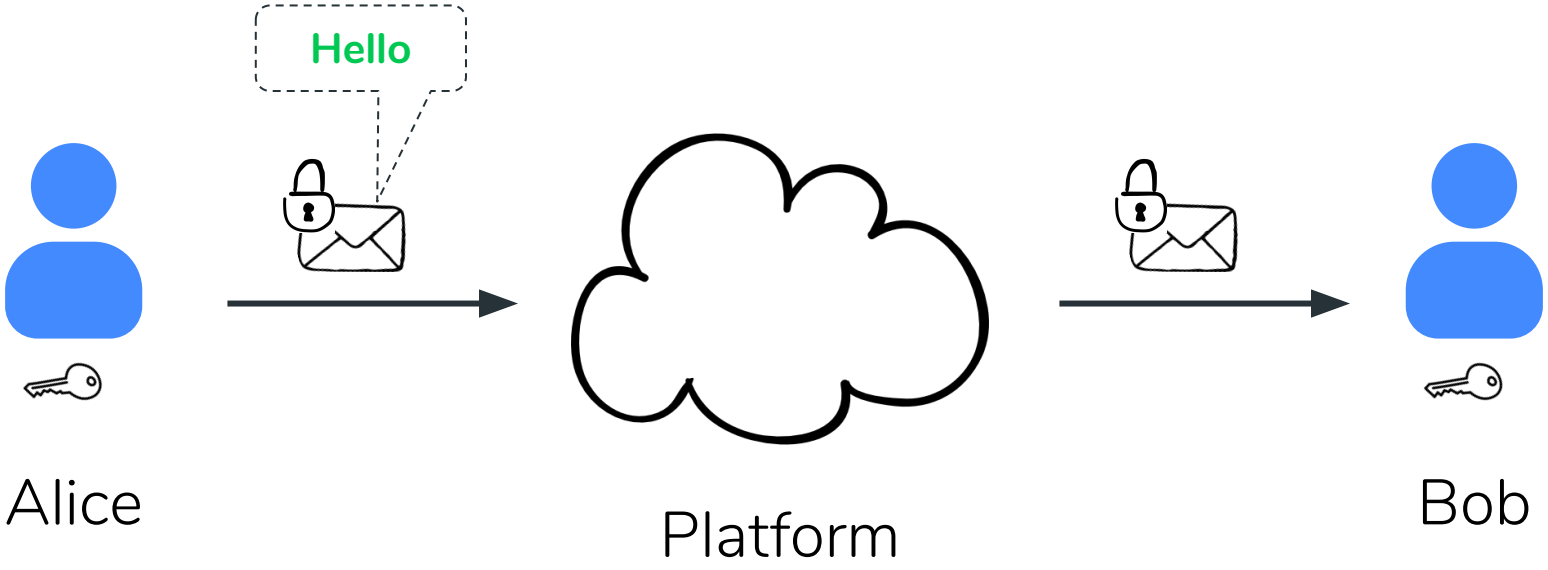
Traceback for End-to-End Encrypted Messaging

Nirvan Tyagi Ian Miers Tom Ristenpart

CCS 2019

Setting: End-to-end encrypted (E2EE) messaging



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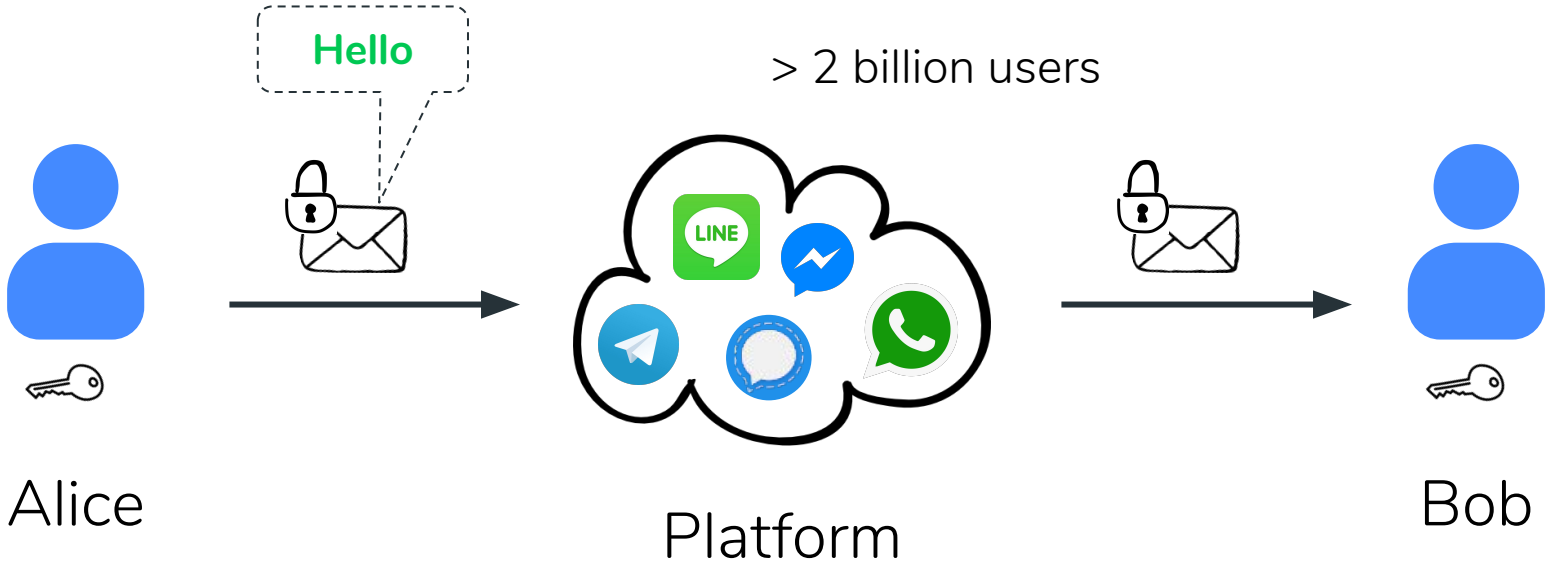
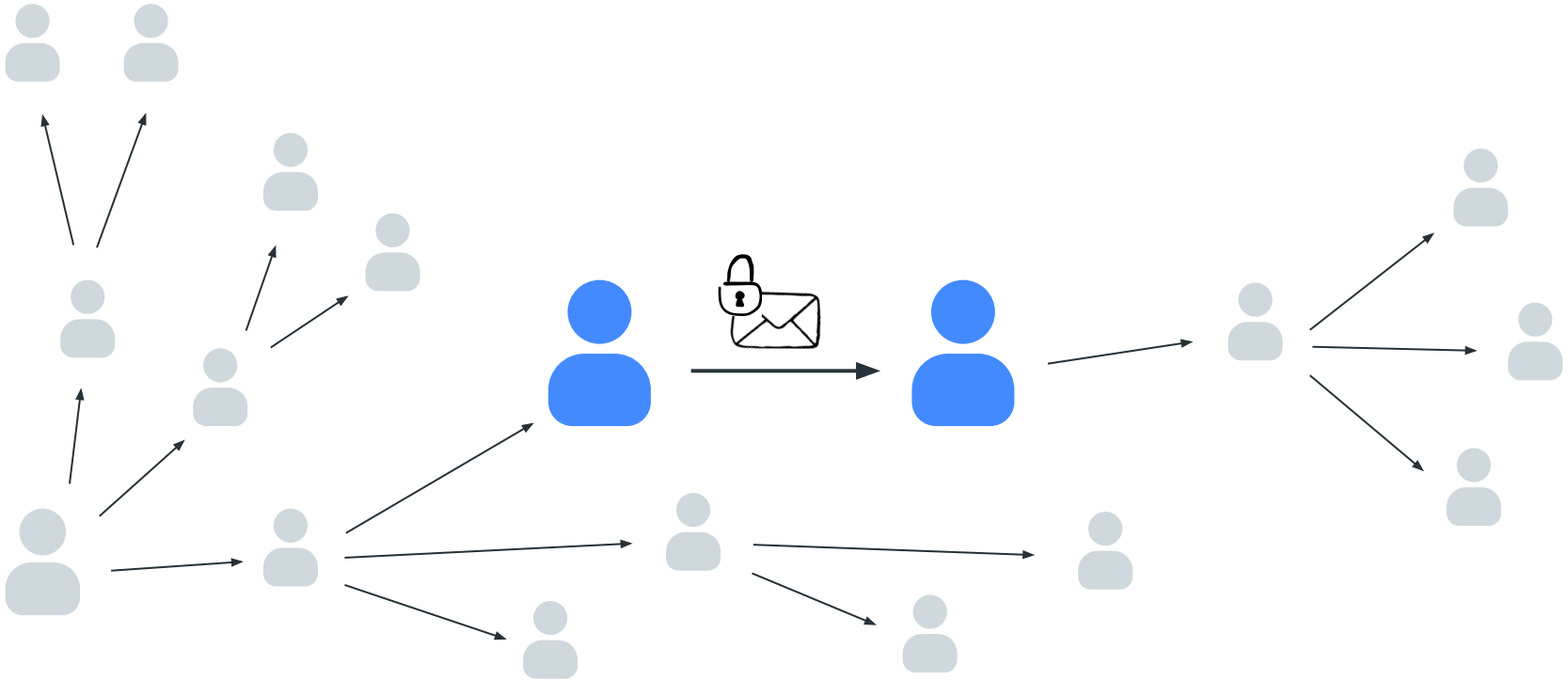
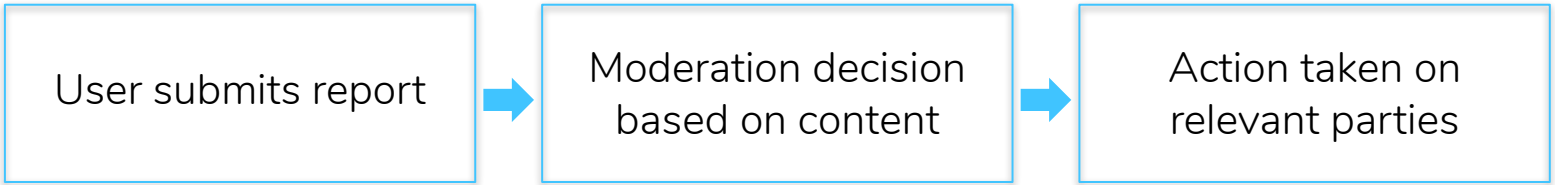


Problem: Viral forwarding of misinformation in E2EE messaging



Problem: Viral forwarding of misinformation in E2EE messaging

Content moderation for user-driven reports



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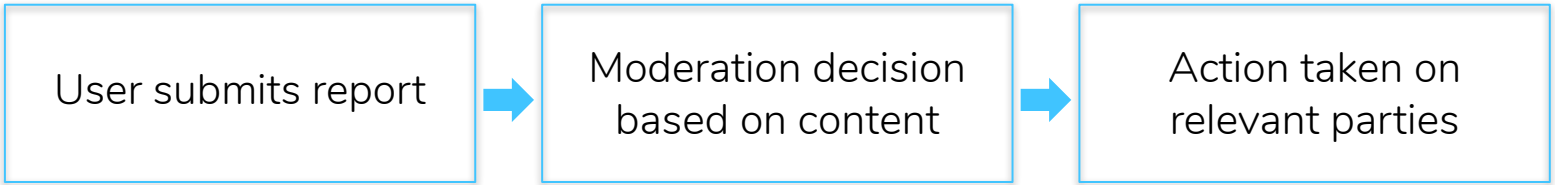

Combination of machine learning and human review

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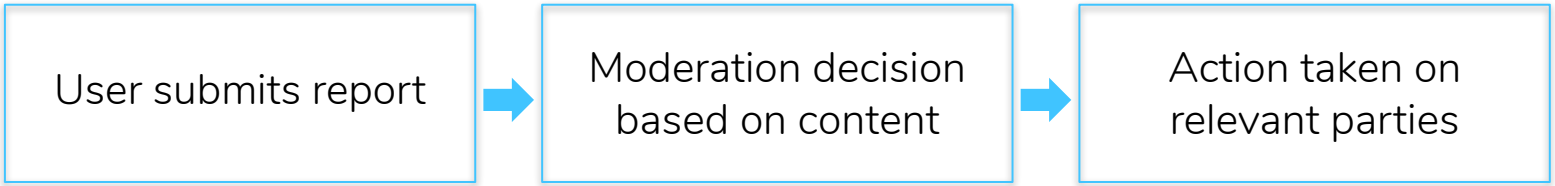
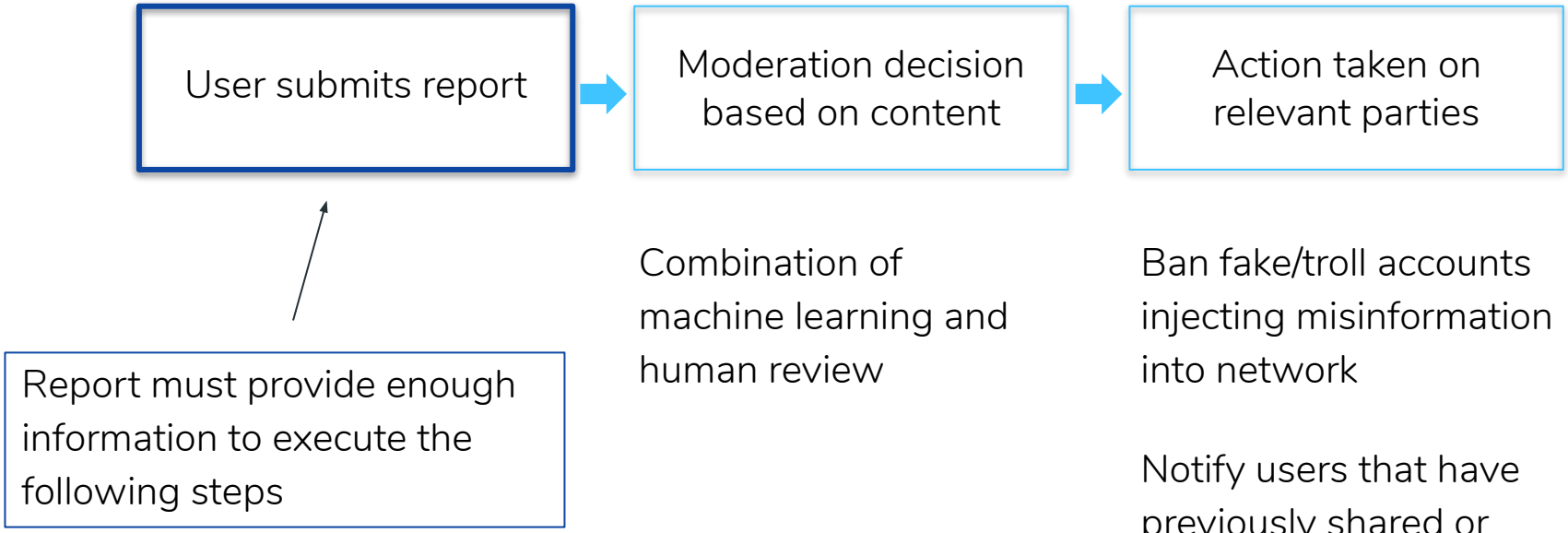


Combination of machine learning and human review

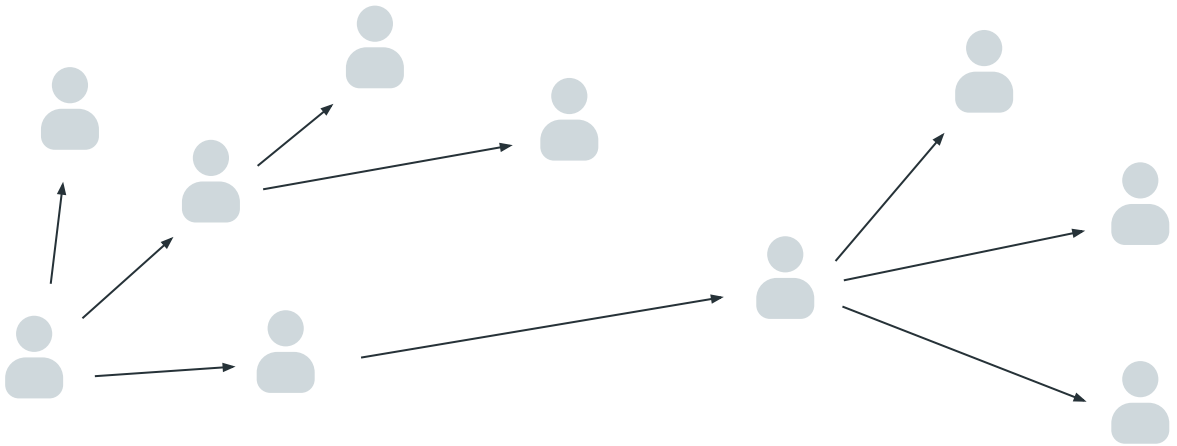
Ban fake/troll accounts injecting misinformation into network

