Post-Quantum

Cryptography Conference

Symmetric Key Exchange: Lightweight Alternatives for a Post-Quantum IoT

Bor de Kock

Assistant Professor of Cryptology at NTNU Trondheim

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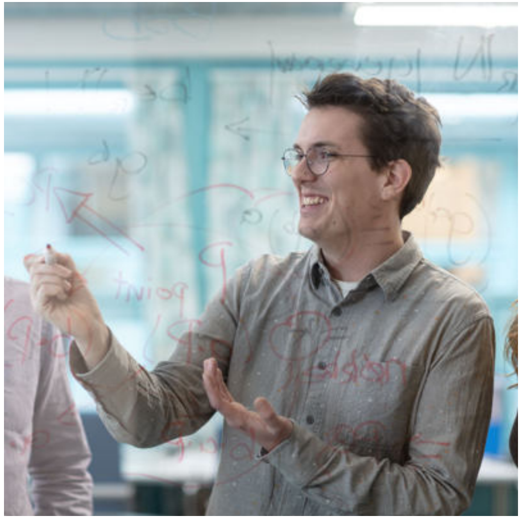
Post-Quantum Cryptography Conference

November 8, 2023

About me

Bor de Kock, assistant professor cryptology

- MSc from Eindhoven University of Technology
- PhD on Post-Quantum Key Exchange, from NTNU



My research interests:

Post-quantum cryptography, key exchange, password-based crypto, authentication, security models, ratcheting, etc.

in other words: practical crypto!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Iceland Sea
ÍSLAND
Akureyri
Reykjavík
Gunnbjørn Fjeld
Trondheim
NORGE
SVERIGE
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Umeå
Tampere
Turku
Helsinki
Bergen
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Uppsala
Stockholm
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Нижний Новгород
Ярославль
Смоленск
Cairngorms National Park
Streymoy
Lindesnes

Norwegian University of Science and Technology

Trondheim, Gjøvik and Ålesund

Largest university in Norway

43.000 students

32 cryptographers

Let’s talk key exchange…

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- Making key exchange post-quantum is an ongoing effort

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- Most serious candidates are inefficient, compared to SoA

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- Symmetric algorithms such as AES are post-quantum
- Symmetric algorithms such as AES are very efficient
- Many security features we like are missing.

What do we want to achieve?

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- Pre-shared symmetric keys

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- Synchronization

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- Forward security
- Synchronization
- Concurrent Correctness

In this talk…

Symmetric Key Exchange with Full Forward Security and Robust Synchronization

Colin Boyd, Gareth T. Davies, Bor de Kock, Kai Gellert, Tibor Jager and Lise Millerjord

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- 3 very efficient AKE protocols with linear key evolution

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- Formalization of synchronization robustness as a security property

Authenticated Key Exchange - AKE

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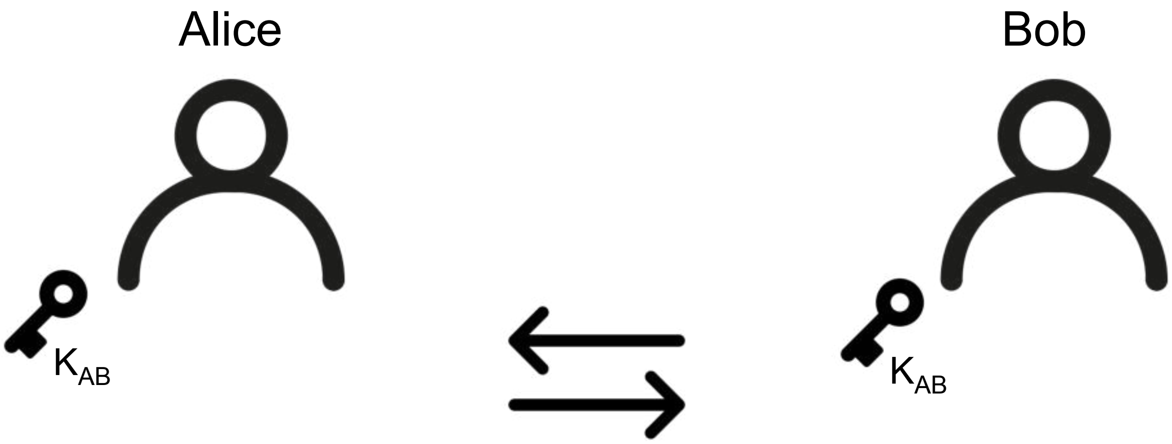

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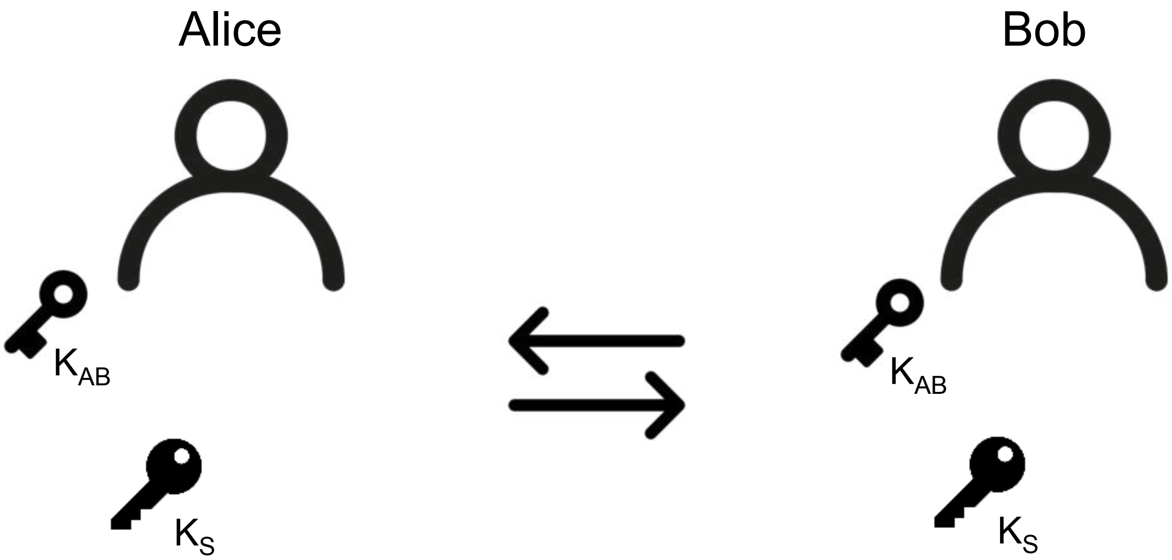

Forward Security

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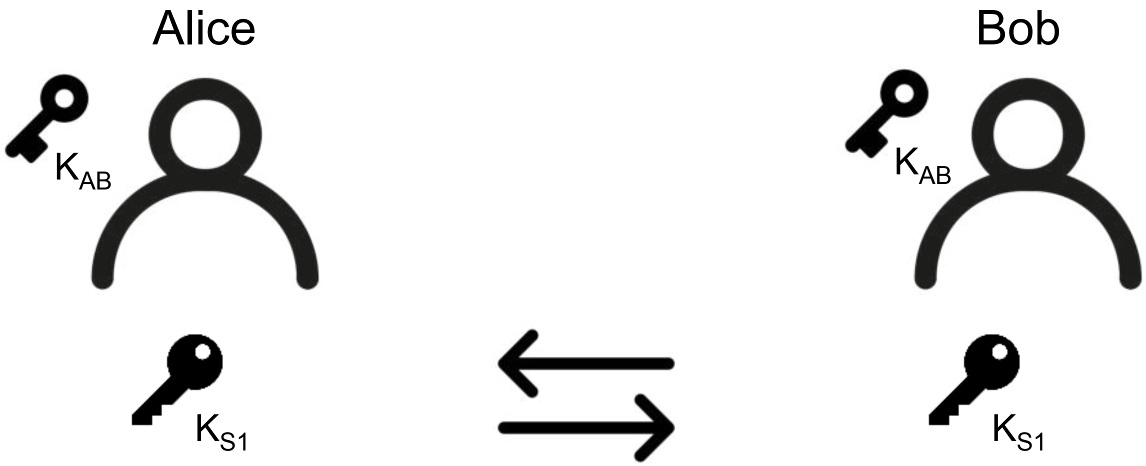

