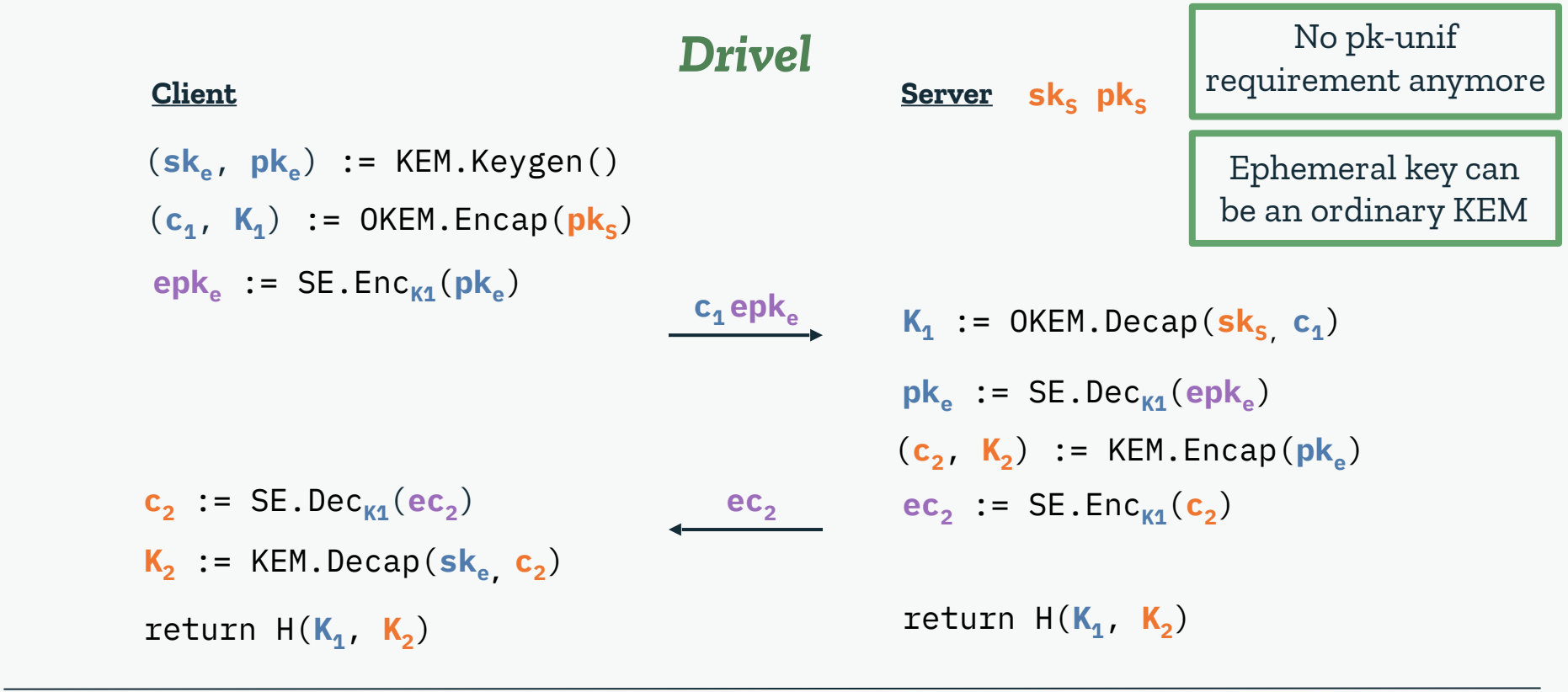

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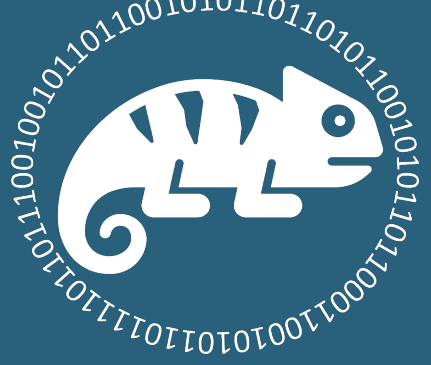

Bonus OEINC Application: Hybrid PAKE

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Password authenticated key exchange (PAKE)