Notify users that have previously shared or received misinformation

Content moderation for user-driven reports

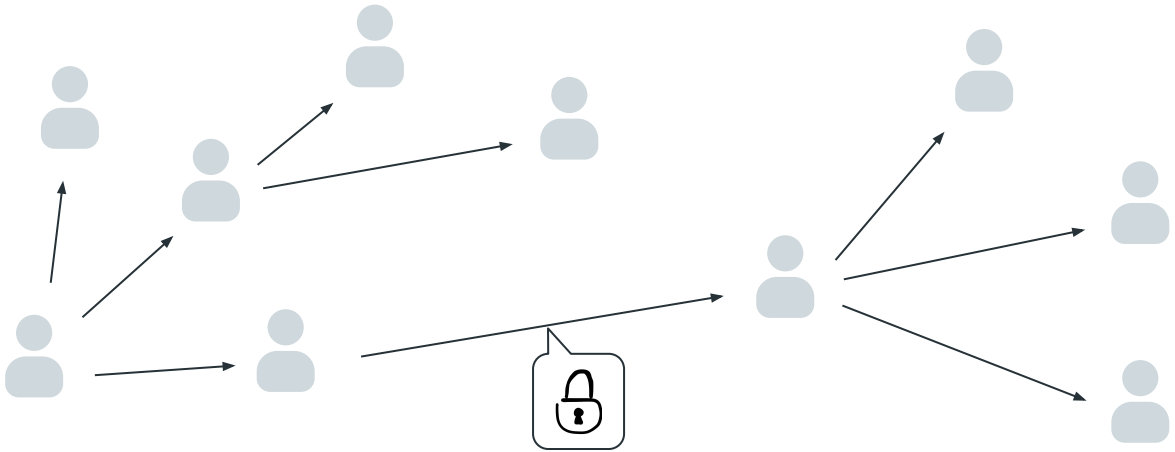


E2EE hides information useful for content moderation of misinformation



E2EE hides information useful for content moderation of misinformation

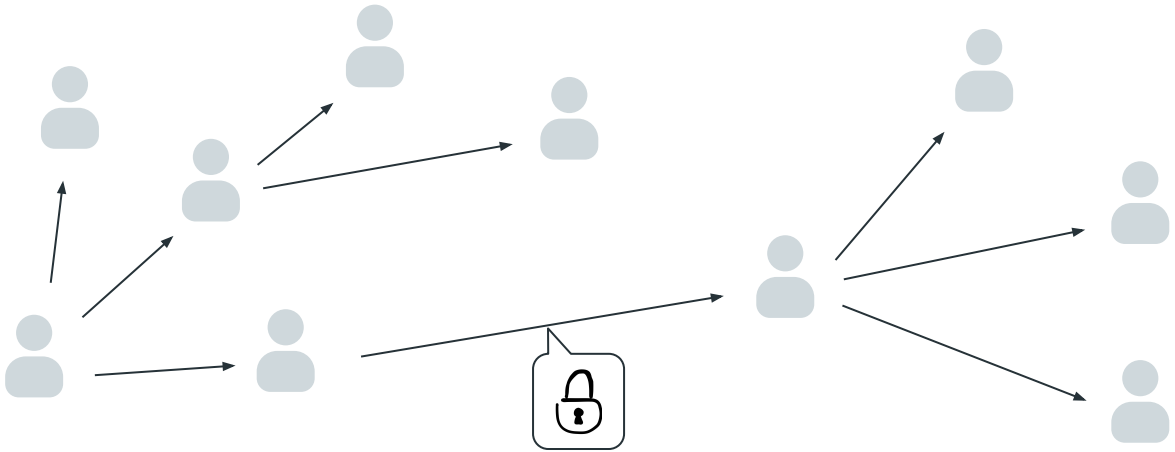
- Platform doesn’t see message content



Message content is encrypted!

E2EE hides information useful for content moderation of misinformation

- Platform doesn't see message content
- Platform doesn't see forwarding relationships



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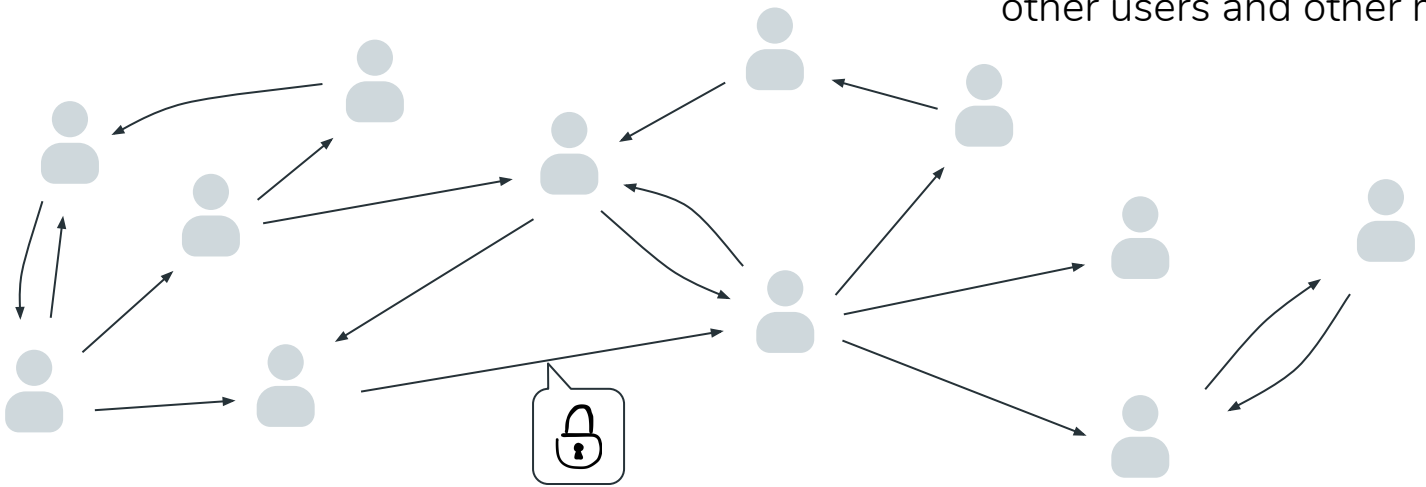
- Platform doesn't see message content
- Platform doesn't see forwarding relationships

Forwarding traffic is muddled by other users and other messages

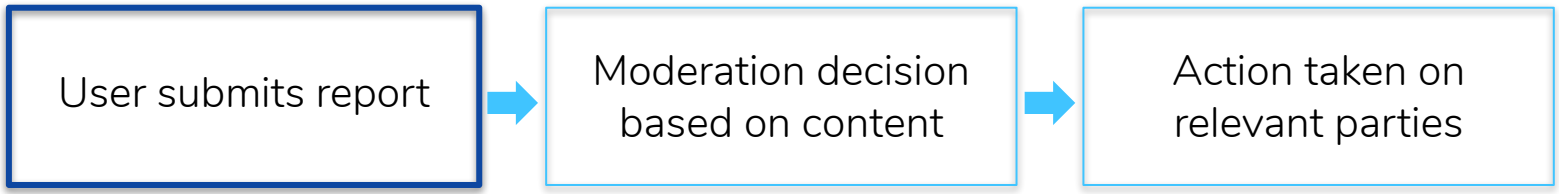


Message content is encrypted!

This work: **Tracing** in E2EE messaging

[TMR CCS'19]

- **Message tracing**: new cryptographic functionality for user-driven reporting of forwards in E2EE messaging
  - Path traceback: chain of messages from source to reporter
  - Tree traceback: entire forwarding tree of messages originating from source



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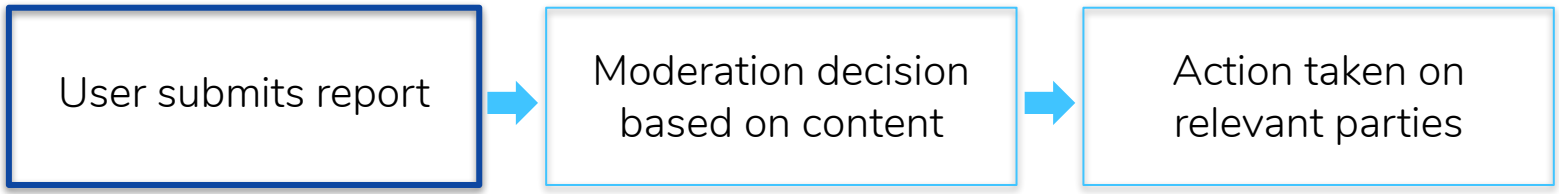
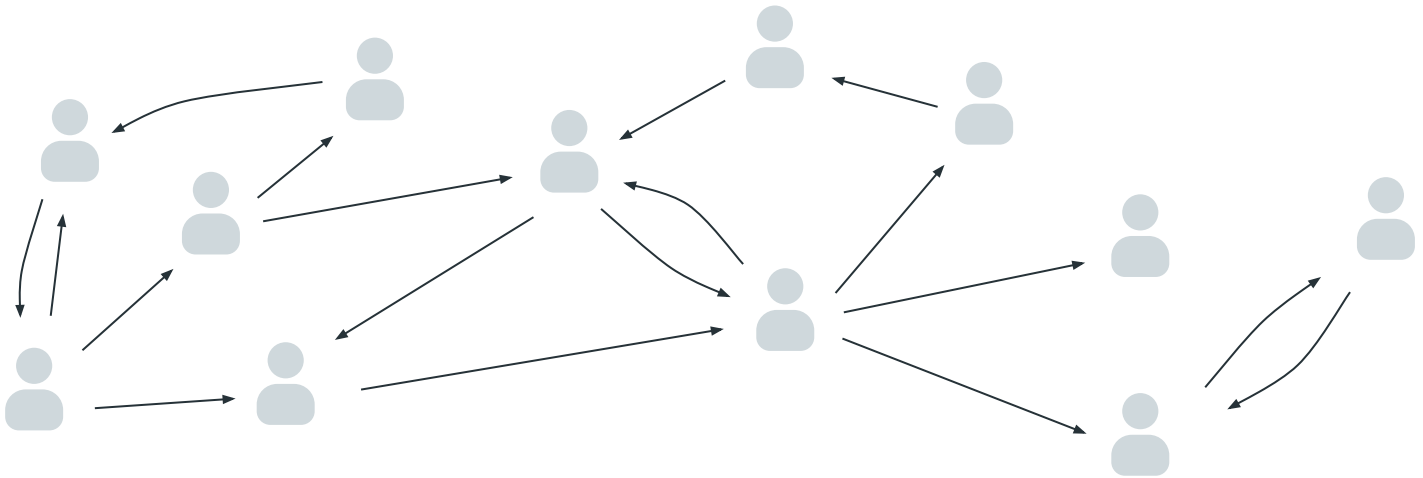
[TMR CCS'19]

- **Message tracing**: new cryptographic functionality for user-driven reporting of forwards in E2EE messaging
    - Path traceback: chain of messages from source to reporter
    - Tree traceback: entire forwarding tree of messages originating from source
- Formal confidentiality and accountability security notions for tracing
- Implementation and evaluation of practicality



Prior work: Abuse reporting in E2EE messaging

Message franking [FB white paper ’17], [GLR CRYPTO’17], [DGRW CRYPTO’18]



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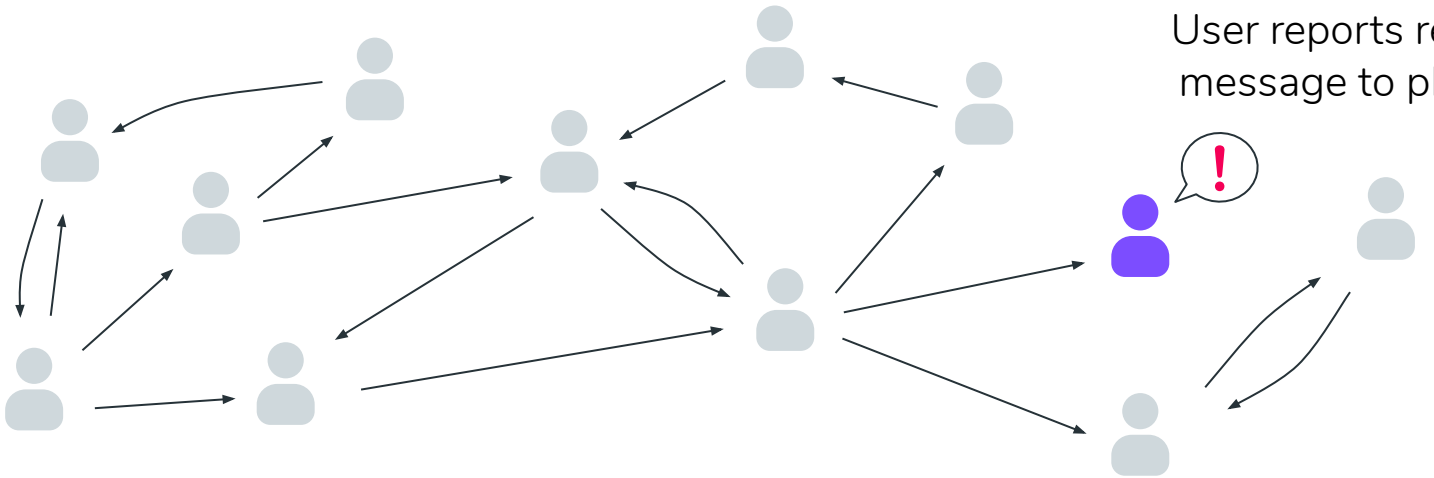

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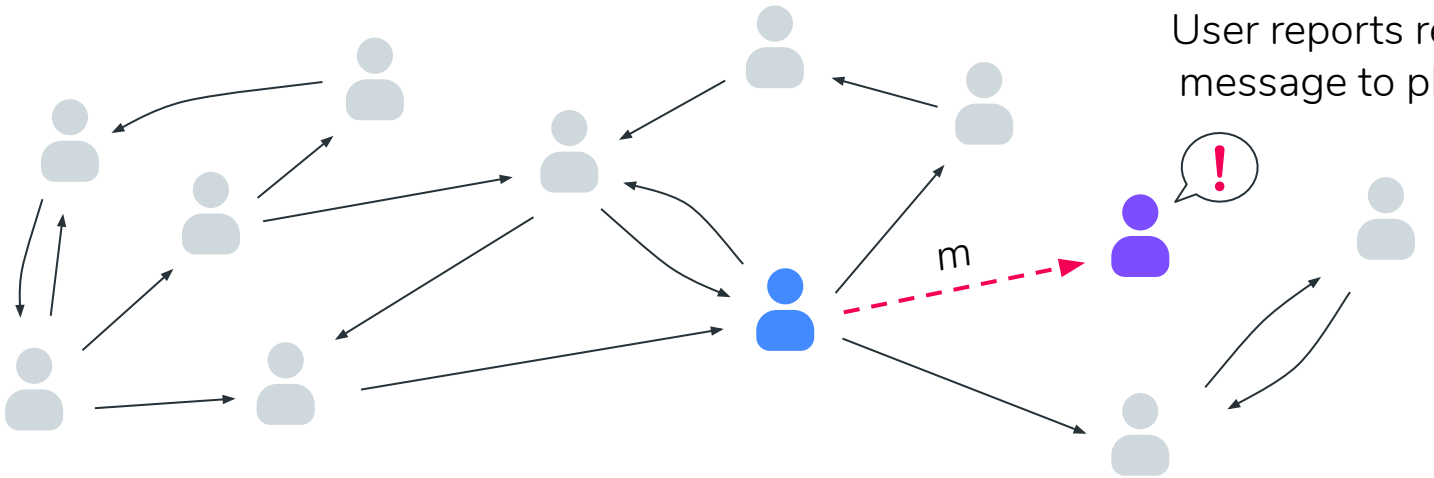

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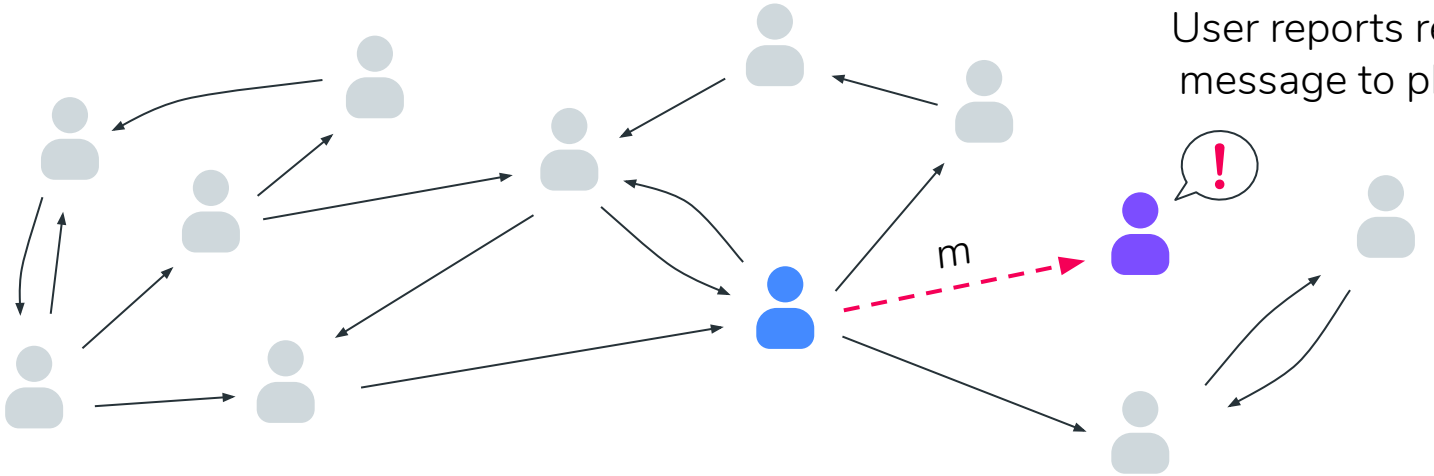
Platform learns message and sender, but nothing more about where message came from or where it reached