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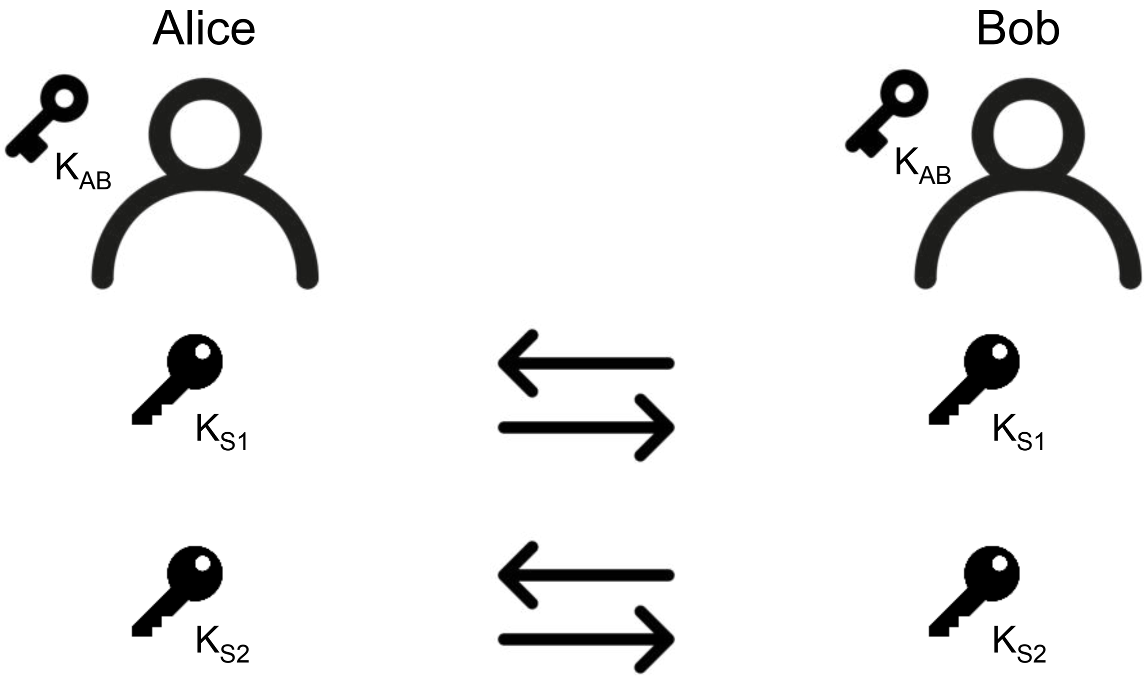

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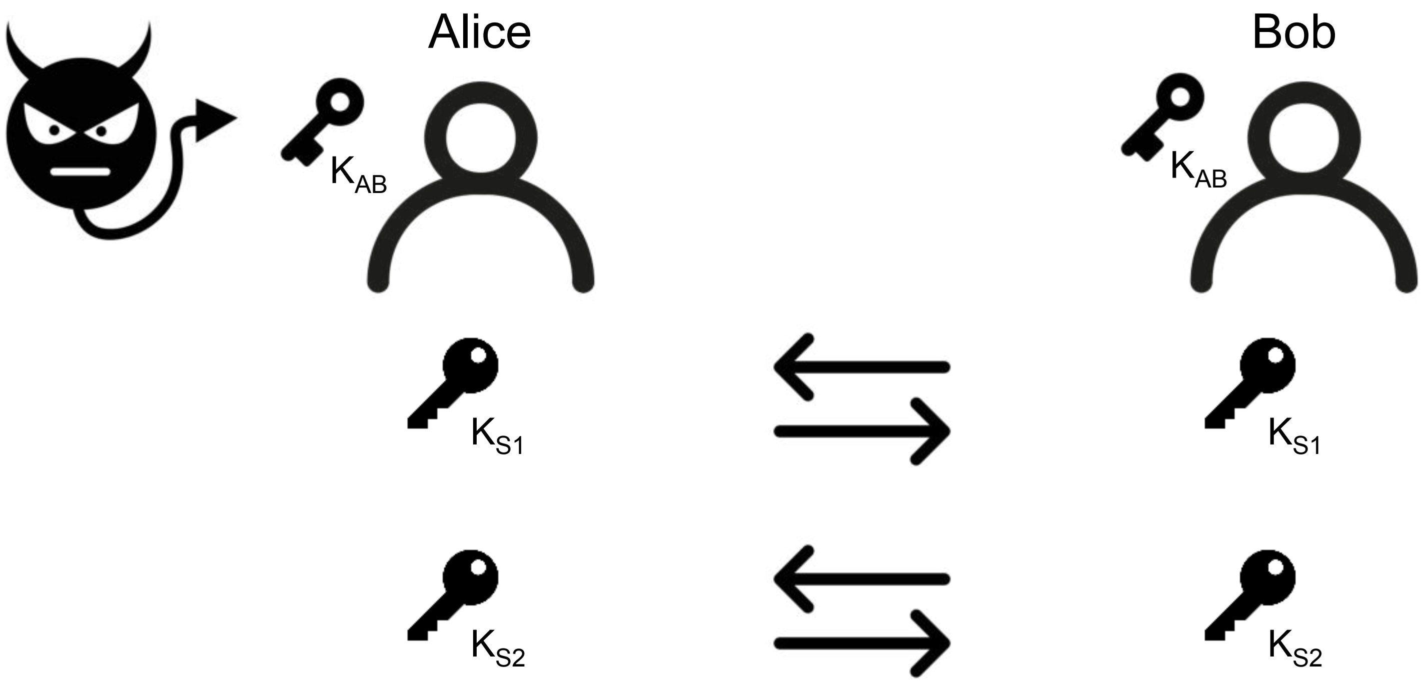

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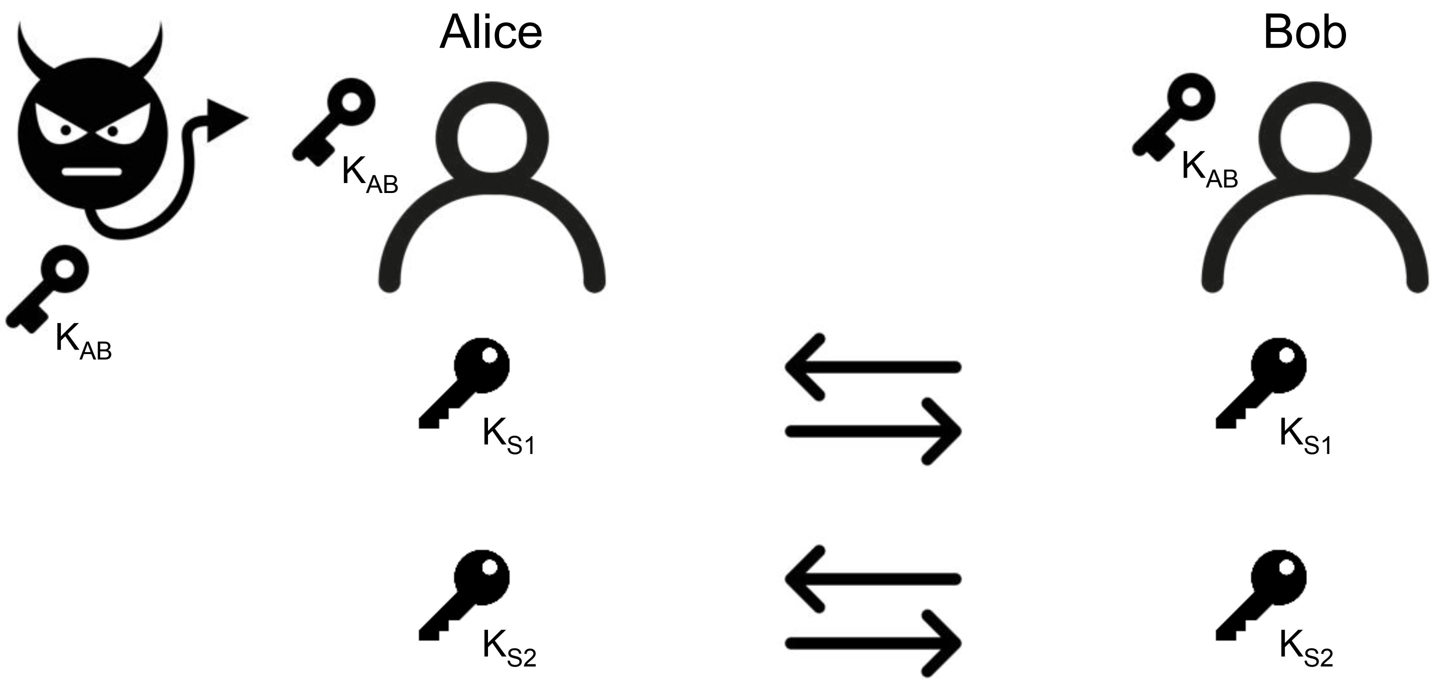