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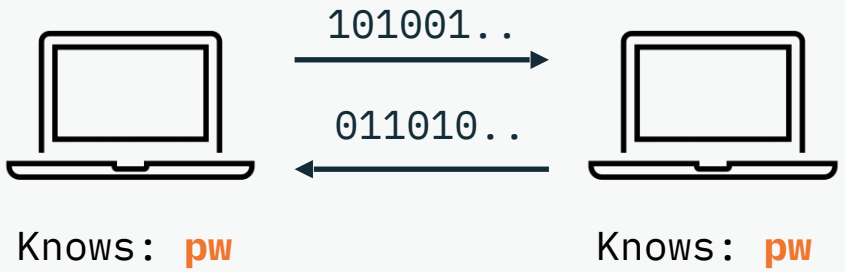
Parties w/ **low-entropy password** want to establish a **high-entropy shared secret**:



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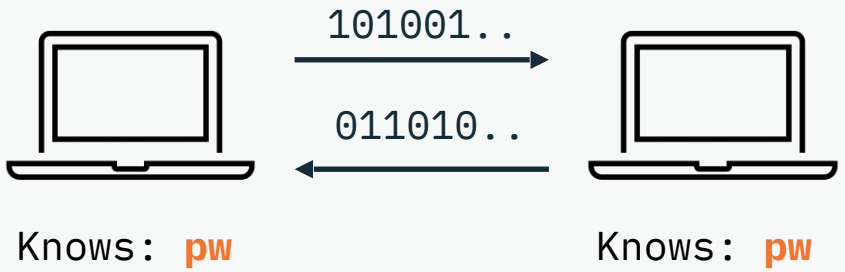

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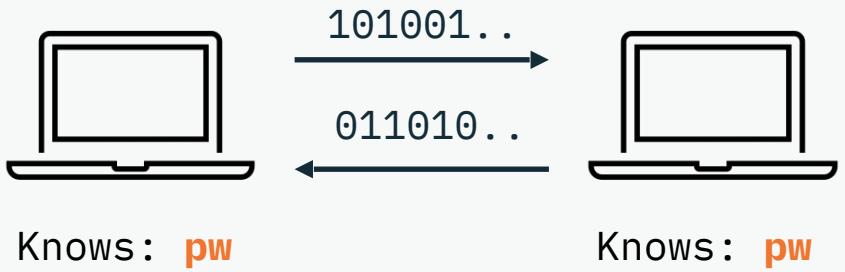

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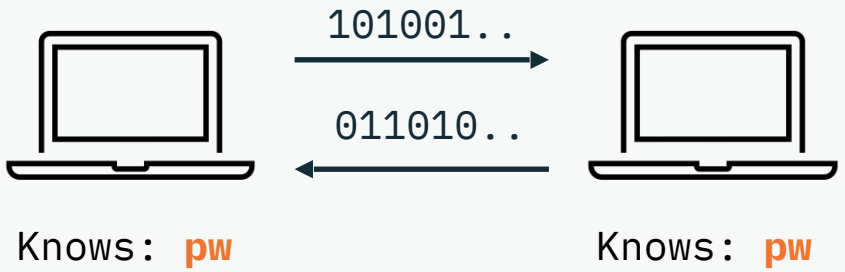

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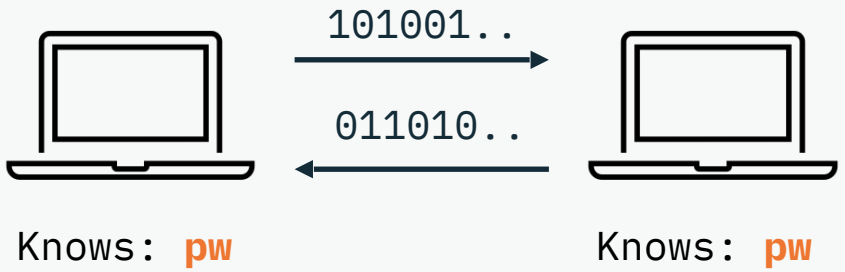