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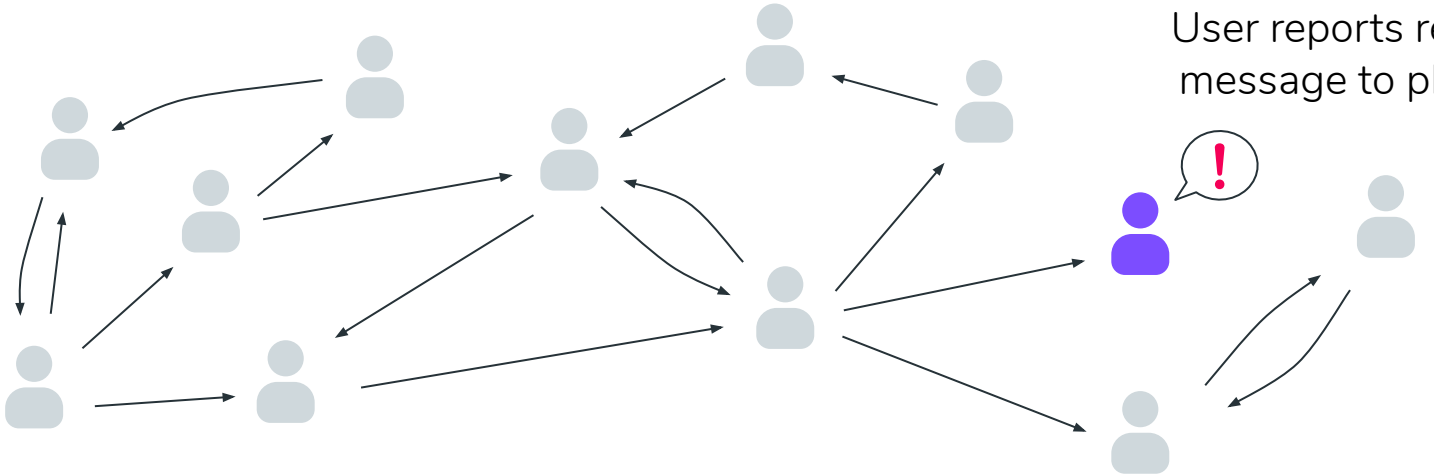

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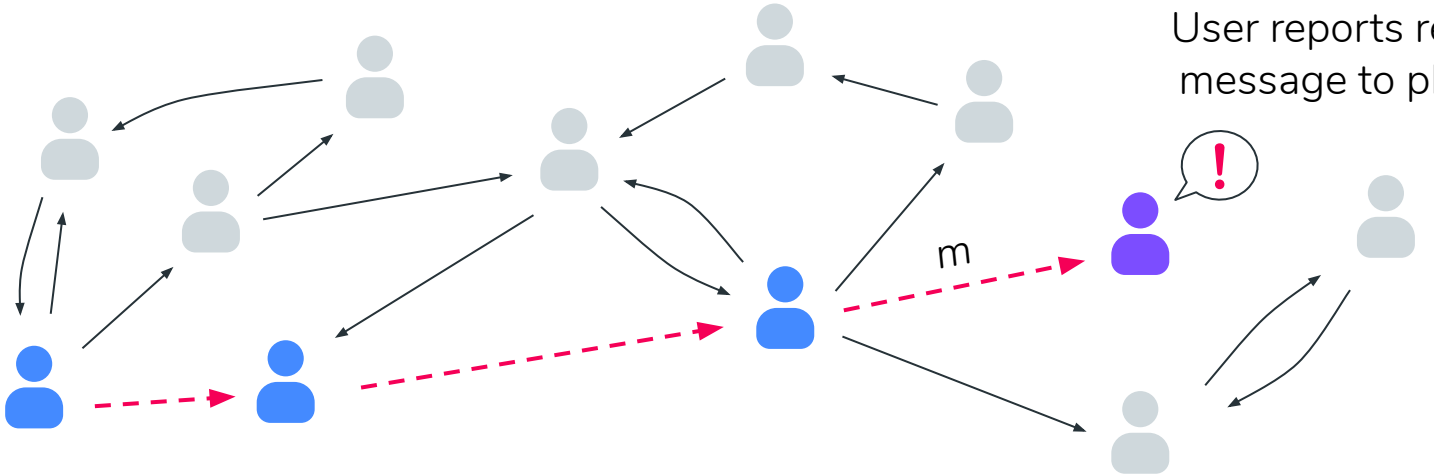
[TMR CCS'19]

- Two constructions for message tracing
  - Path traceback



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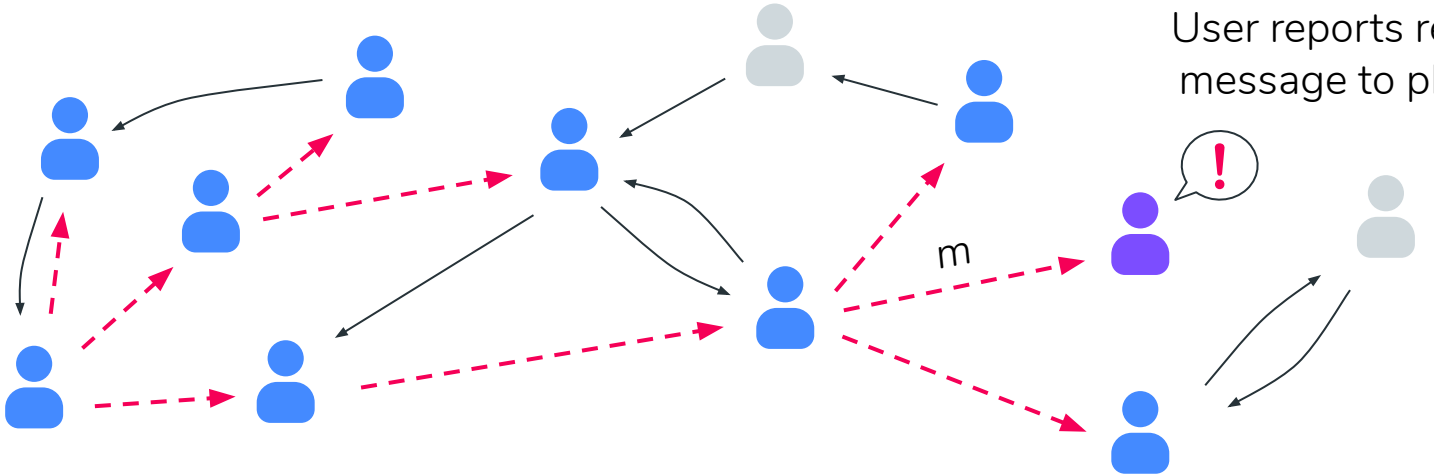
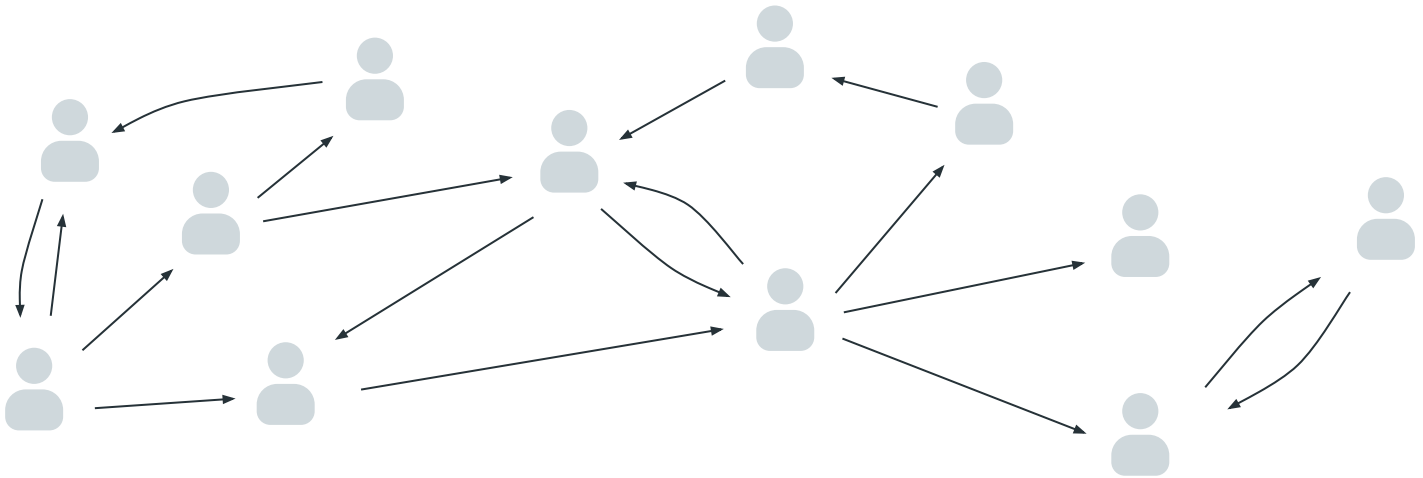


Goal: Act like standard E2EE messaging before report



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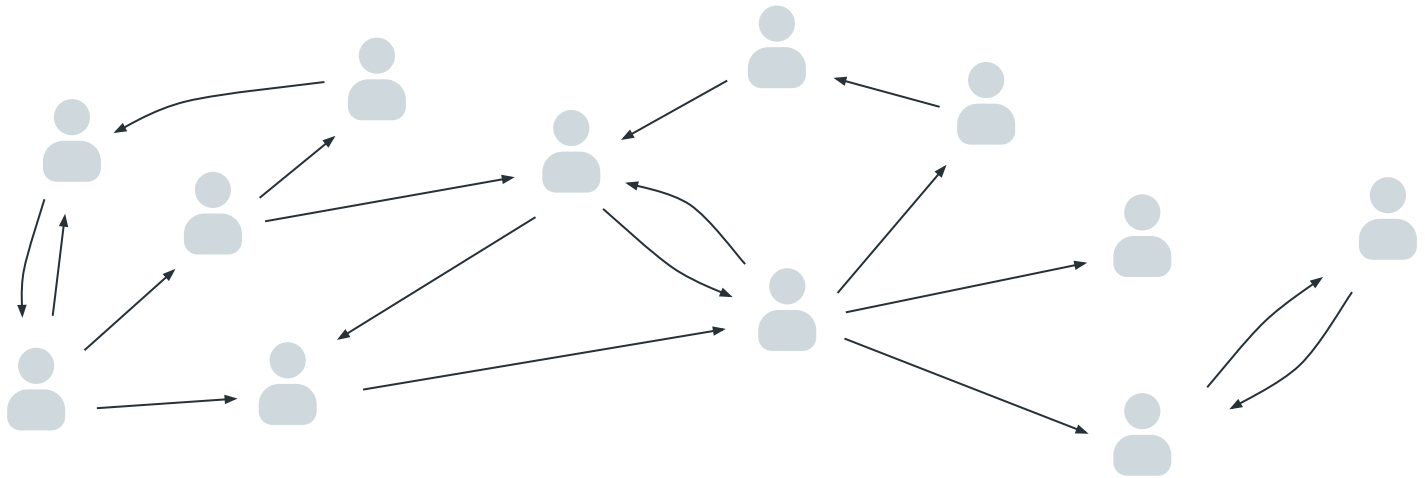
Before report

Platform view: encrypted content and metadata (participants, length, and timing)



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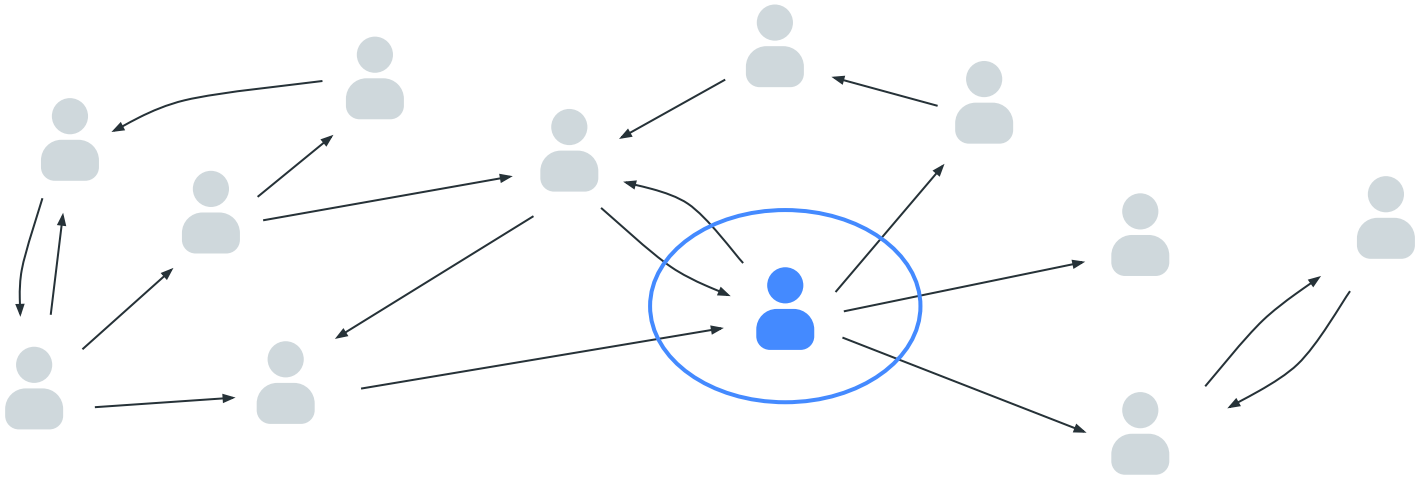

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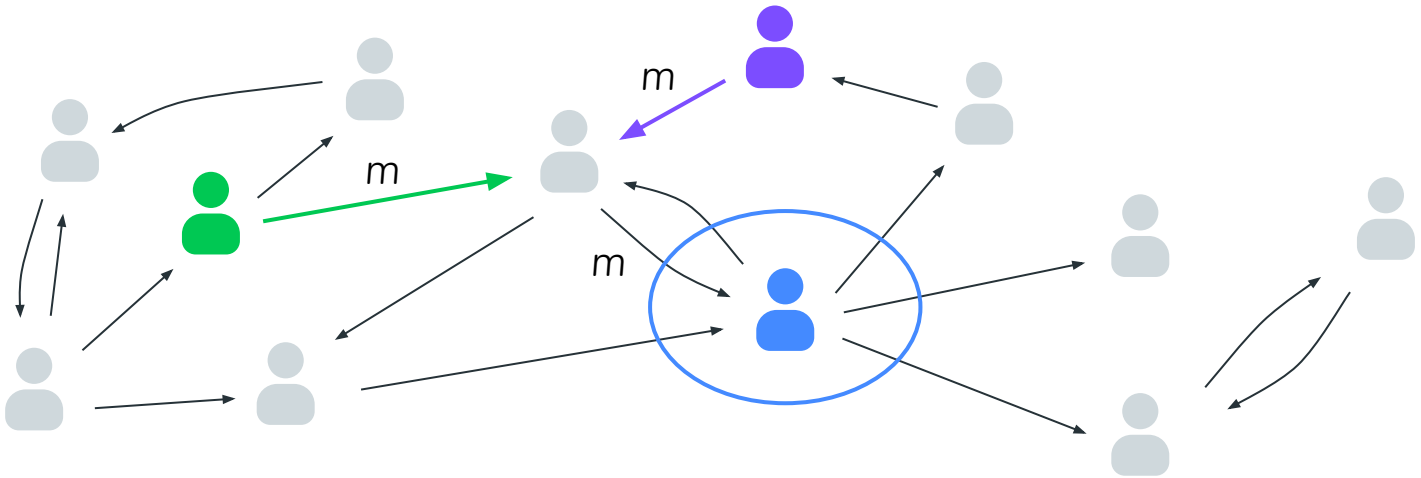

User shouldn't learn forwarding info of received messages

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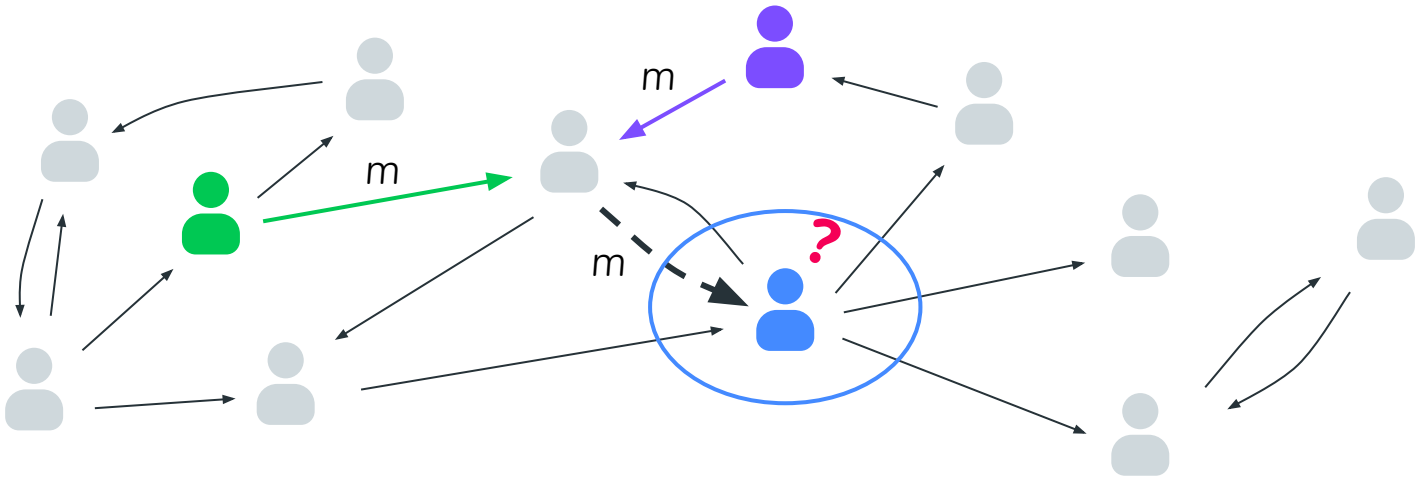