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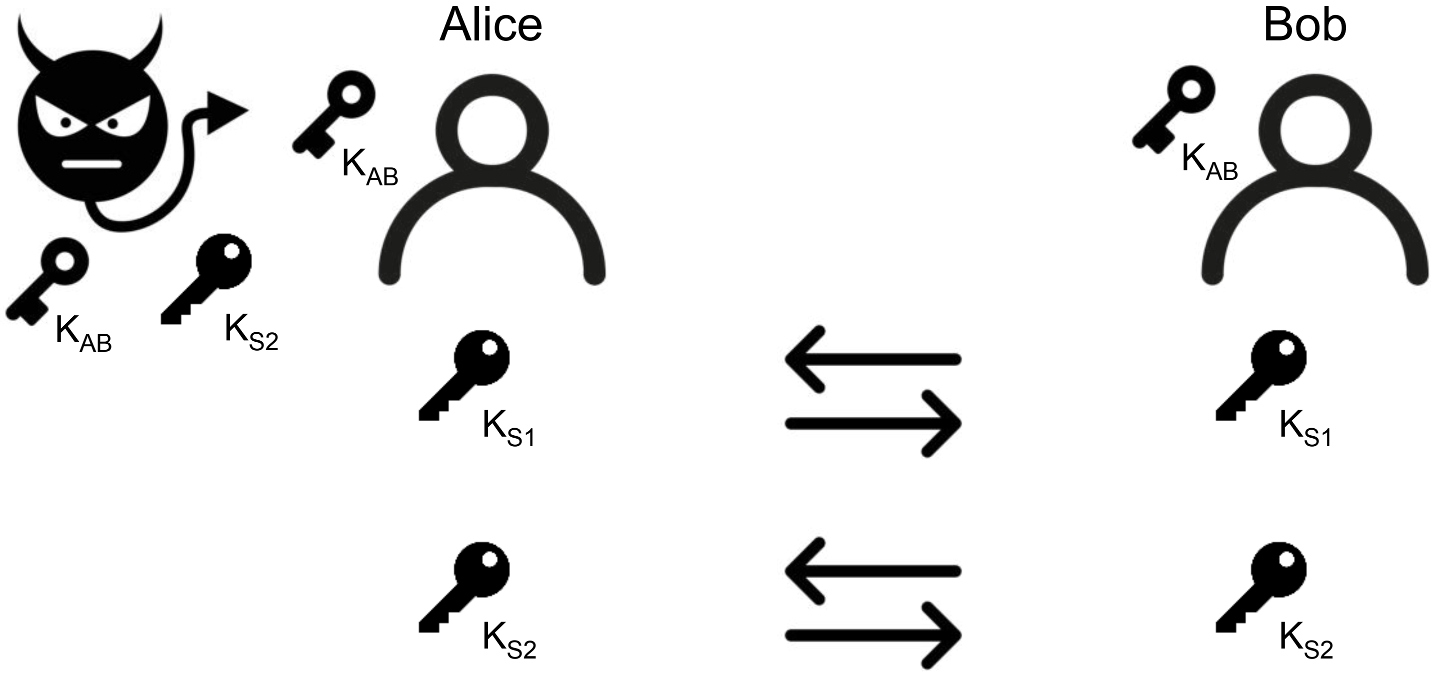
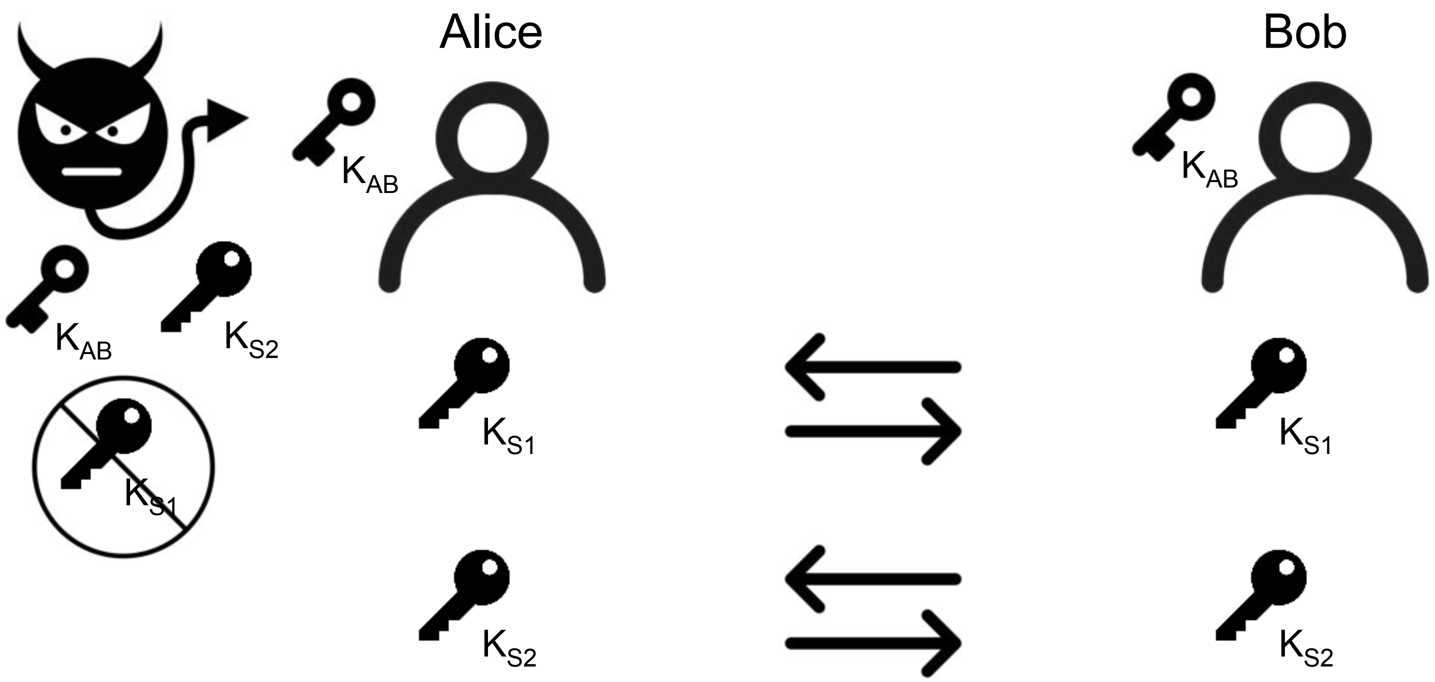


NTNU

Forward Security



Achieving Forward Security

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- Triggered evolution: evolve after session key derivation