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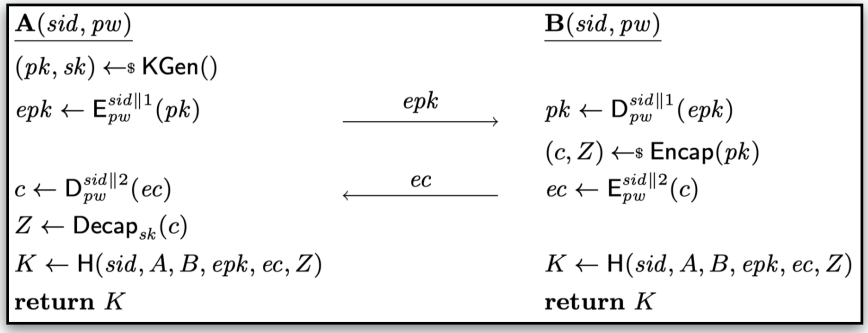

CAKE

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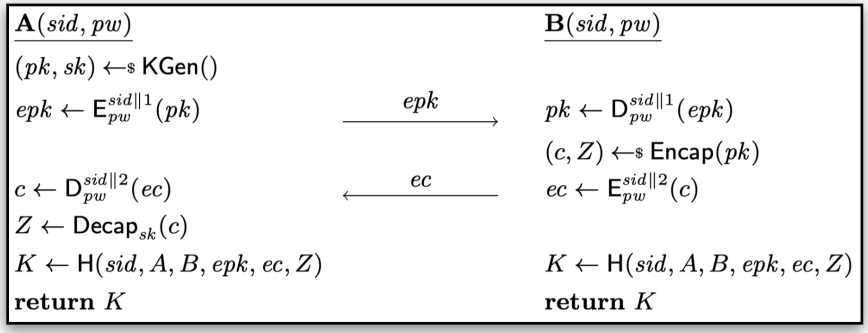
Requires **ciphertext and public key uniformity***



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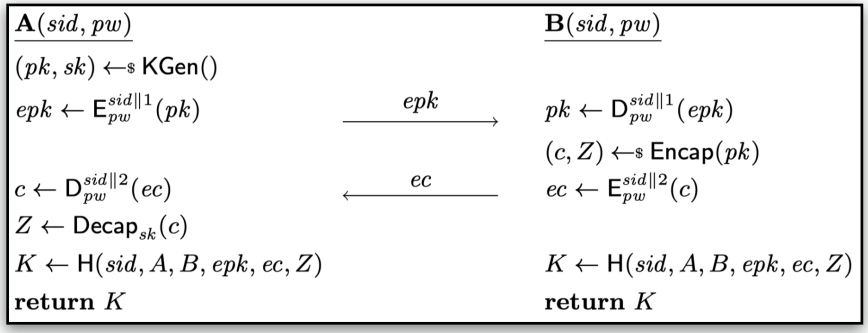

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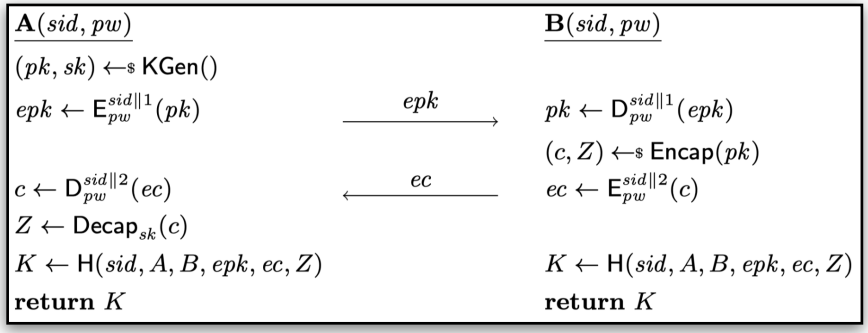
- Undo this optimization. Call it **StatFrodoKEM**