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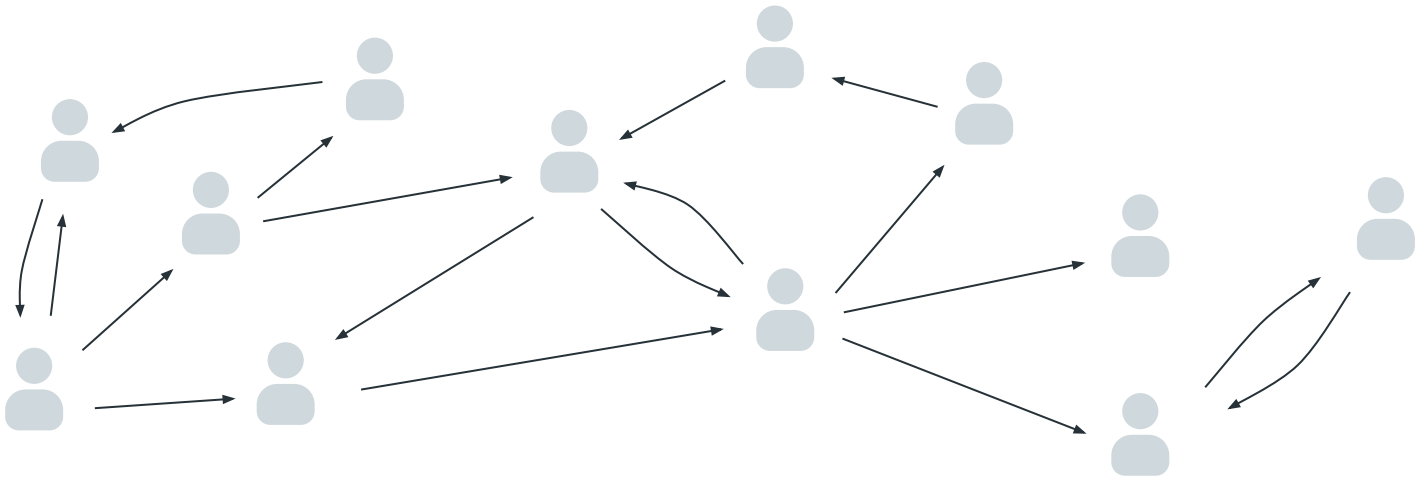
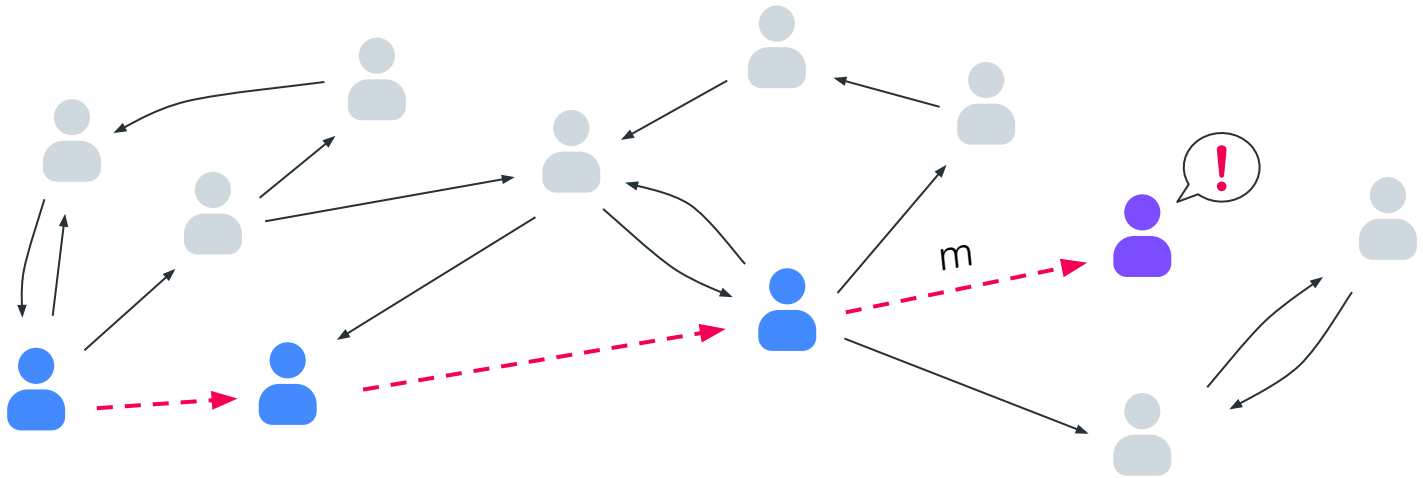


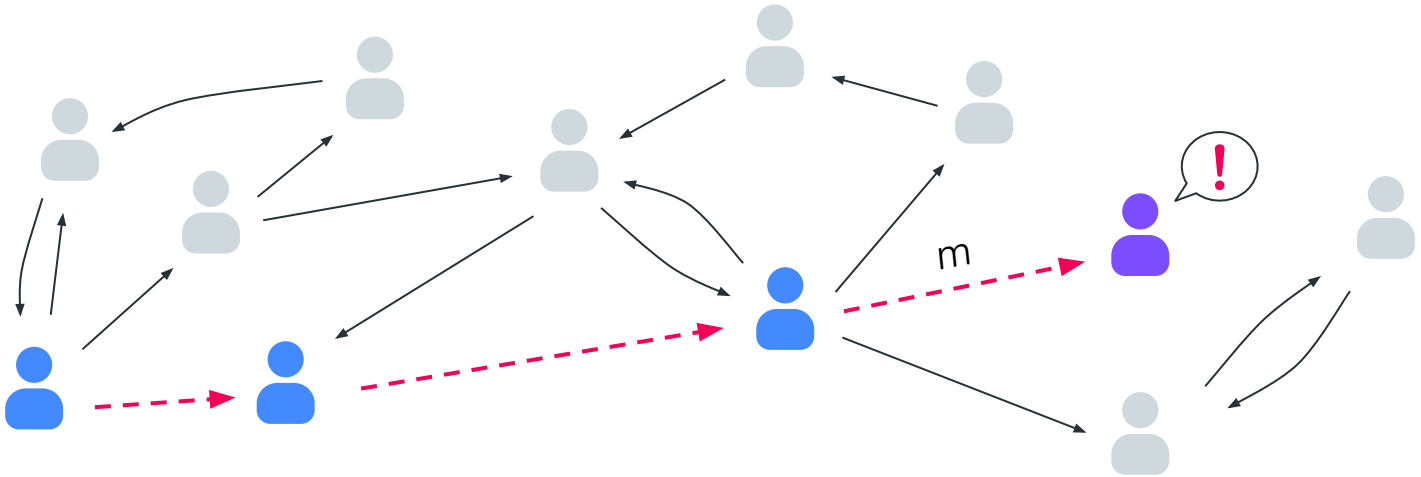
Goal: Reveal limited information after report

After report

Platform view: message content and forward links of traceback target (e.g. path, tree)



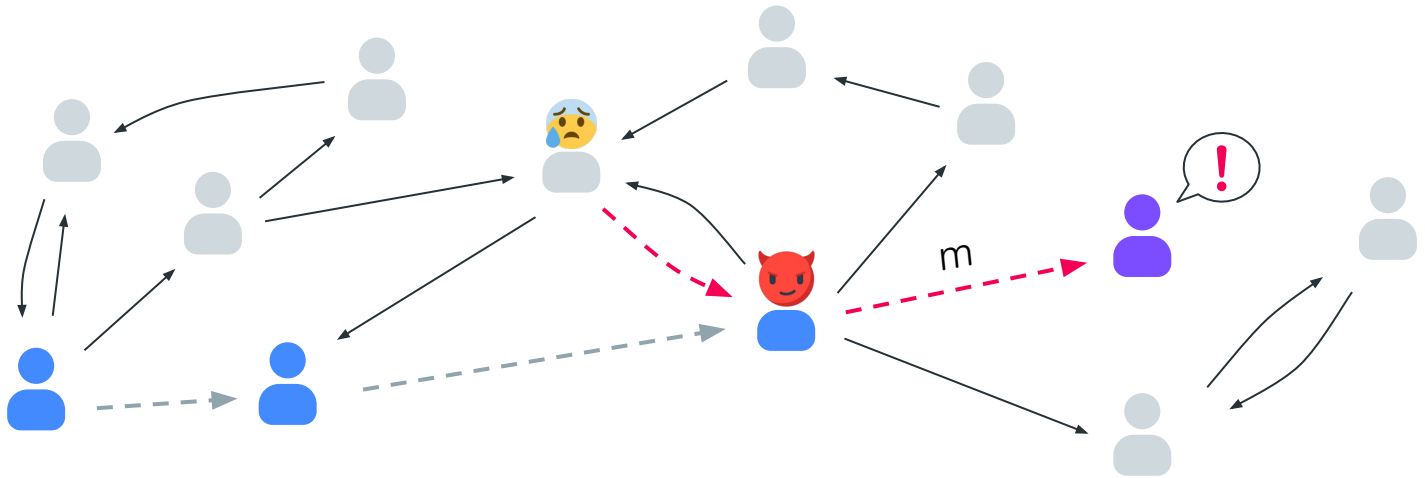
Goal: Report consists of accurate information



Goal: Report consists of accurate information

Trace accountability

An honest user cannot be framed for an action they didn't perform



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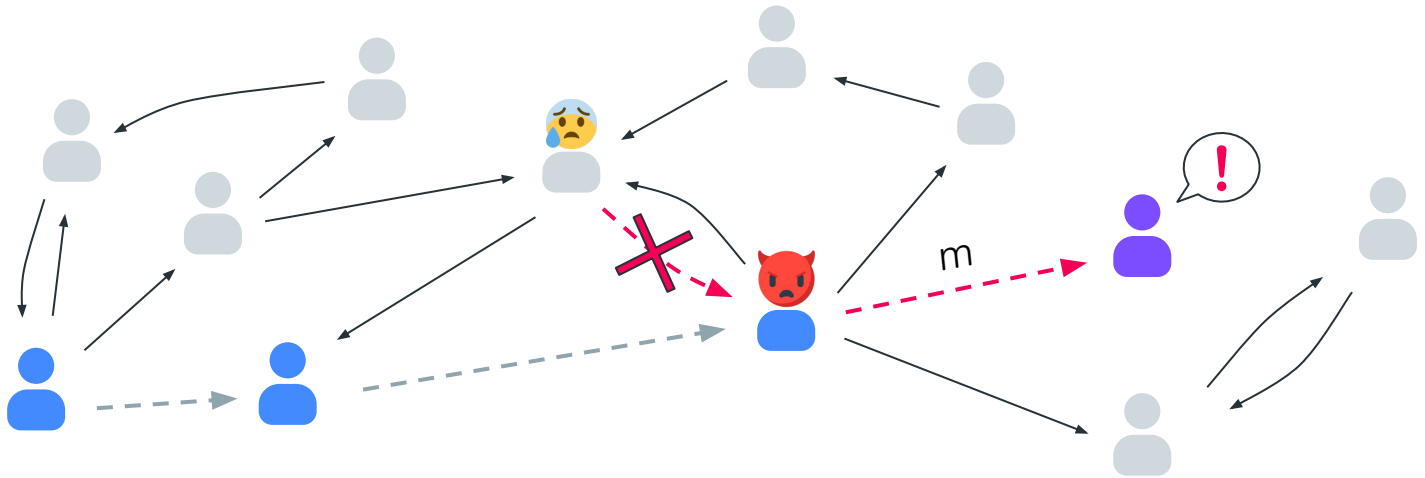

Malicious user can partition trace, but will be blamed as source

Path traceback

Idea: Linked list of encrypted pointers

Alice

Bob

Charlie

Path traceback

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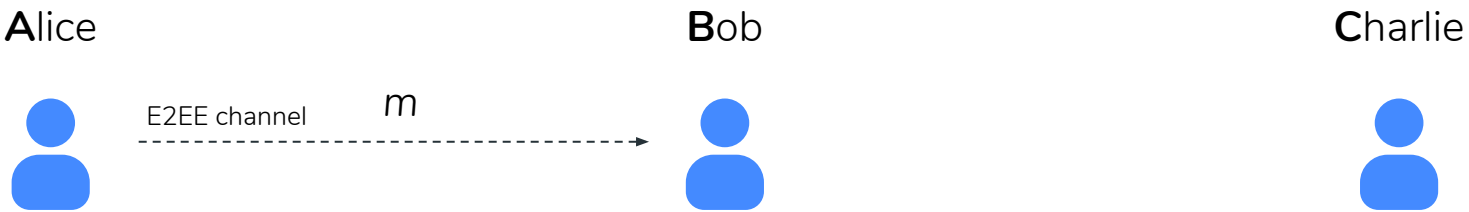

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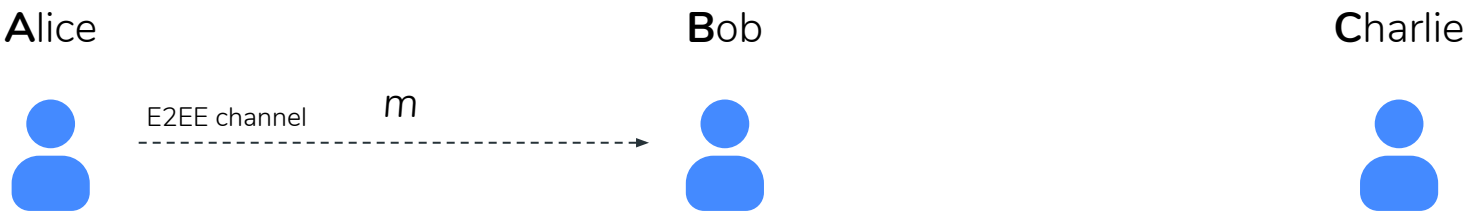

- E2EE channel that is decoupled from message tracing

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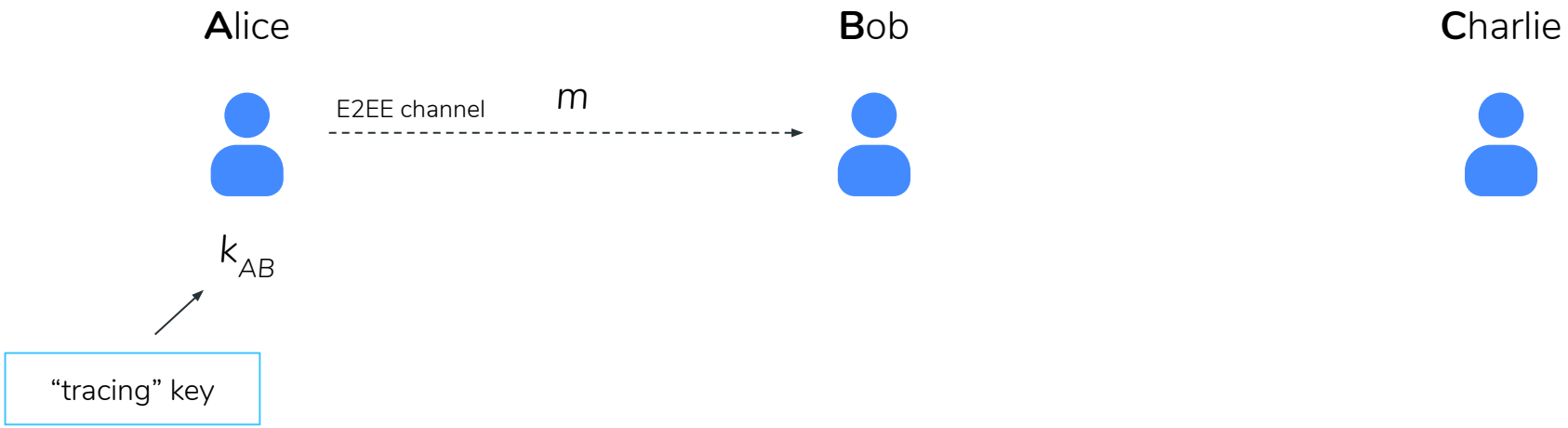

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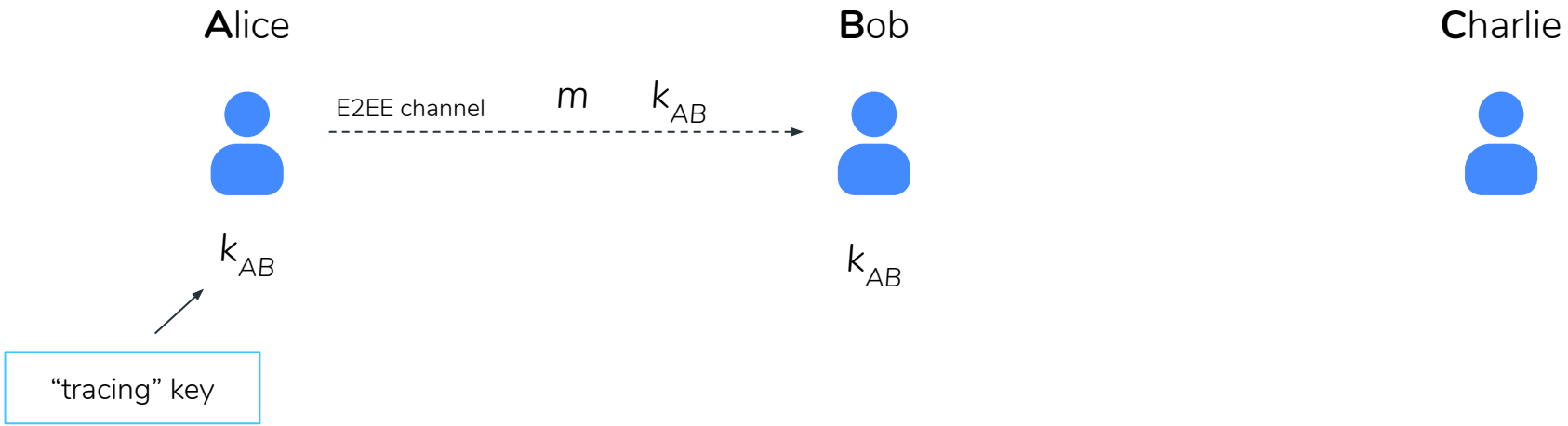