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Protocol	Auth.	# of Messages	Sync. Rob. Weak	Sync. Rob. Full	Conc. Corr.	Forward Security
SAKE [ACF20]	Mutual	5	✗	✗	✗	✓
SAKE-AM [ACF20]	Mutual	4	✗	✗	✗	✓

Example protocol: LP2

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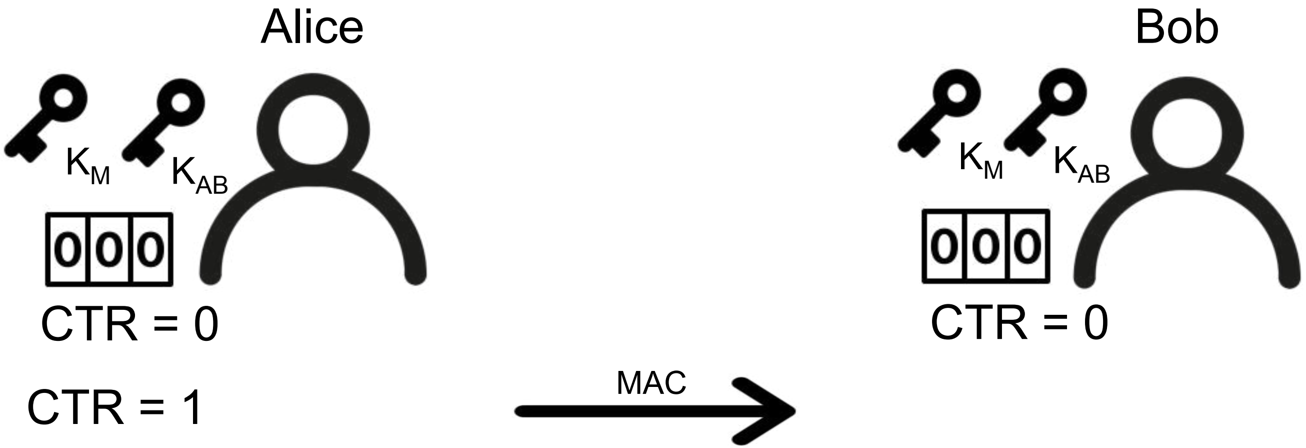

NTNU

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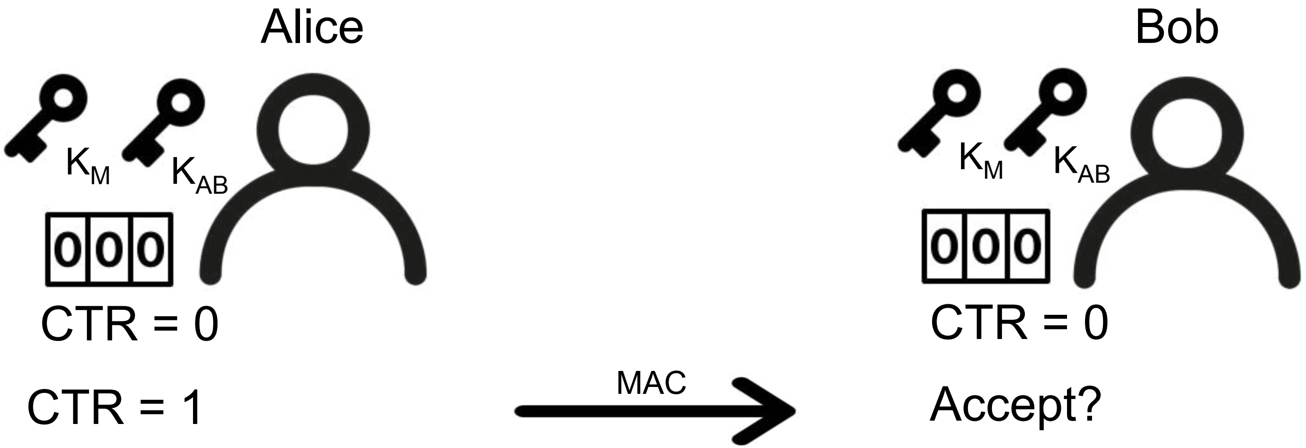

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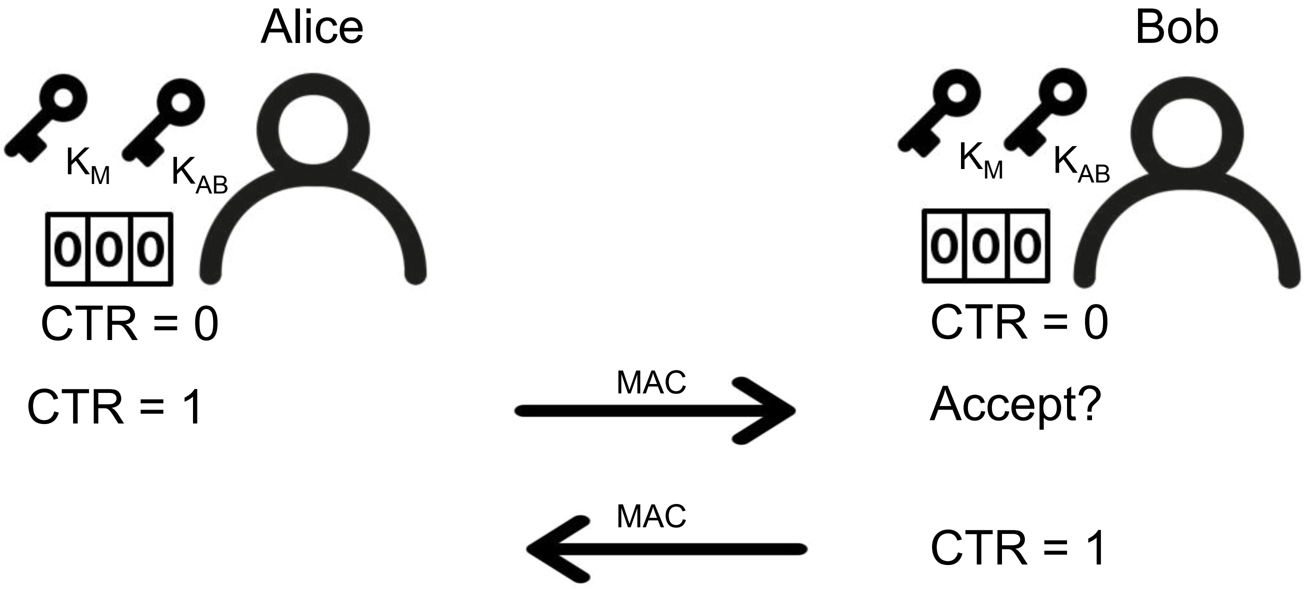