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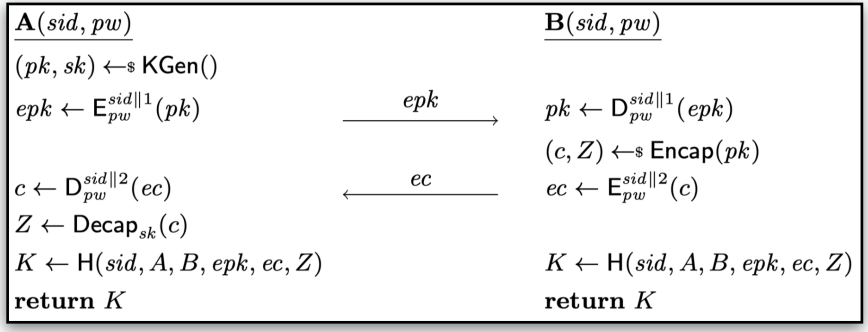
CAKE[OEINC[DHKEM+Elligator, StatFrodoKEM]]



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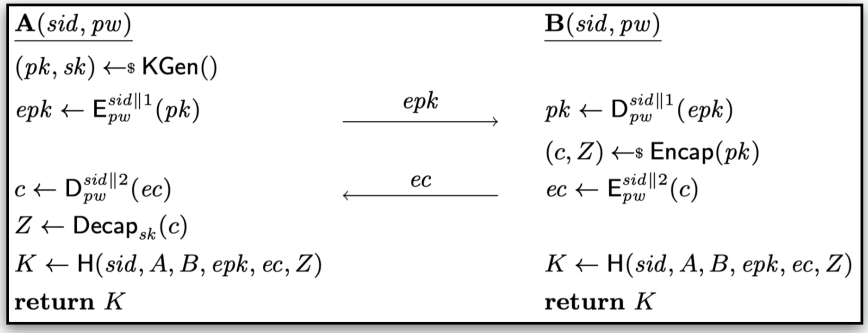

CAKE

First hybrid PAKE with security against adaptive corruptions

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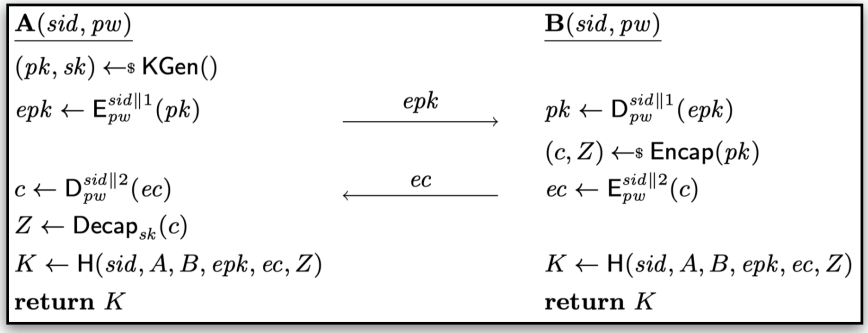

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2 rounds. Other PAKEs are 3 rounds or inefficient (350x slowdown).

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Hence

CAKE[OEINC[DHKEM+Elligator, StatFrodoKEM]]

$\mathbf{A}(sid, pw)$		$\mathbf{B}(sid, pw)$
$(pk, sk) \leftarrow\$ \mathsf{KGen}()$		
$epk \leftarrow \mathsf{E}_{pw}^{sid\|\|1}(pk)$	$\xrightarrow{epk}$	$pk \leftarrow \mathsf{D}_{pw}^{sid\|\|1}(epk)$
		$(c, Z) \leftarrow\$ \mathsf{Encap}(pk)$
$c \leftarrow \mathsf{D}_{pw}^{sid\|\|2}(ec)$	$\xleftarrow{ec}$	$ec \leftarrow \mathsf{E}_{pw}^{sid\|\|2}(c)$
$Z \leftarrow \mathsf{Decap}_{sk}(c)$		
$K \leftarrow \mathsf{H}(sid, A, B, epk, ec, Z)$		$K \leftarrow \mathsf{H}(sid, A, B, epk, ec, Z)$
return K		**return** K

CAKE

First hybrid PAKE with security against adaptive corruptions

2 rounds. Other PAKEs are 3 rounds or inefficient (350x slowdown).

7.5x comms overhead compared to 3-round PAKEs

Conclusion

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Hybrid Obfuscated Key Exchange and KEMs

ia.cr/2025/408

Felix Günther
Michael Rosenberg
Douglas Stebila
Shannon Veitch

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Questions?

Ask me questions irl

References:

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