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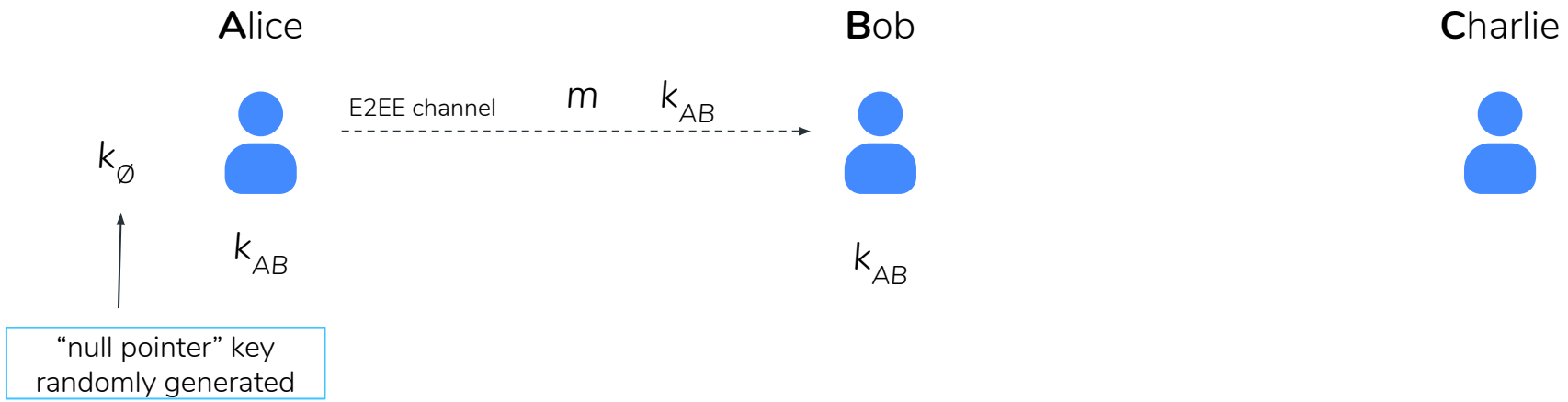

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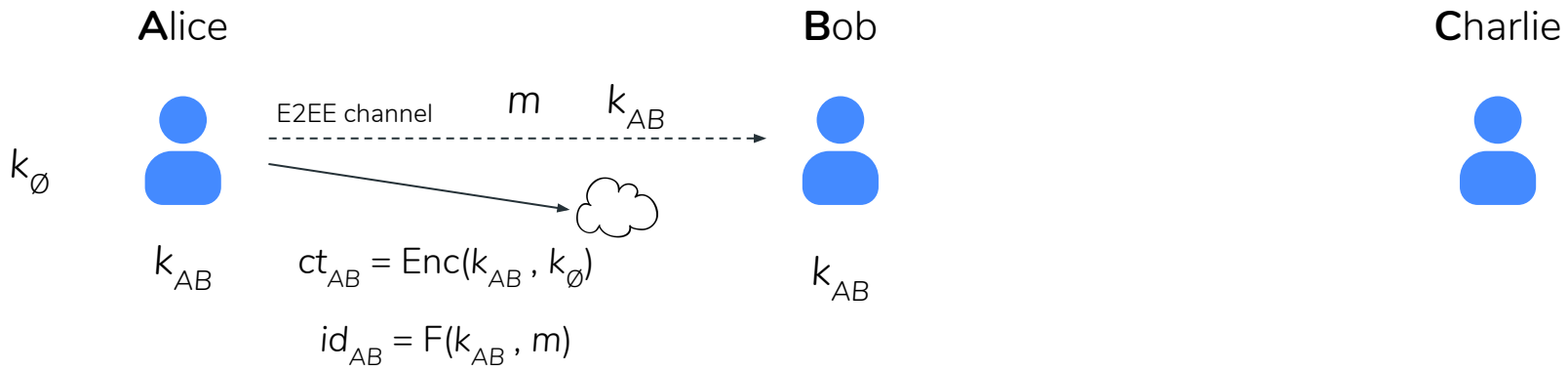

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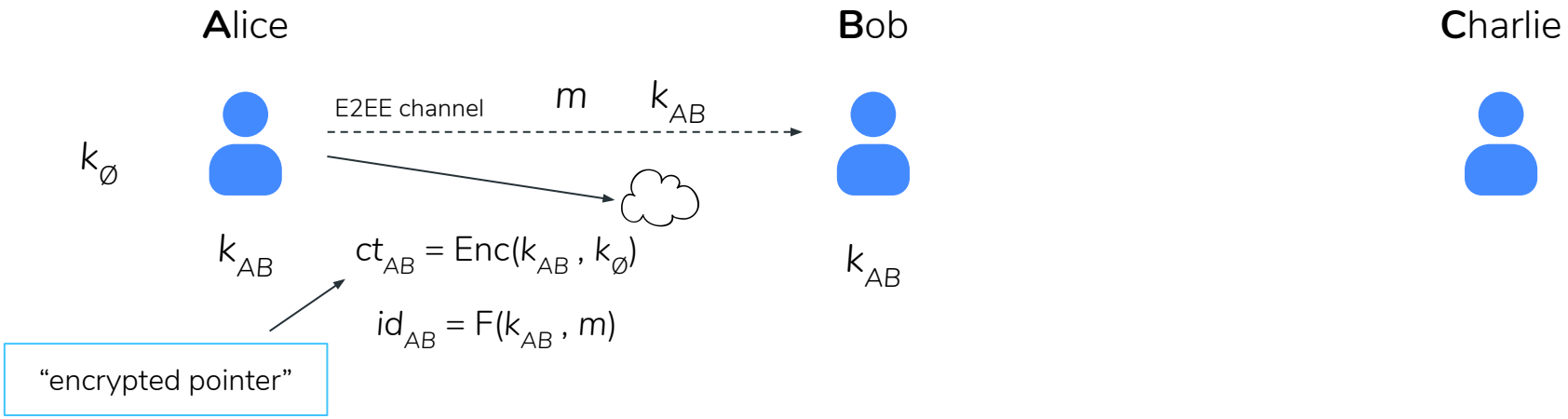

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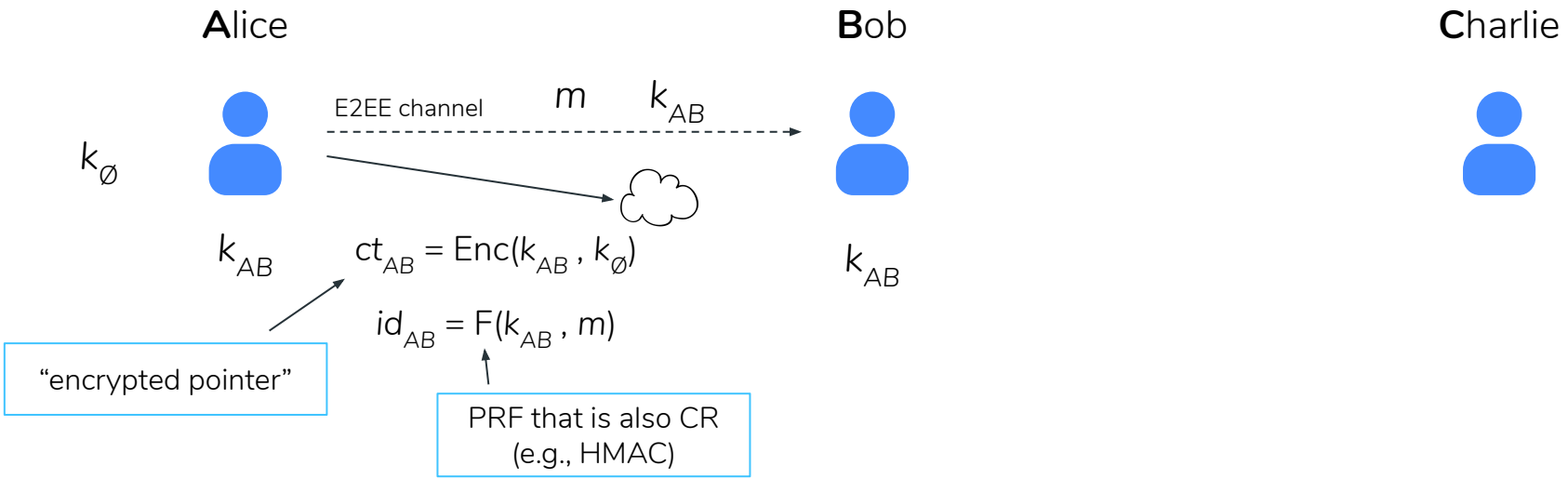

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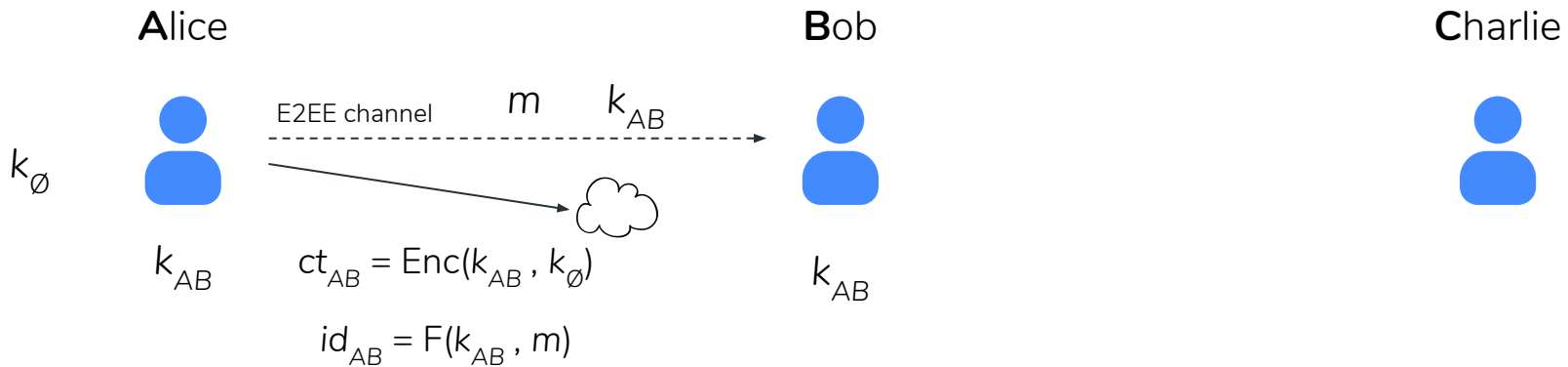
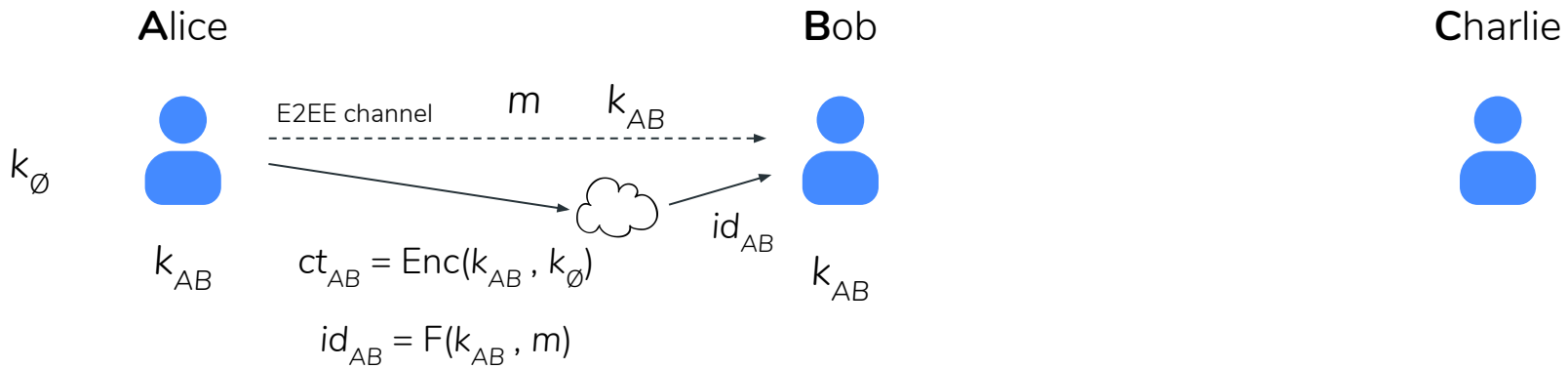


Table stored on platform

id_{AB}	ct_{AB}

Path traceback

Idea: Linked list of encrypted pointers



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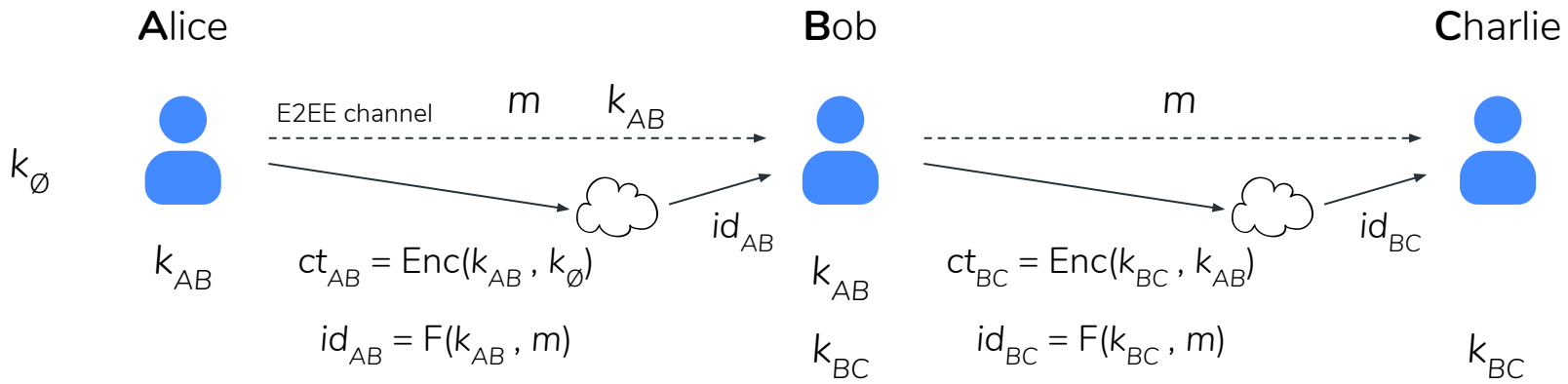

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id_{AB}	ct_{AB}
id_{BC}	ct_{BC}

Path traceback

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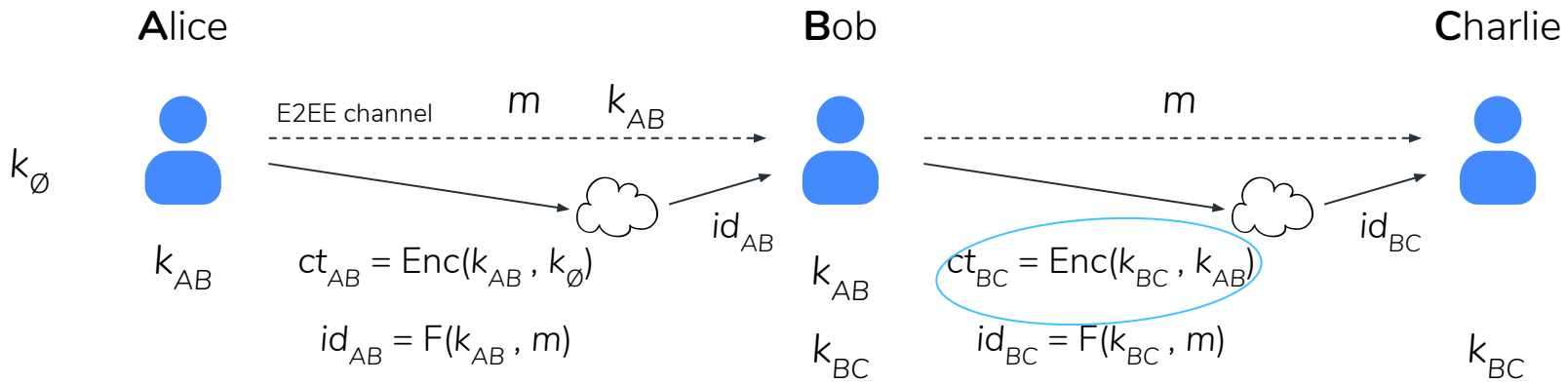