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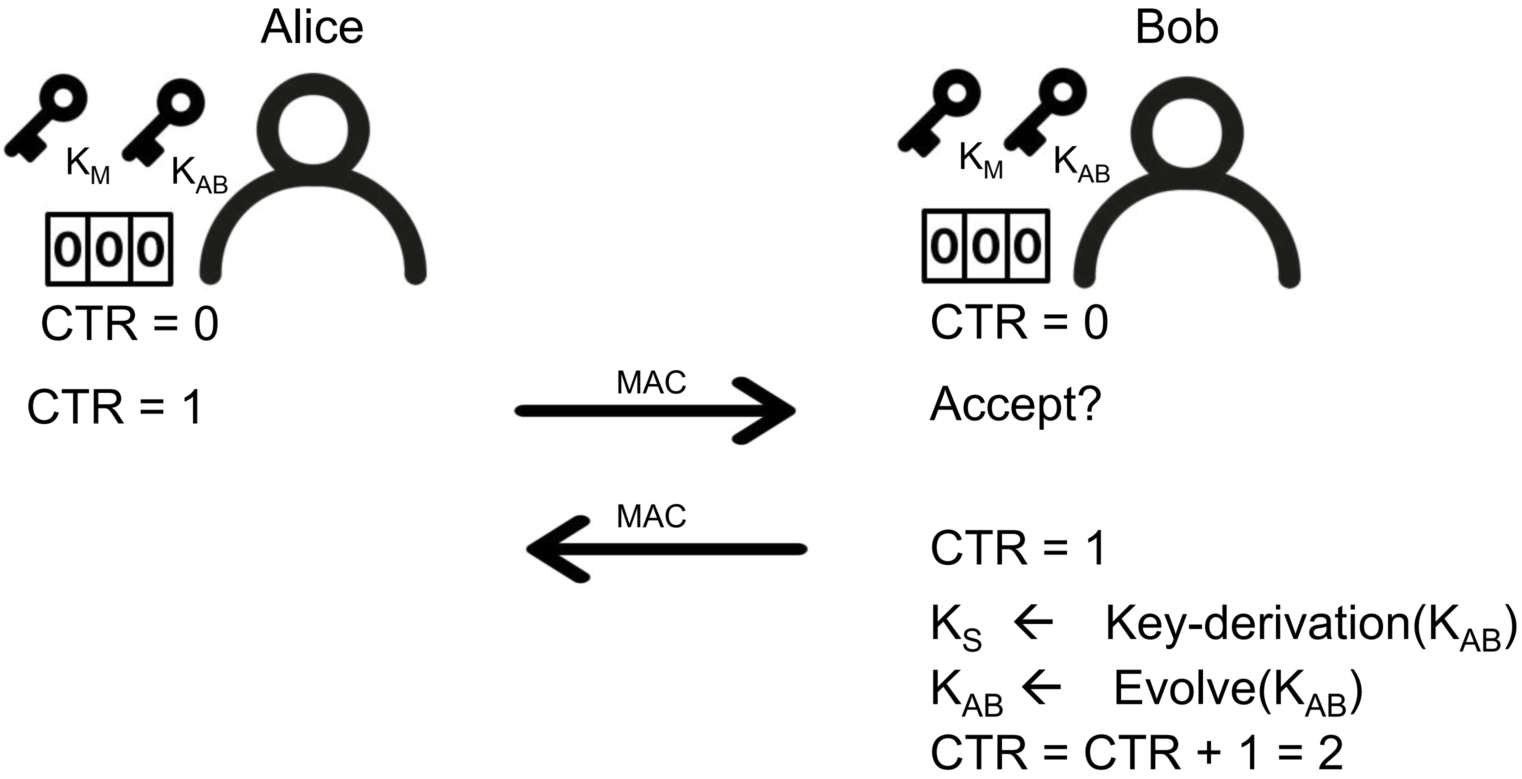

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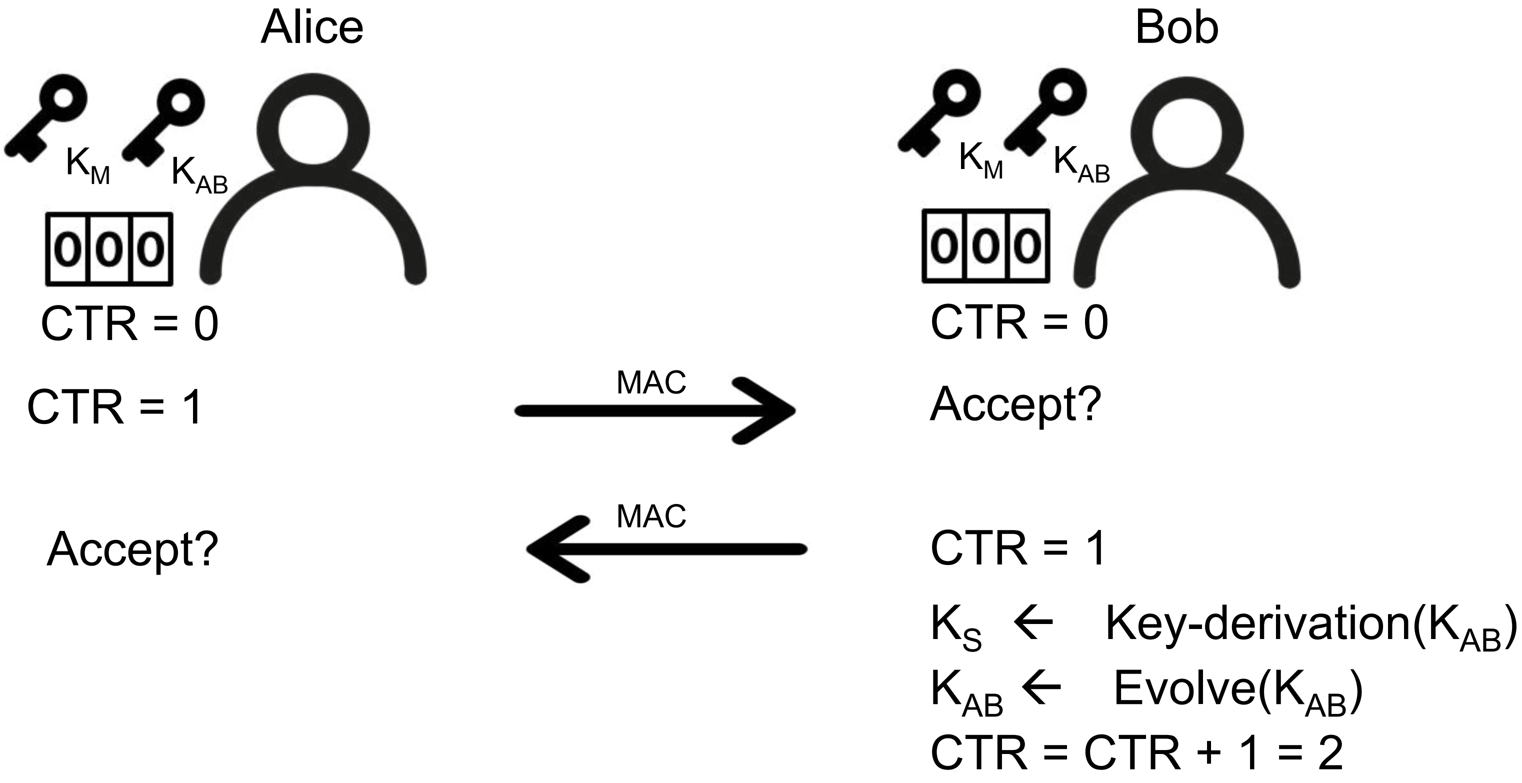

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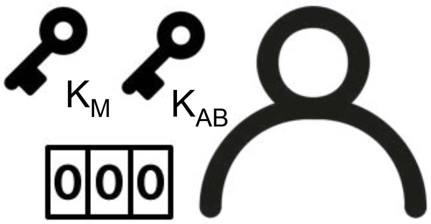
Alice



CTR = 0

CTR = 1

MAC →

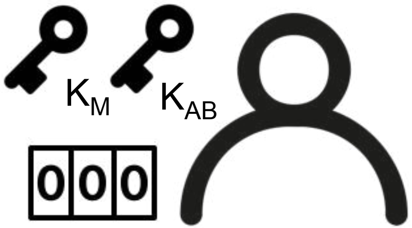
Accept?