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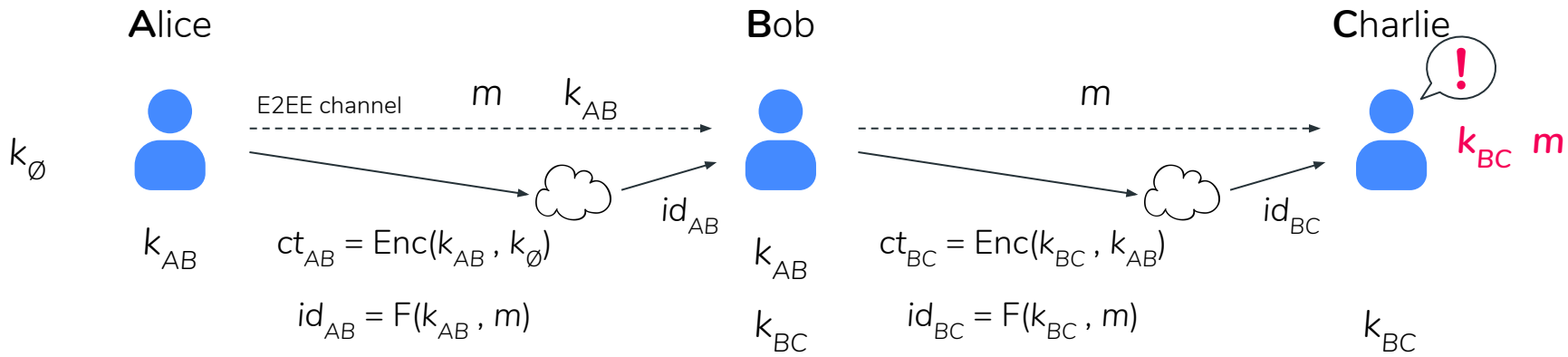

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id_{AB}	ct_{AB}
id_{BC}	ct_{BC}

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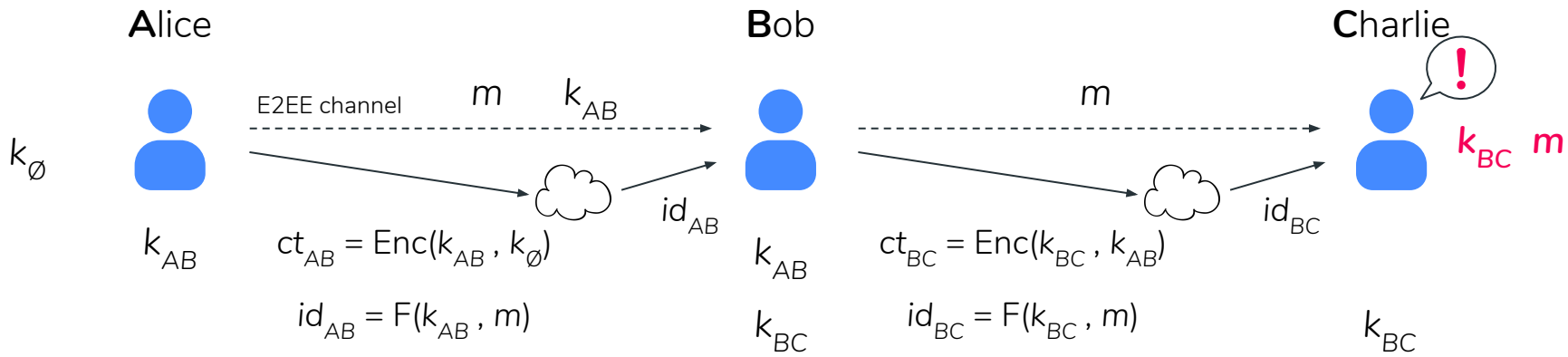

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	id_{AB}	ct_{AB}
$F(k_{BC}, m)$ →	id_{BC}	ct_{BC}

Path traceback

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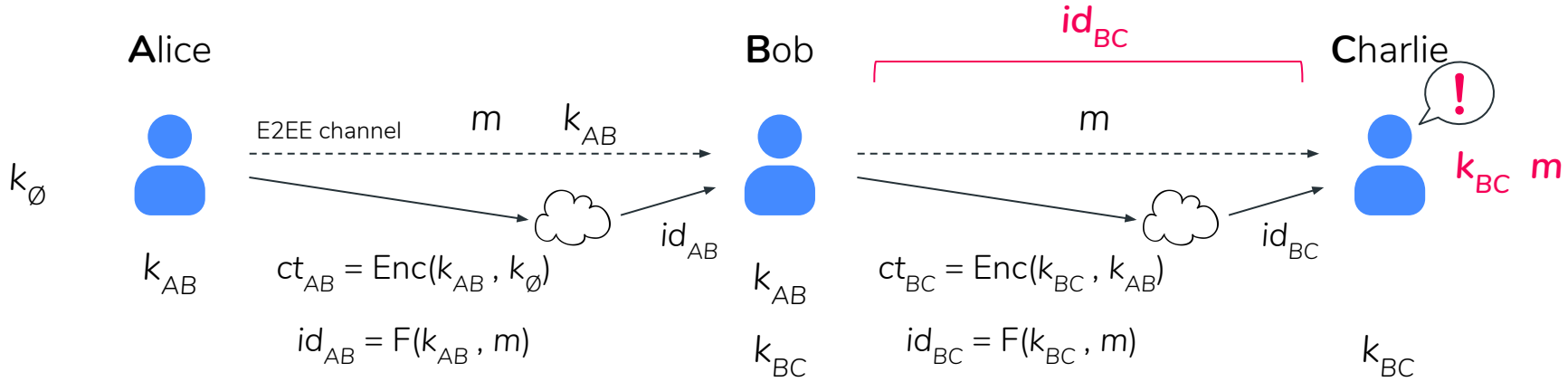

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$F(k_{BC}, m)$ →	id_{BC}	ct_{BC}

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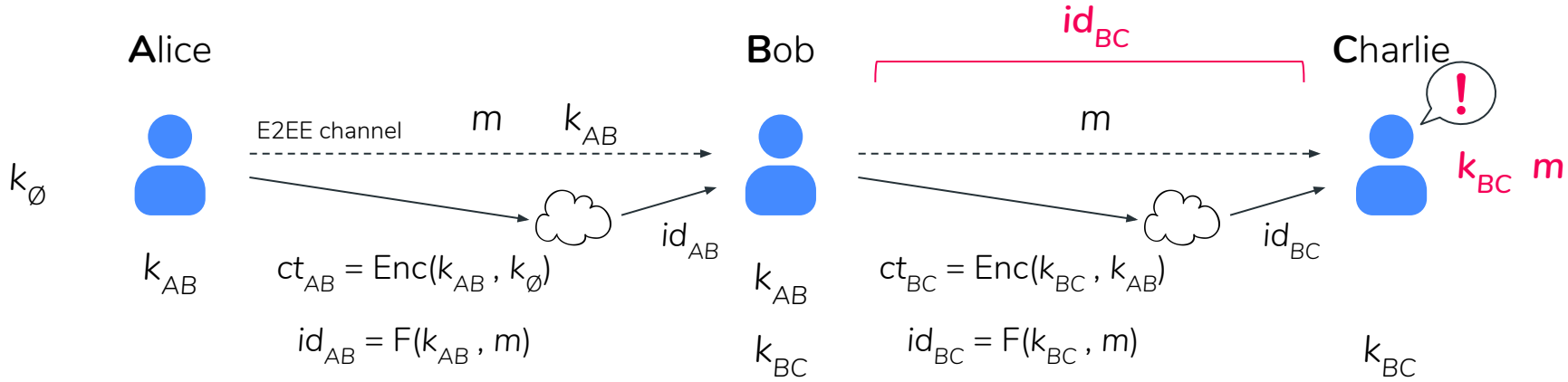

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id_{AB}	ct_{AB}
id_{BC}	ct_{BC}

$F(k_{BC}, m) \rightarrow$

Decrypt and dereference ct_{BC}

$k_{AB} = Dec(k_{BC}, ct_{BC})$

Path traceback

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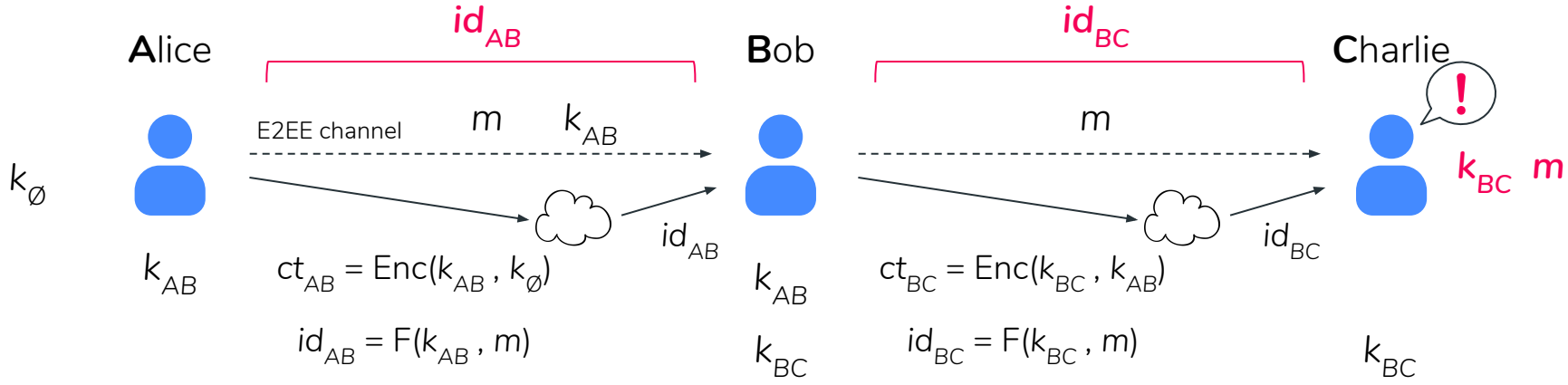

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$F(k_{AB}, m)$ →	id_{AB}	ct_{AB}
$F(k_{BC}, m)$ →	id_{BC}	ct_{BC}

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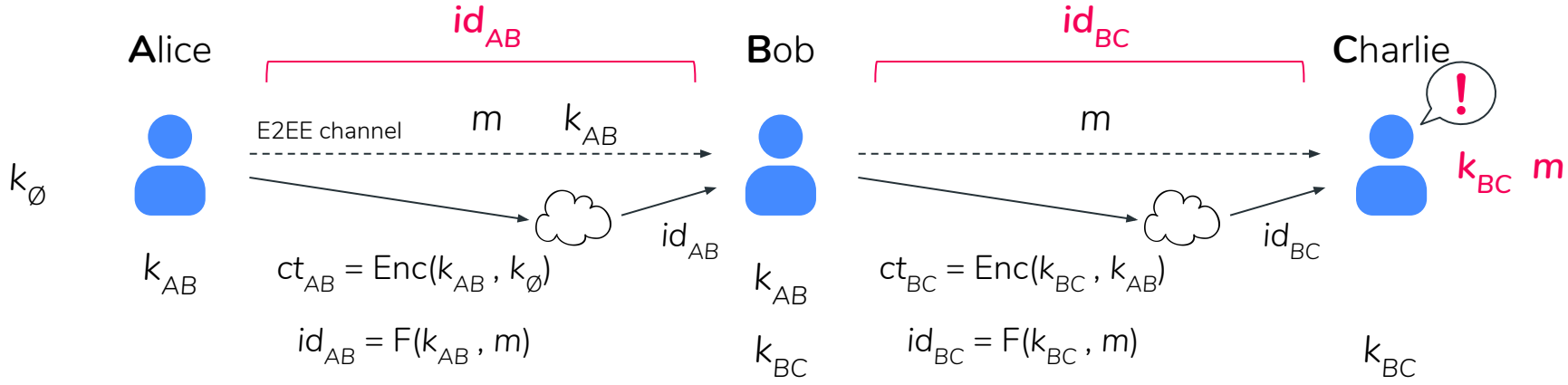

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	id_{AB}	ct_{AB}
$F(k_{AB}, m)$ →		
$F(k_{BC}, m)$ →	id_{BC}	ct_{BC}

Decrypt and dereference ct_{BC}

$k_{AB} = Dec(k_{BC}, ct_{BC})$

Decrypt and dereference ct_{AB}

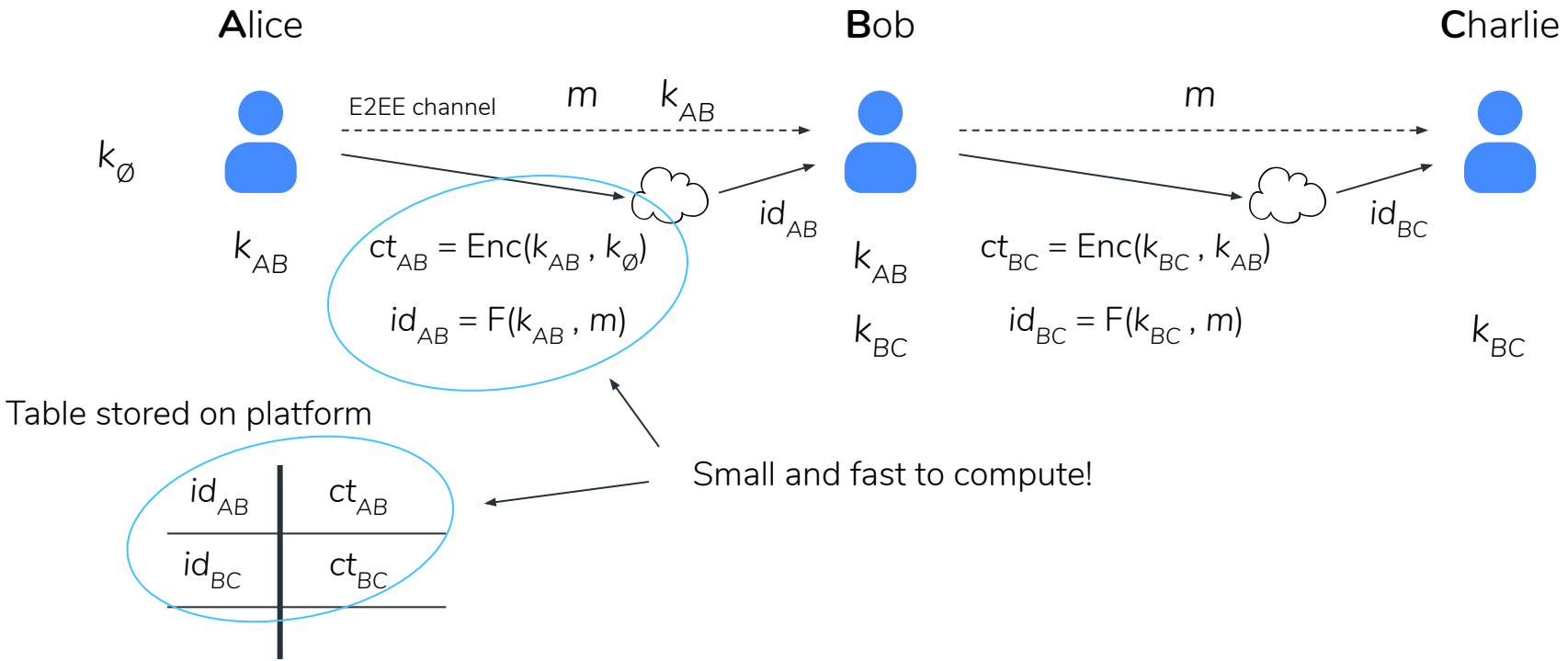
$k_{\emptyset} = Dec(k_{AB}, ct_{AB})$

$F(k_{\emptyset}, m)$ not in table

⇒ beginning of forward chain!

Path traceback

Idea: Linked list of encrypted pointers



Path traceback

Idea: Linked list of encrypted pointers

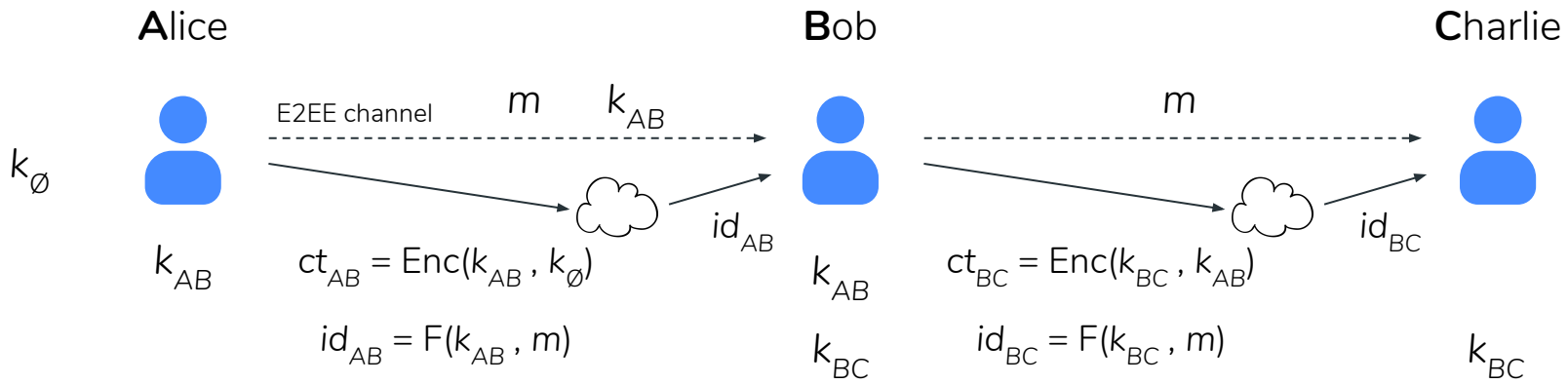
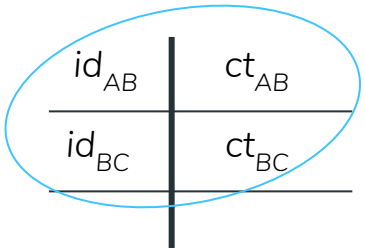


Table stored on platform



Before report

Platform view: Ciphertexts and PRF outputs without keys

User view: Keys without ciphertext

Path traceback

Idea: Linked list of encrypted pointers

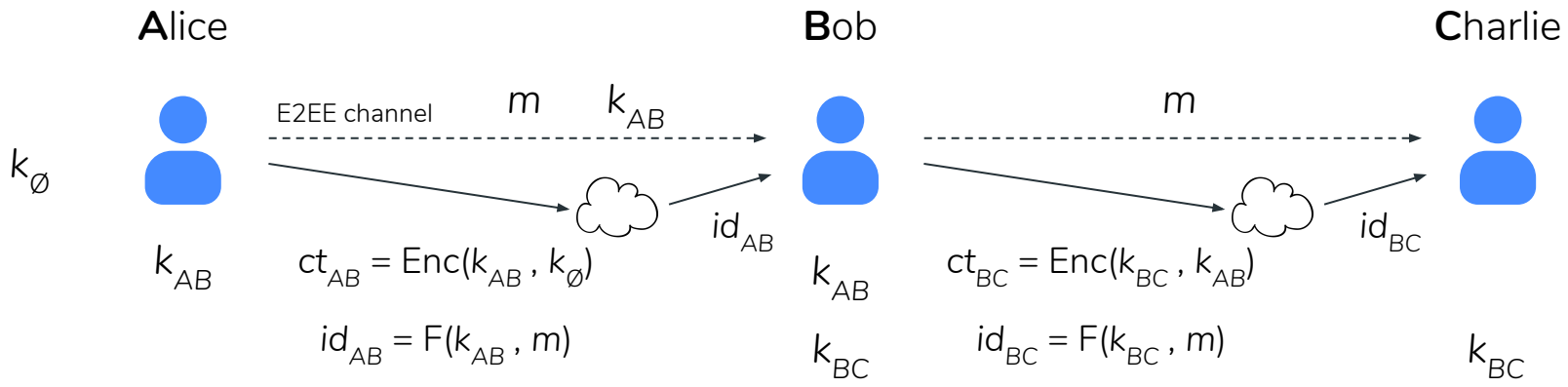
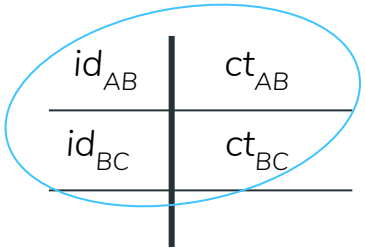


Table stored on platform



Before report
Platform view: Ciphertexts and PRF outputs without keys
User view: Keys without ciphertext

After report
Platform view: Learns keys only for rows of trace

Path traceback

Idea: Linked list of encrypted pointers

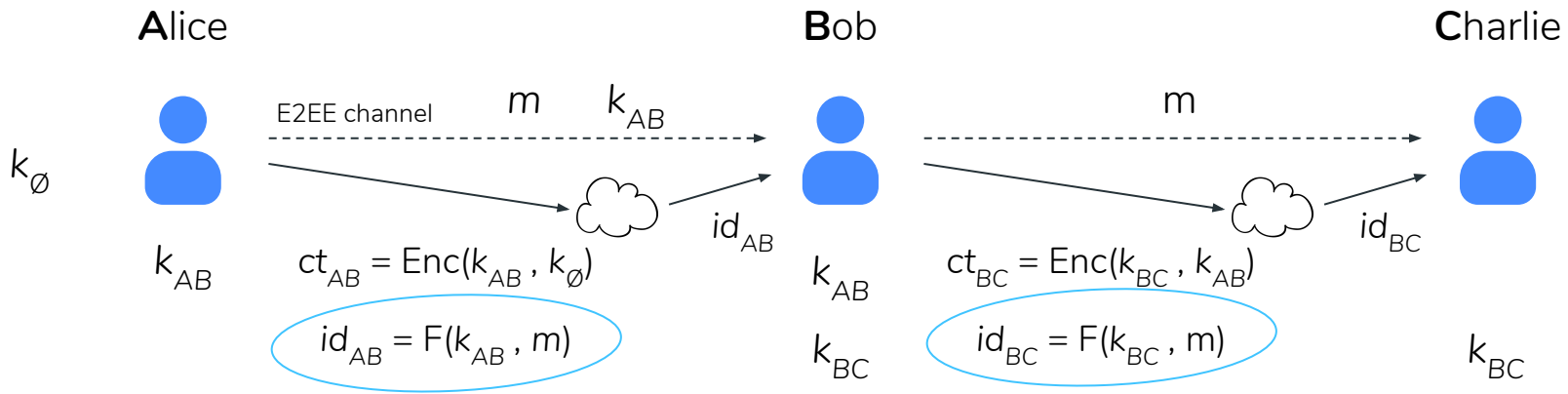


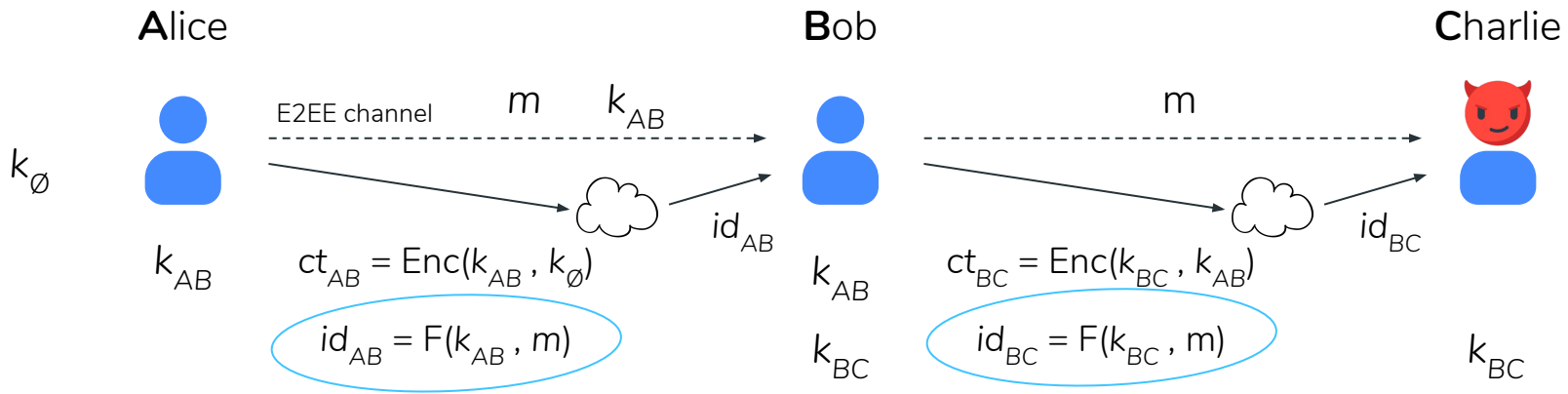
Table stored on platform

id_{AB}	ct_{AB}
id_{BC}	ct_{BC}

Trace accountability
Pointer “dereferences” are bound to a message

Path traceback

Idea: Linked list of encrypted pointers



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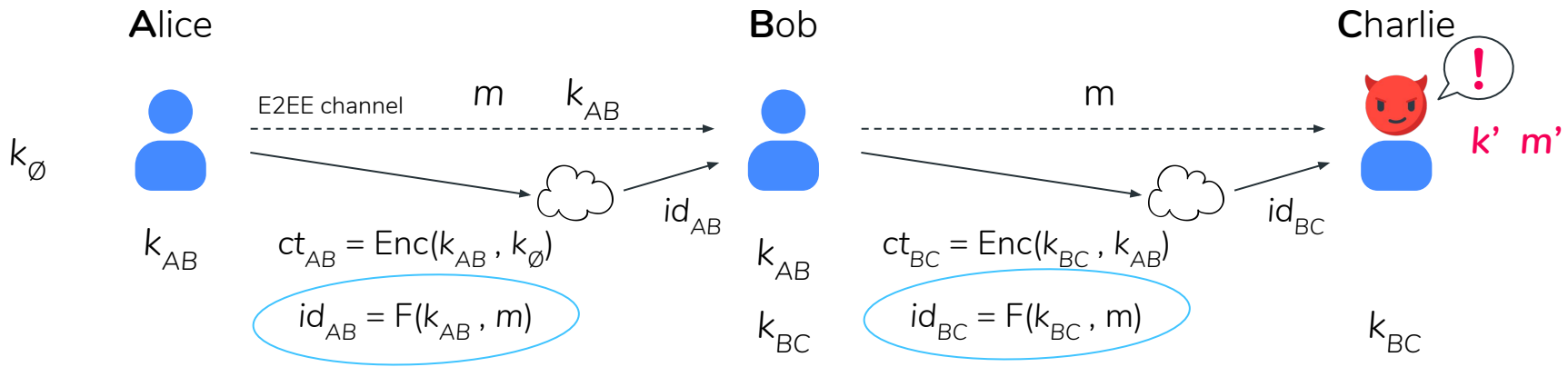

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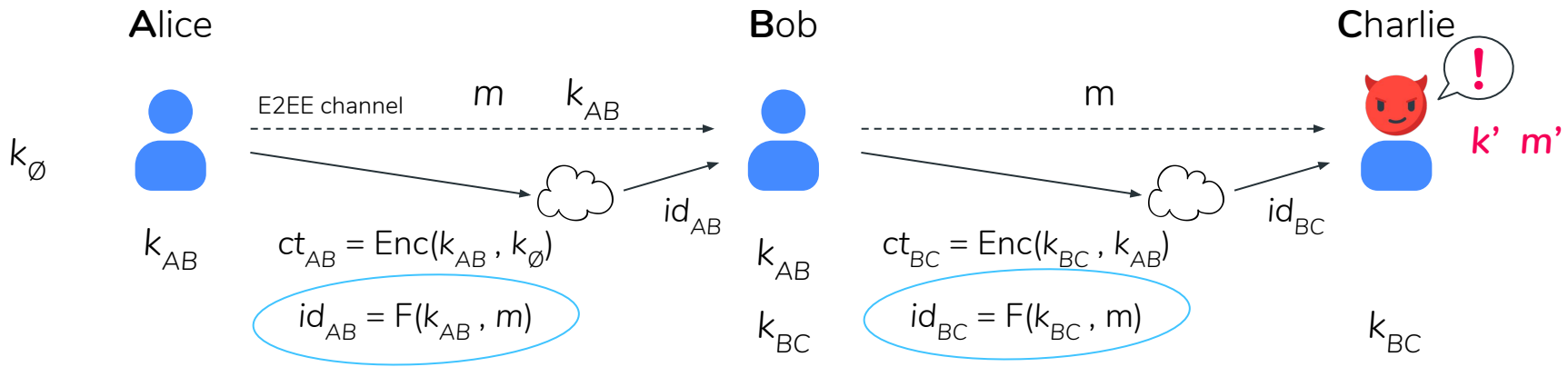

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To break accountability, $F(k', m')$ must collide with id_{BC}

Path traceback

Idea: Linked list of encrypted pointers

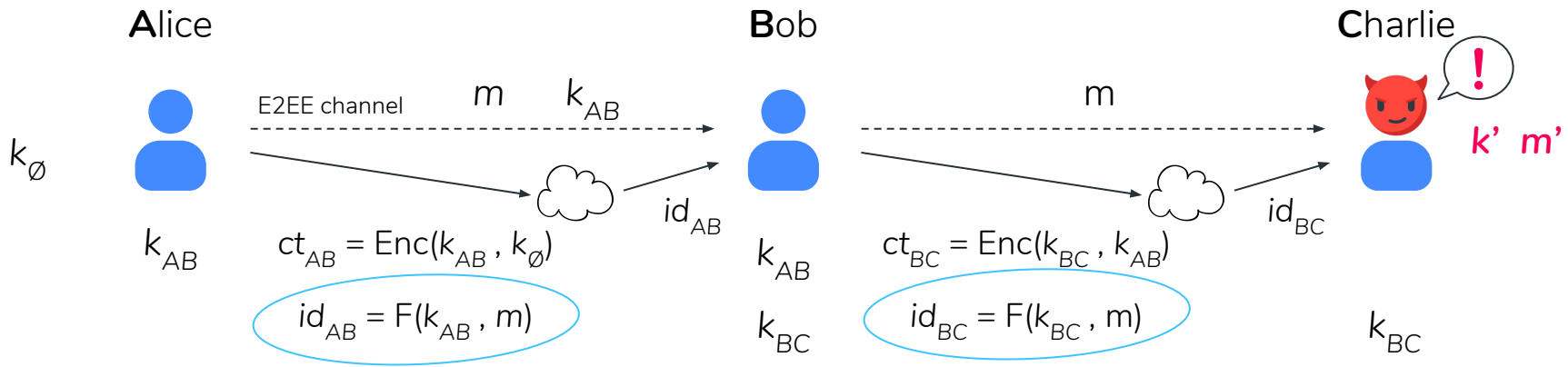

Table stored on platform

id_{AB}	ct_{AB}
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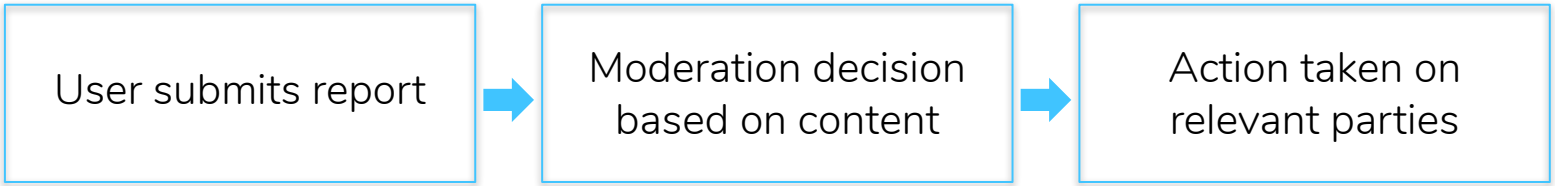
Trace accountability
Pointer "dereferences" are bound to a message

To break accountability, $F(k', m')$ must collide with id_{BC}

See paper for security proofs!

Path traceback

Idea: Linked list of encrypted pointers



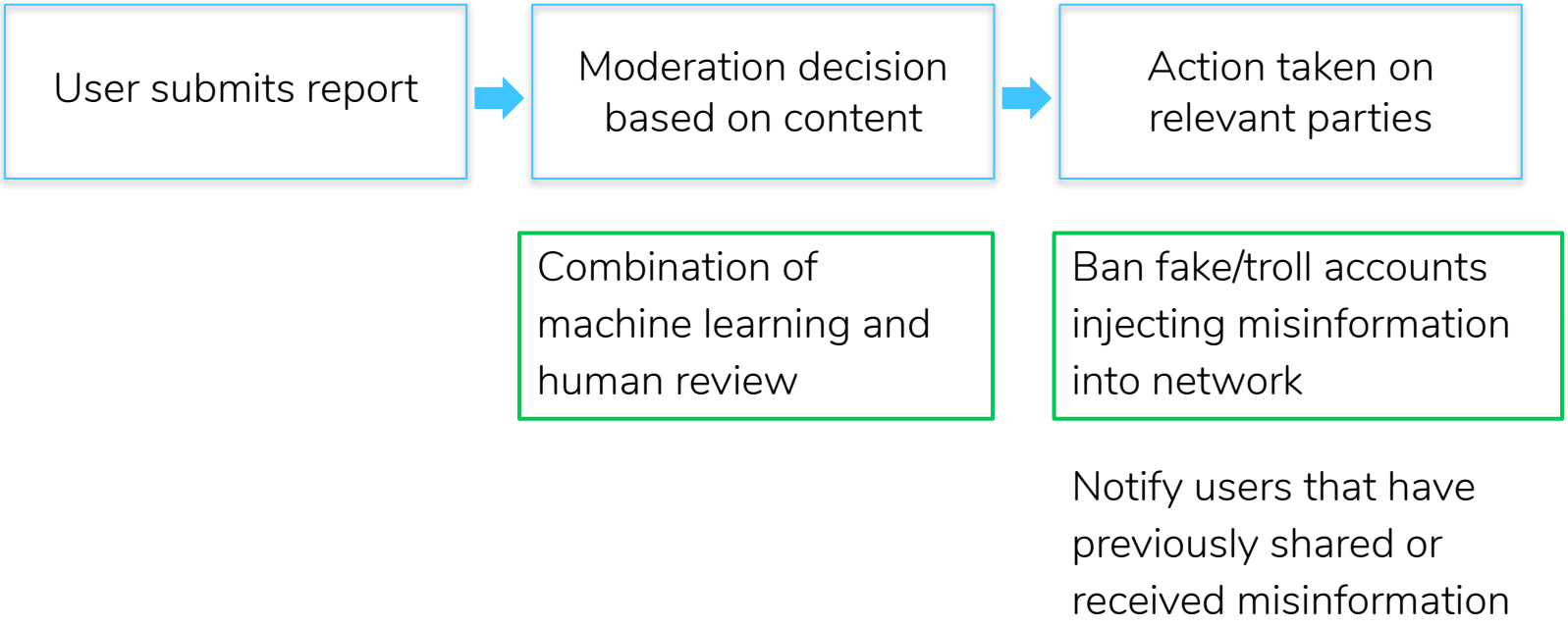
Combination of machine learning and human review

Ban fake/troll accounts injecting misinformation into network

Notify users that have previously shared or received misinformation

Path traceback

Idea: Linked list of encrypted pointers



Path traceback

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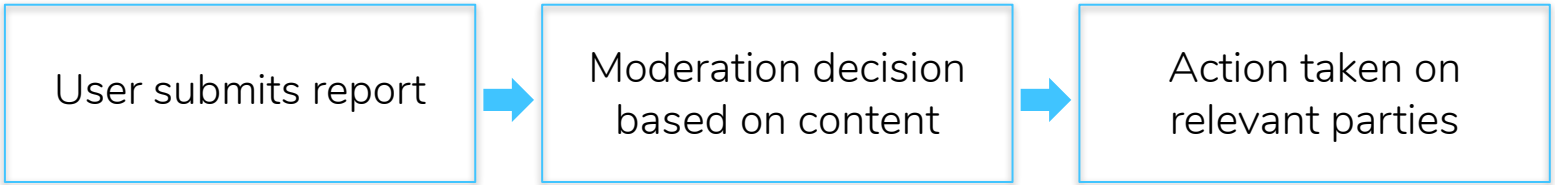


Combination of machine learning and human review

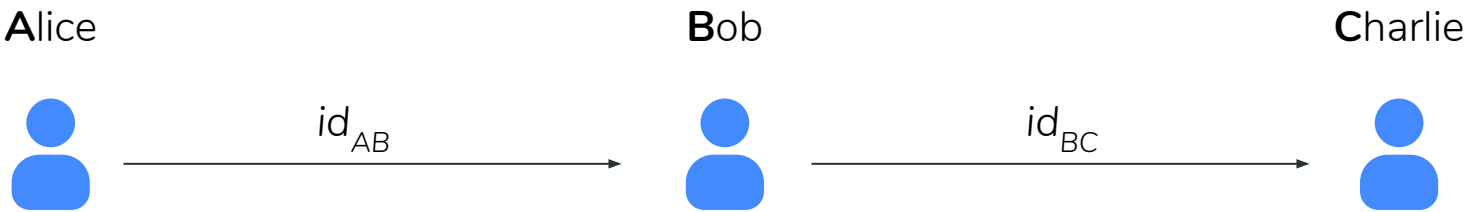
Ban fake/troll accounts injecting misinformation into network

Need something more than path traceback!