$K_S \leftarrow$ Key-derivation(K_{AB})

$K_{AB} \leftarrow$ Evolve(K_{AB})

CTR = CTR + 1 = 2

Bob



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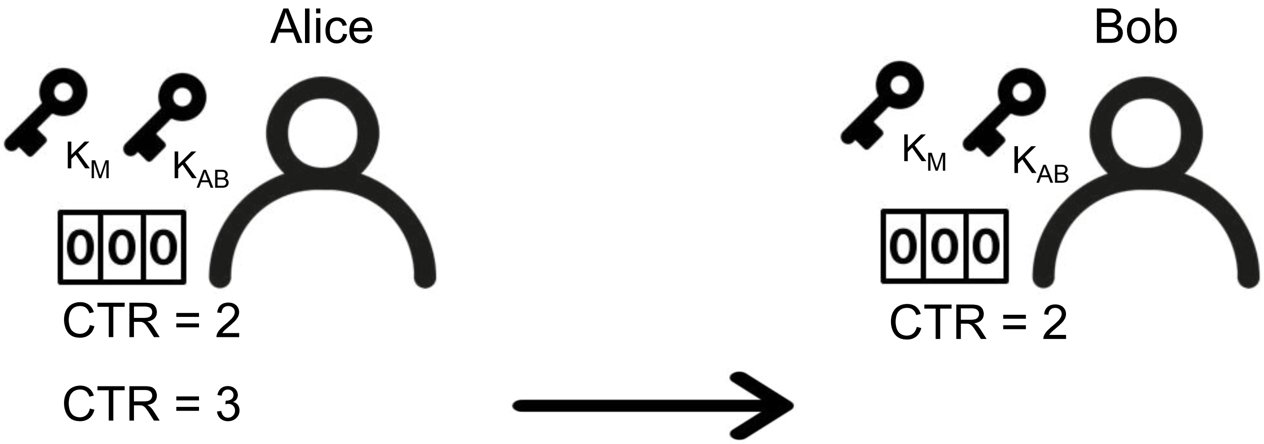

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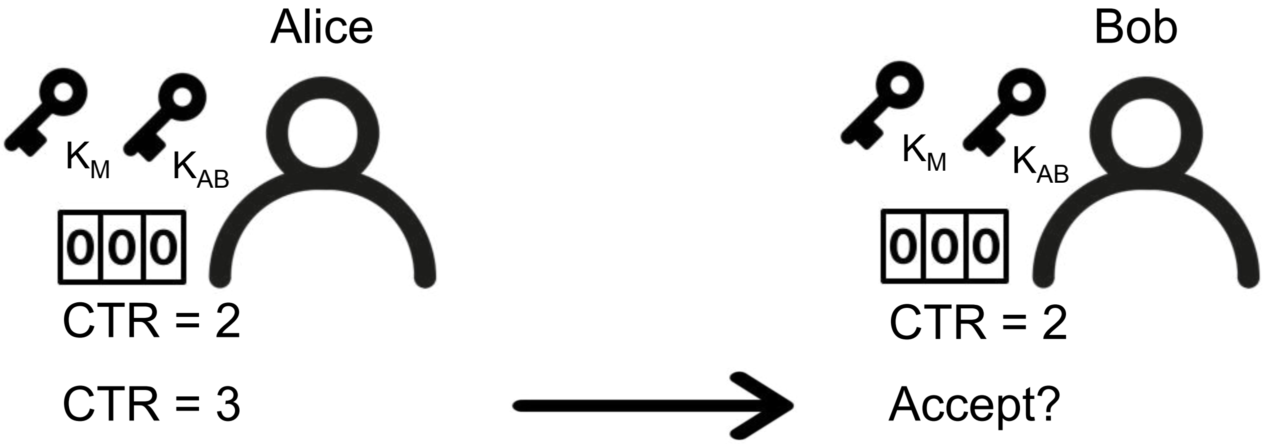

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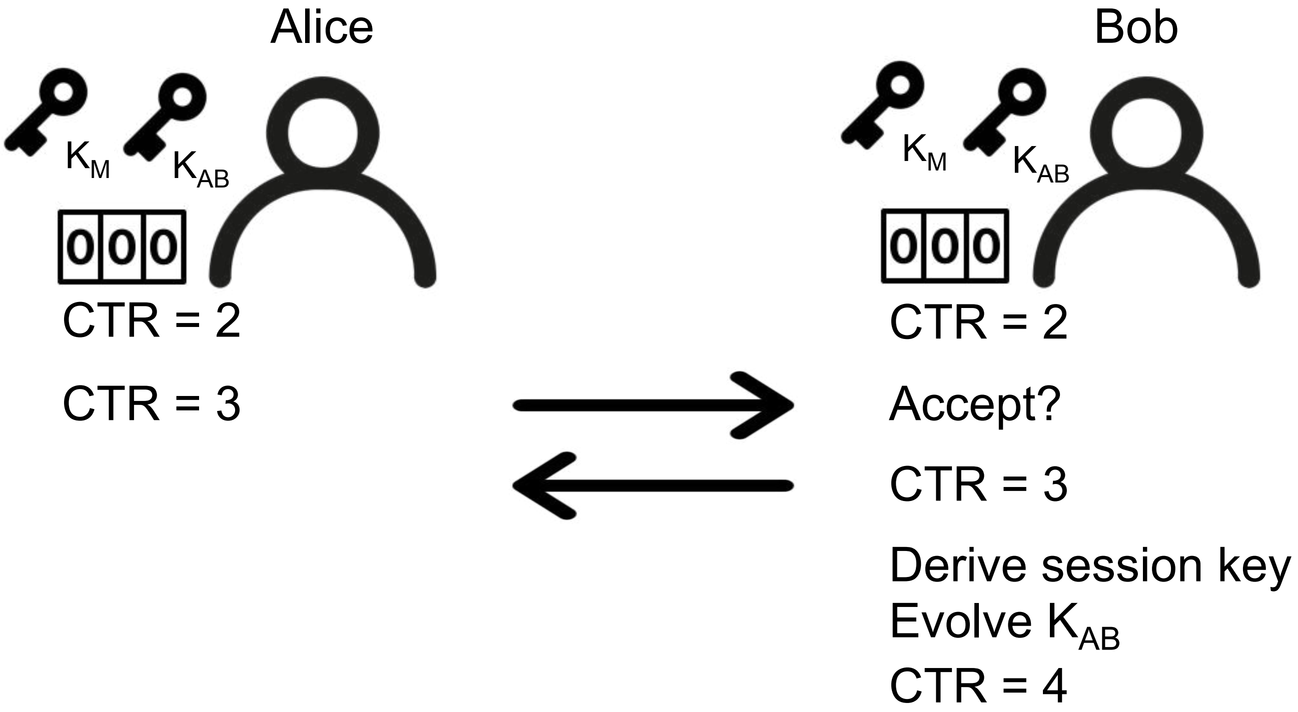

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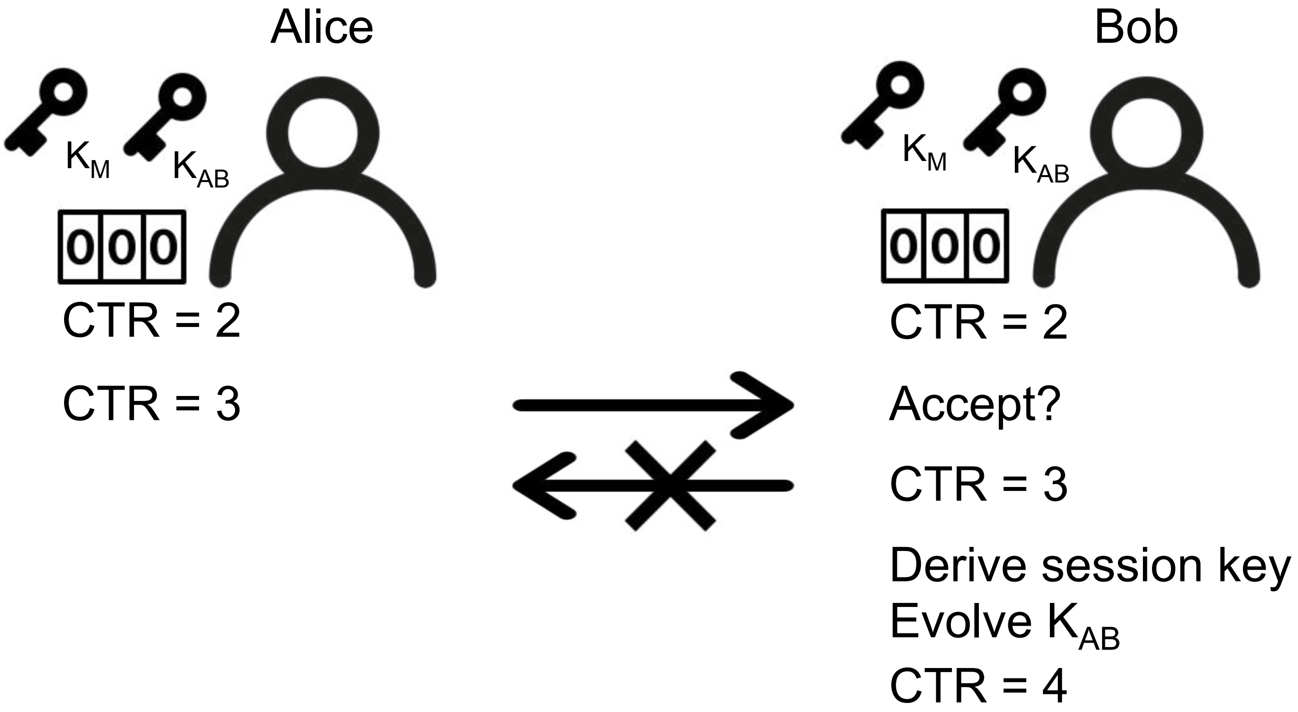