Notify users that have previously shared or received misinformation

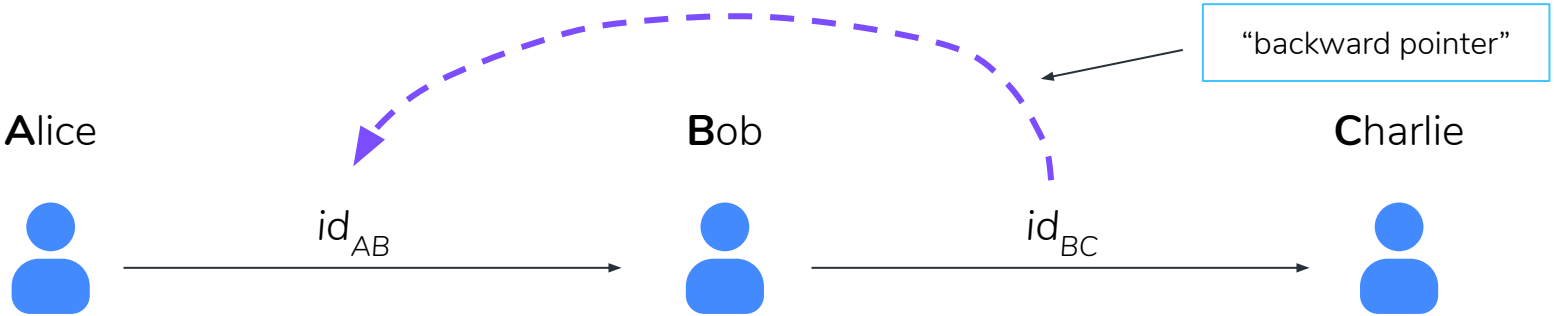
Extension: Tree traceback

Idea: “Doubly” linked list of encrypted pointers



Extension: Tree traceback

Idea: “Doubly” linked list of encrypted pointers



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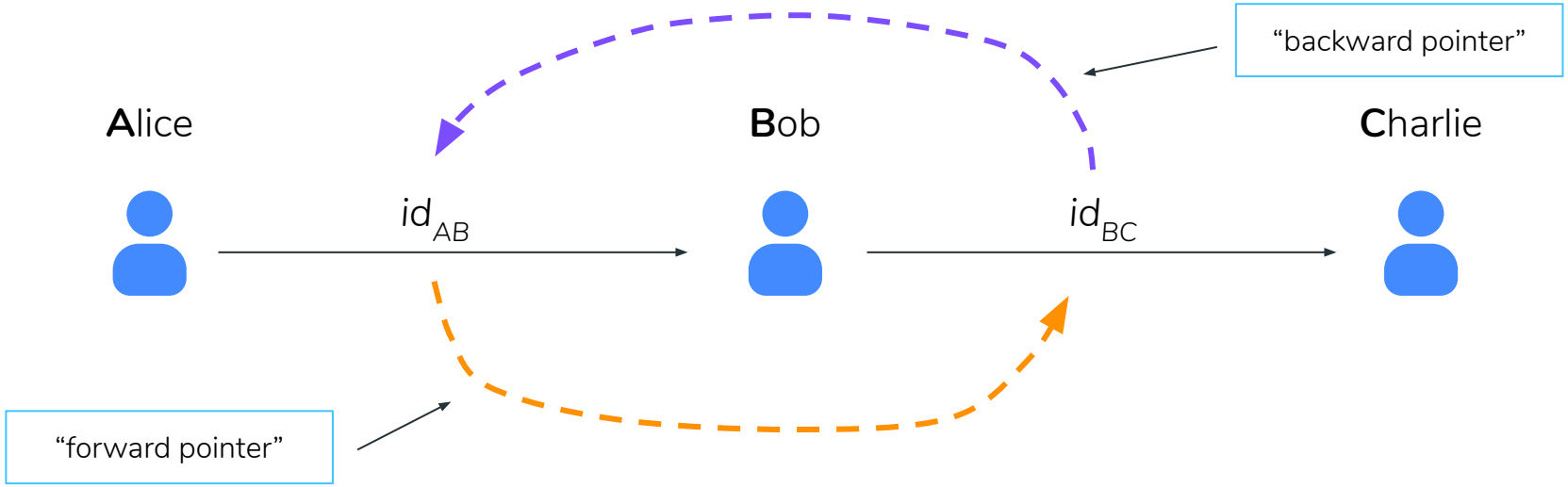

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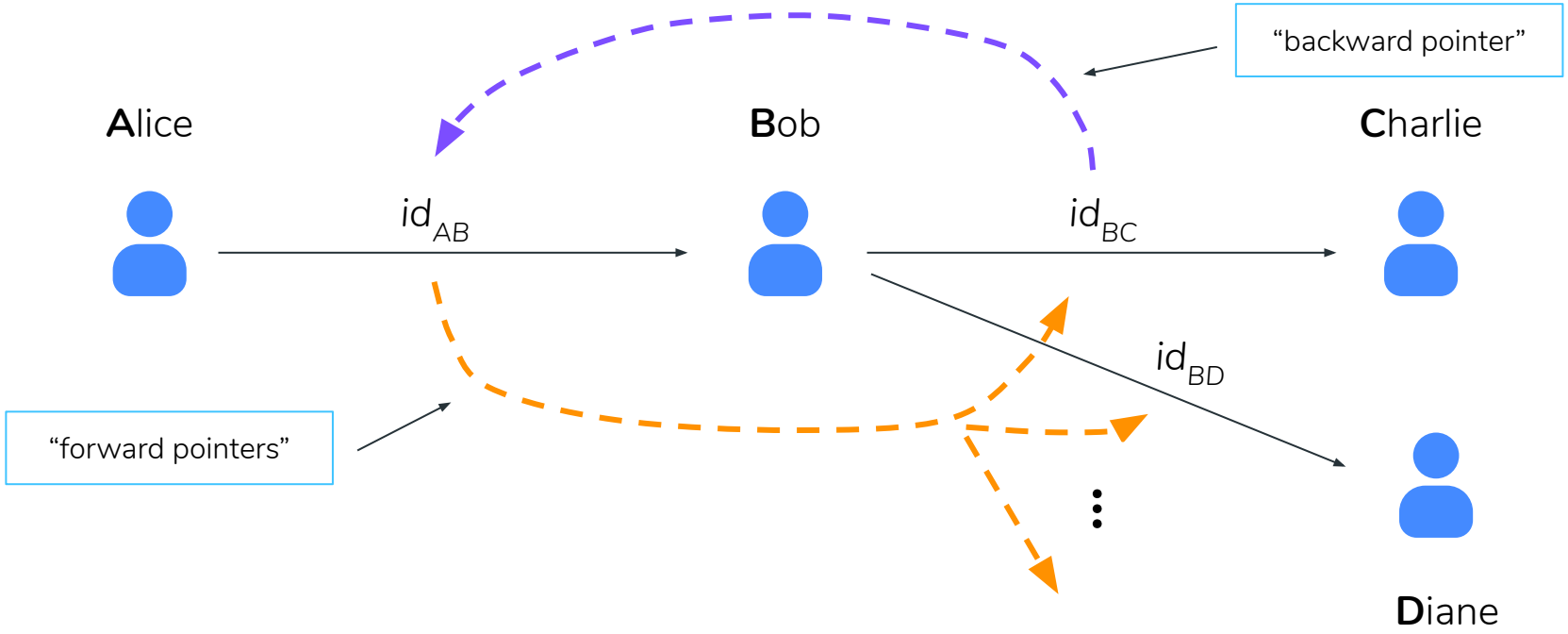

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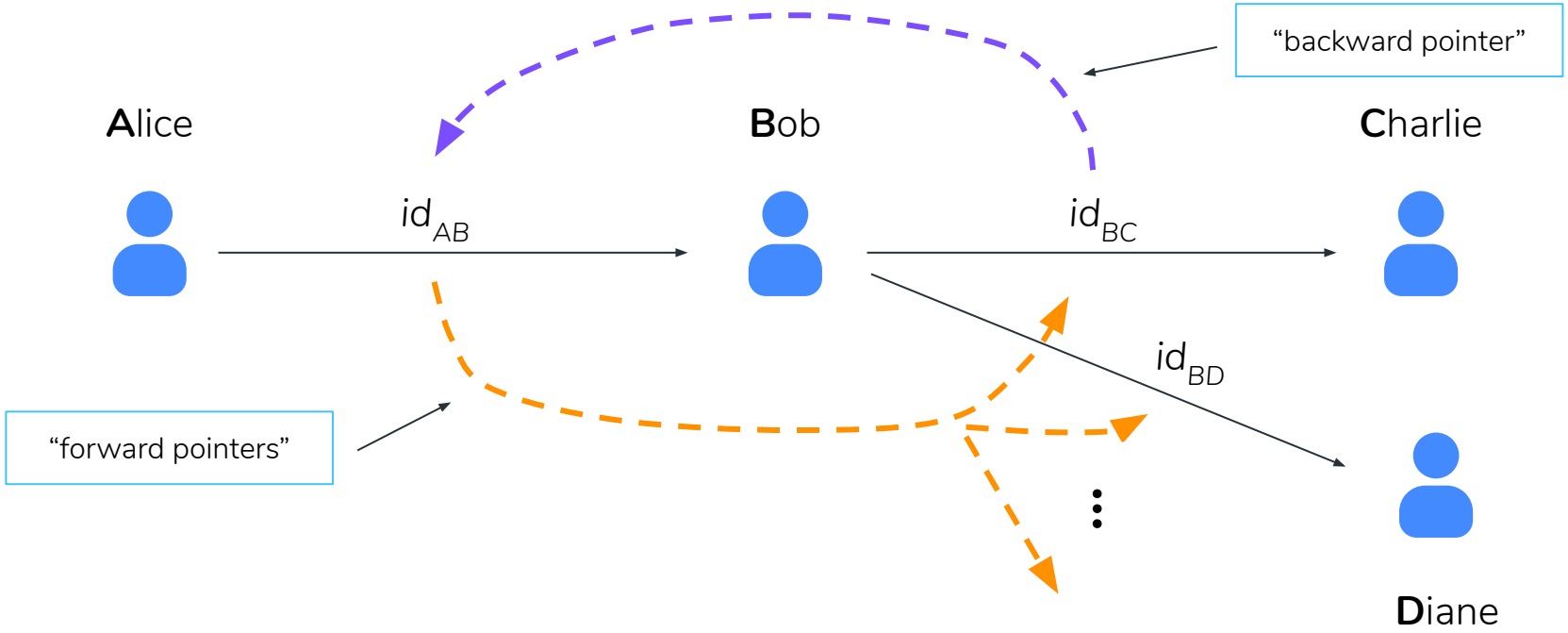

See paper for full details of construction!

(uses PRG and secret sharing)

Performance evaluation

- Path and Tree traceback implemented in < 500 lines of Rust
- Server table stored in in-memory Redis database

https://github.com/nirvantyagi/tracing

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- Server table stored in in-memory Redis database

- Fast (uses only efficient symmetric cryptography)
    - Client side: < 50 µs to generate and verify tracing tags
    - Server side: Traceback takes < 100 µs / message in trace

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Performance evaluation

- Path and Tree traceback implemented in < 500 lines of Rust
- Server table stored in in-memory Redis database

- Fast (uses only efficient symmetric cryptography)
    - Client side: < 50 µs to generate and verify tracing tags
    - Server side: Traceback takes < 100 µs / message in trace

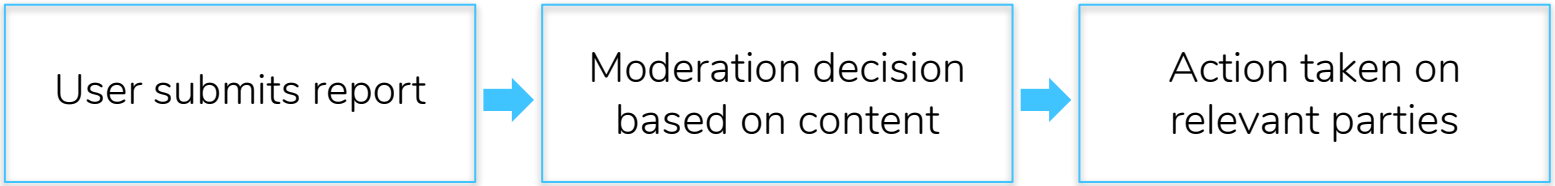
- Platform storage
    - Stores < 100B / message
    - 1 billion messages / day ⇒ ~ 2TB / month
        - Reasonable to store most recent time period sliding window

https://github.com/nirvantyagi/tracing

Deployment considerations

Can tracing be abused to silence socially valuable content?

Future work: Policy and implementation to limit abuse of tracing



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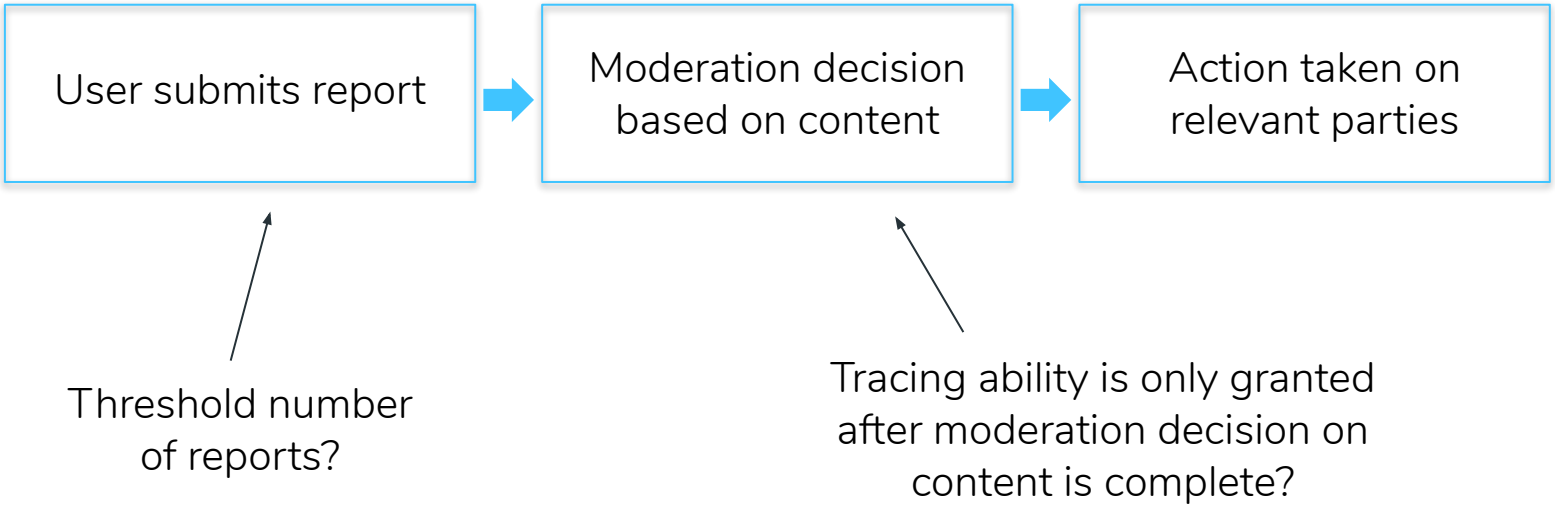

Conclusion

- **Message tracing**: new cryptographic functionality for user-driven reporting of forwards in E2EE messaging
    - Path traceback: chain of messages from source to reporter
    - Tree traceback: entire forwarding tree of messages originating from source
- Formal confidentiality and accountability security notions for tracing
- Implementation and evaluation of practicality

https://github.com/nirvantyagi/tracing