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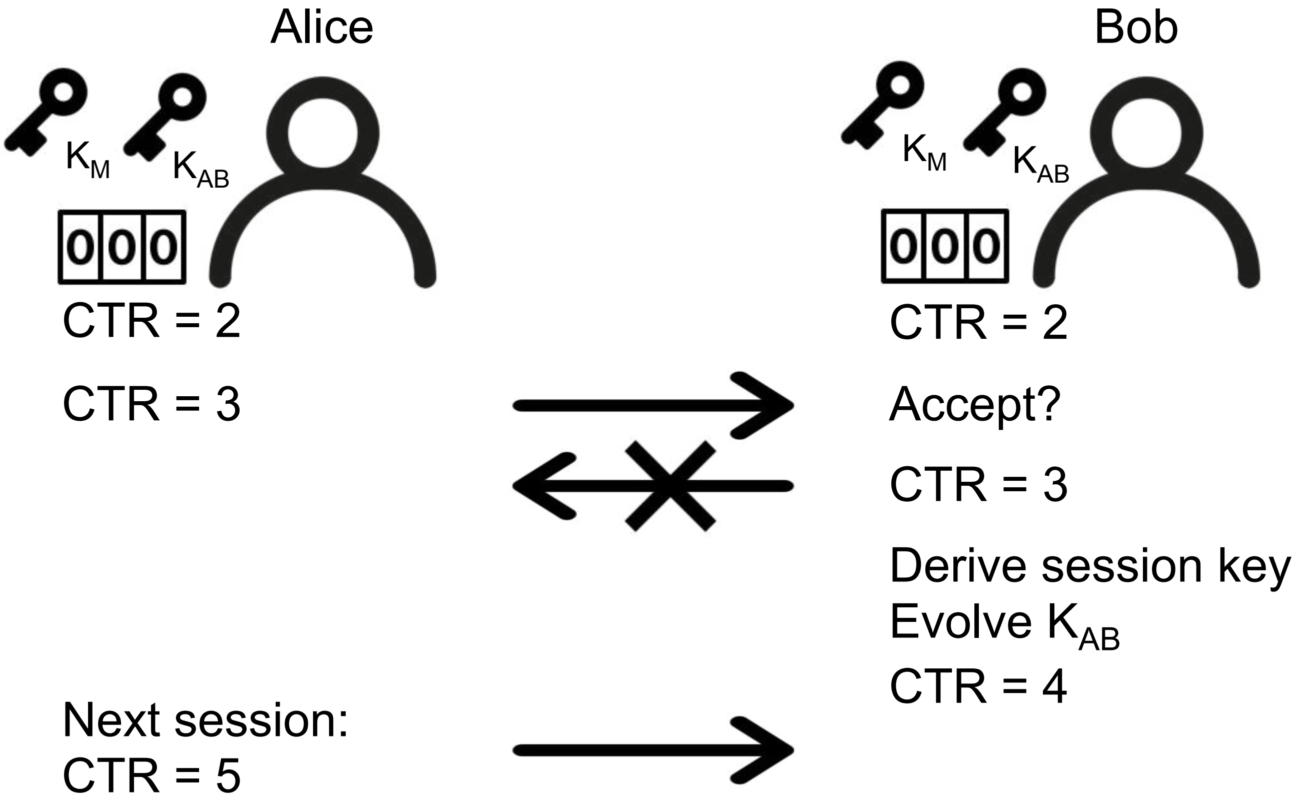

Linear-evolving protocols

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LP2	Mutual	2	✓	✗	✗	✓
LP3	Mutual	3	✓	✗	✗	✓

Security model

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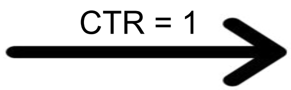
- Model lacks notion of concurrent correctness and synchronization
- Formalization of synchronization robustness – the ability to compute keys in future sessions if something goes wrong

Concurrent Correctness

Concurrent Correctness

Initiate session 1: CTR = 1



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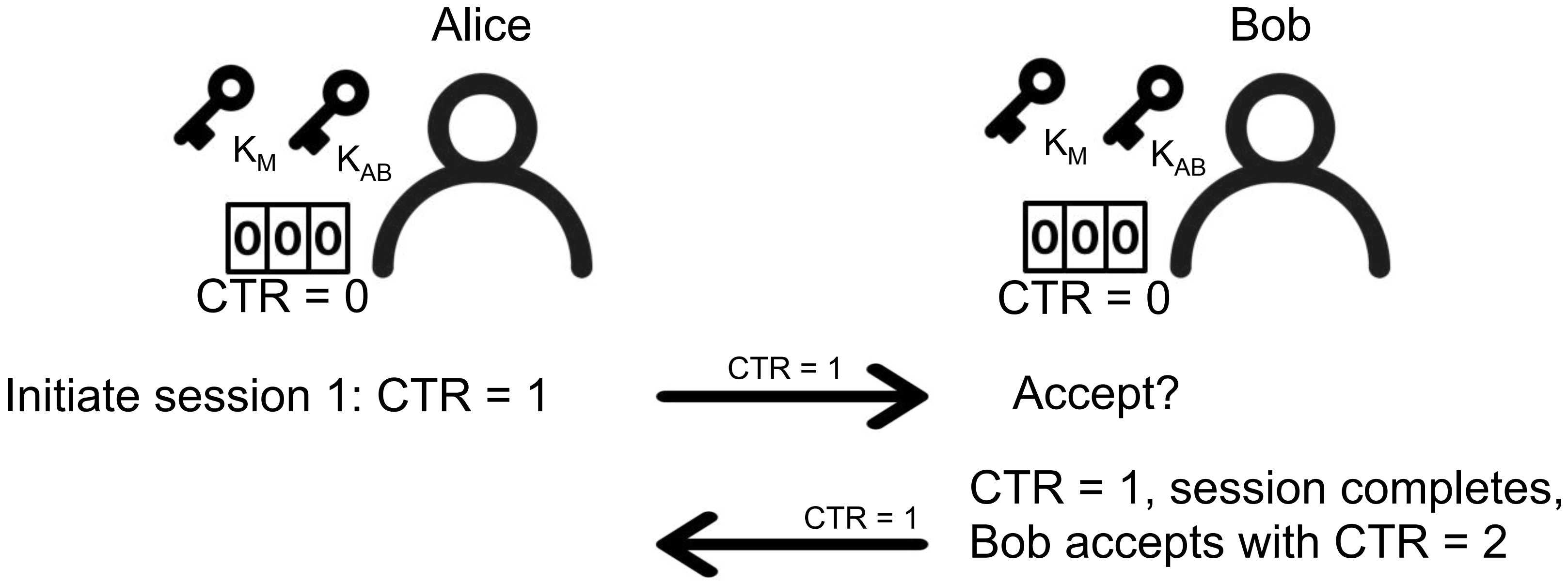

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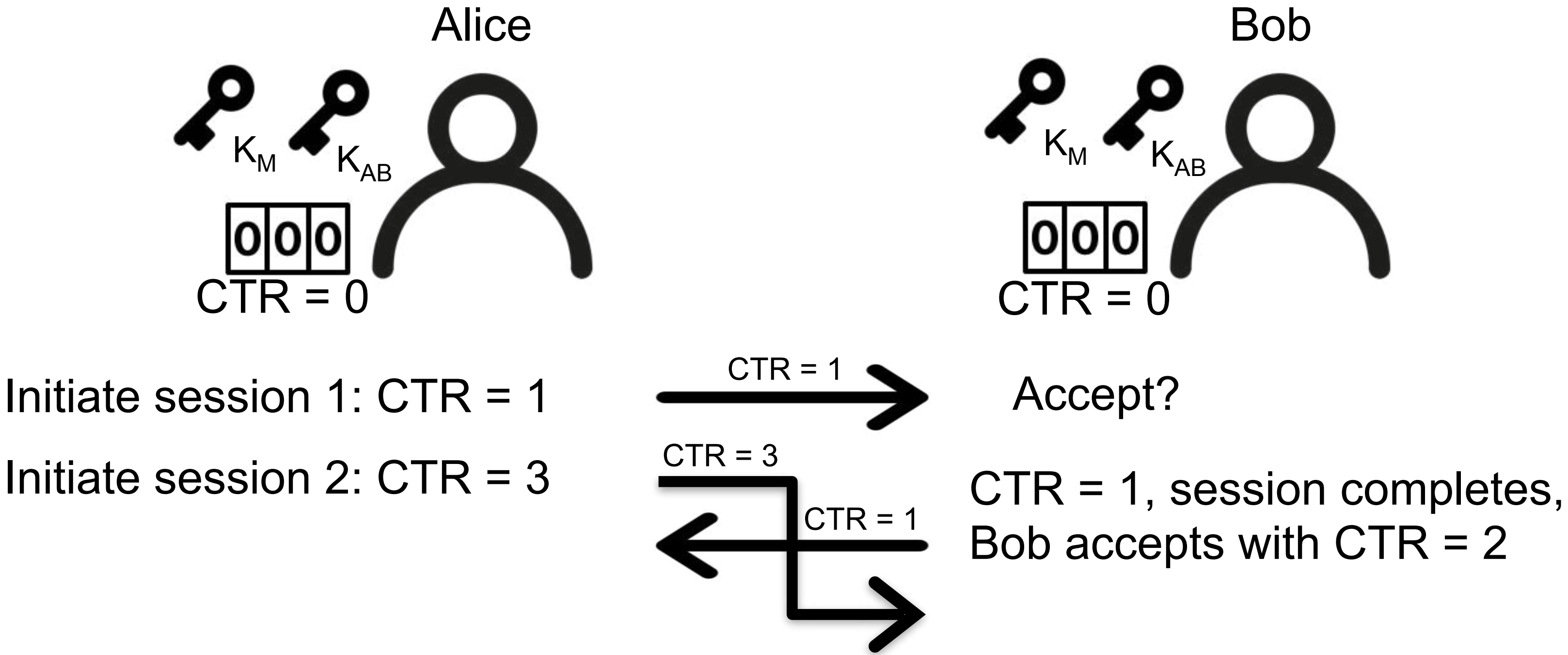
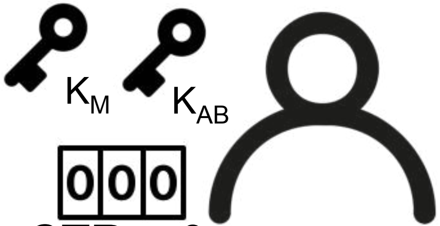


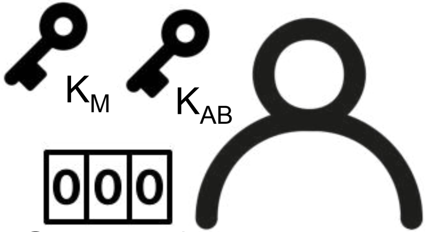
Concurrent Correctness

Alice



CTR = 0

Bob



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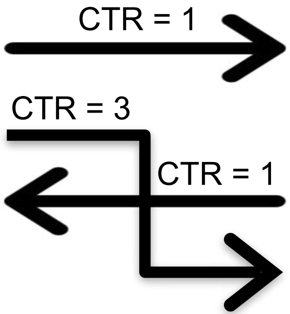

Accept?

Initiate session 2: CTR = 3

CTR = 1, session completes,
Bob accepts with CTR = 2

Accept?
Alice is at CTR = 3,
Aborts session 1

Concurrent Correctness

Initiate session 1: CTR = 1

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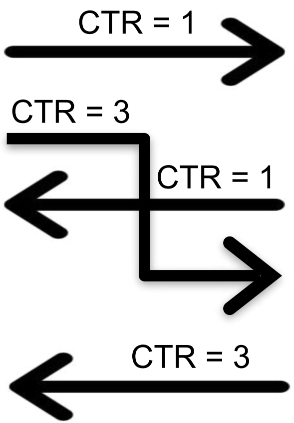

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CTR = 1, session completes,
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Accept?
CTR = 3, session completes,
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Concurrent Correctness

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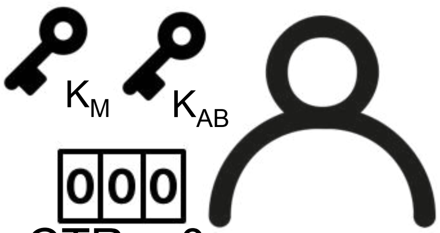

CTR = 0

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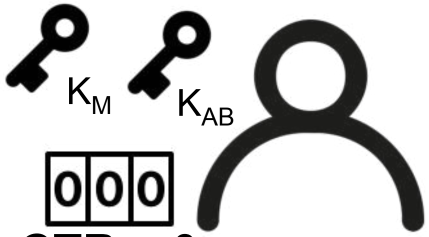

CTR = 0

Initiate session 1: CTR = 1

Initiate session 2: CTR = 3

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Alice is at CTR = 3,
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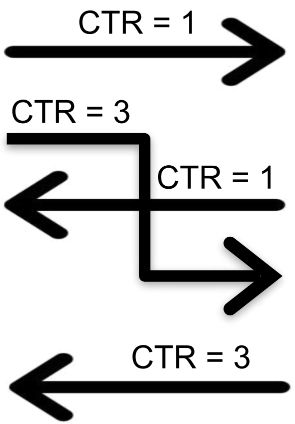

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Synchronization Robustness

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- If the parties get out of sync, we need to be able to resynchronize.
- This definition formalizes this requirement and comes in a weak and a strong flavour.

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- LP2: Allowing role reversal will make the protocol fail to meet this requirement

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- Linearly evolving protocols fail this requirement

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  - Puncturing is commutative – the order in which you puncture values does not matter
- Session key is determined by evaluating on the session nonce
- All concurrent sessions can succeed: puncturing only affects key material of that particular session

The non-linearly evolving protocols

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PP1	R only	1	✓	✓	✓	✓
PP2	Mutual	2	✓	✓	✓	✓

All our protocols

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LP2	Mutual	2	✓	✗	✗	✓
LP3	Mutual	3	✓	✗	✗	✓
PP1	R only	1	✓	✓	✓	✓
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With regard to our work…

- Implementation efforts are underway

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With regard to our work…

- Implementation efforts are underway
- No real world test data yet, but theoretical analysis promising

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- We need to rethink our *systems*, not just our protocols

With regard to our work…

- Implementation efforts are underway
- No real world test data yet, but theoretical analysis promising
- Let me know if you want to get involved!

More info?

Symmetric Key Exchange with Full Forward Security and Robust Synchronization

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