Speedster: An Efficient Multi-party State Channel via Enclaves

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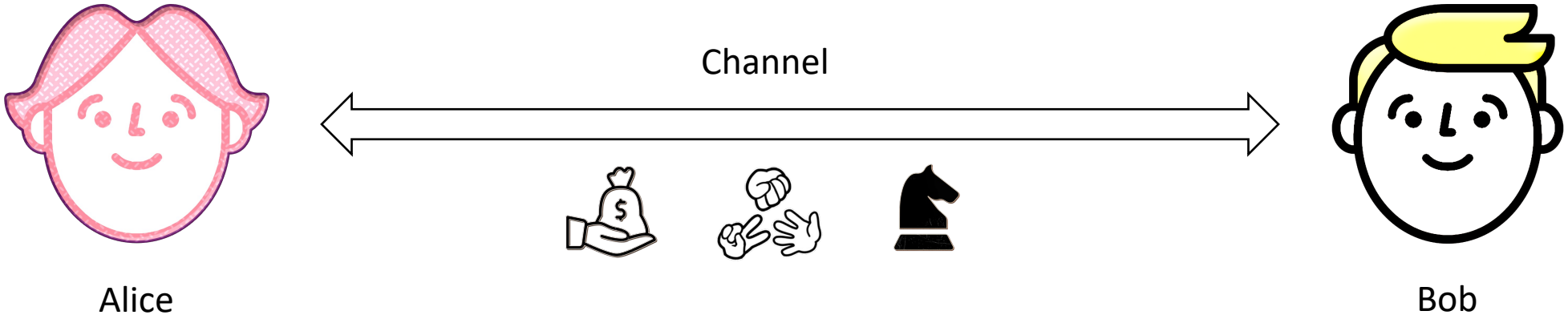
Outline

- **Introduction and Background**
- Architecture of Speedster
- Design and Implementation
- Evaluation
- Conclusion

Why Need Payment/State Channel

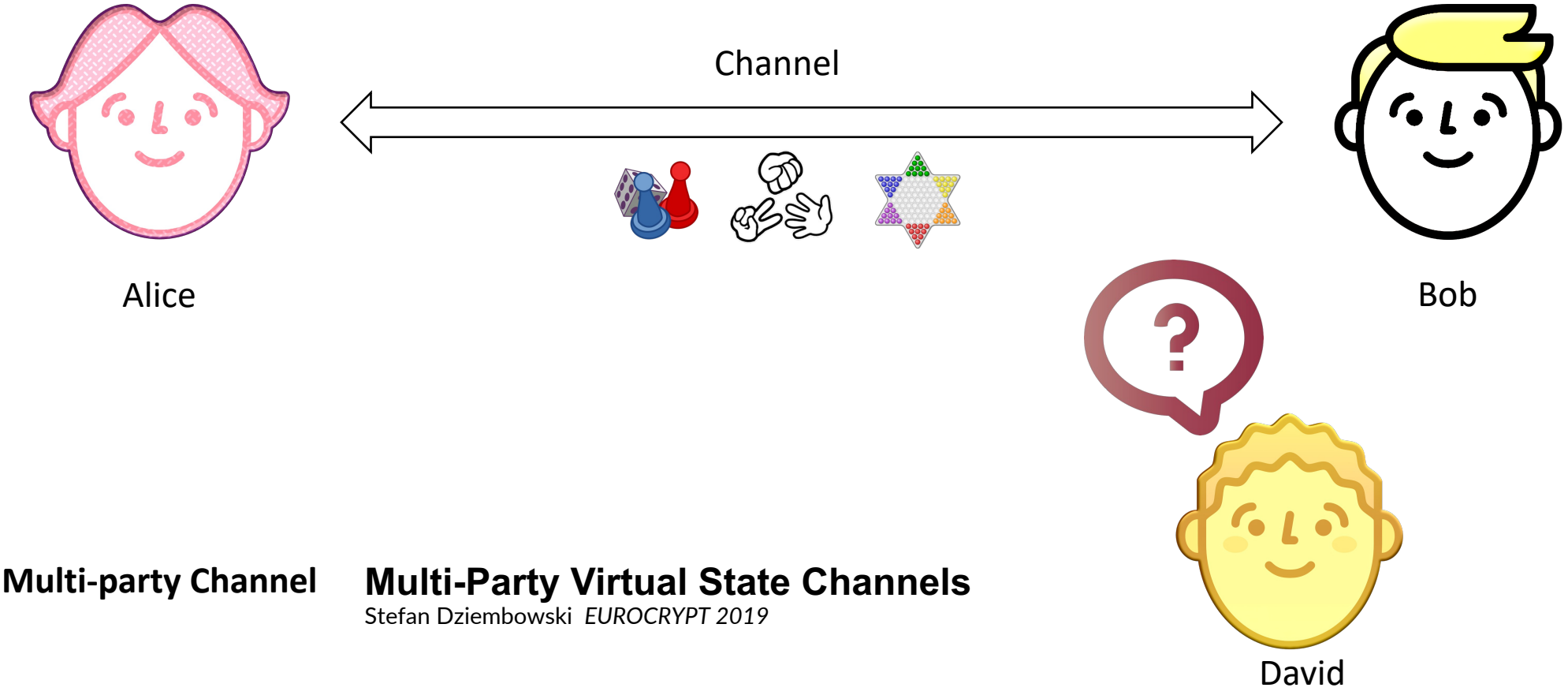


Traditional Channel

Celer

...

Why Need Multi-party State Channel



Multi-party Channel

Multi-Party Virtual State Channels
Stefan Dziembowski *EUROCRYPT 2019*

Challenges: Isolation

1. States in different channels are isolated. Even with hash-time-lock contract (HTLC).

Multi-party state channel needs to synchronize states among channels to prevent double-spending.

Challenges: Efficiency

2. To setup a multi-party state channel, multiple channels need to be created on the blockchain first!

That is expensive and time consuming!

Challenges: Resource Overhead

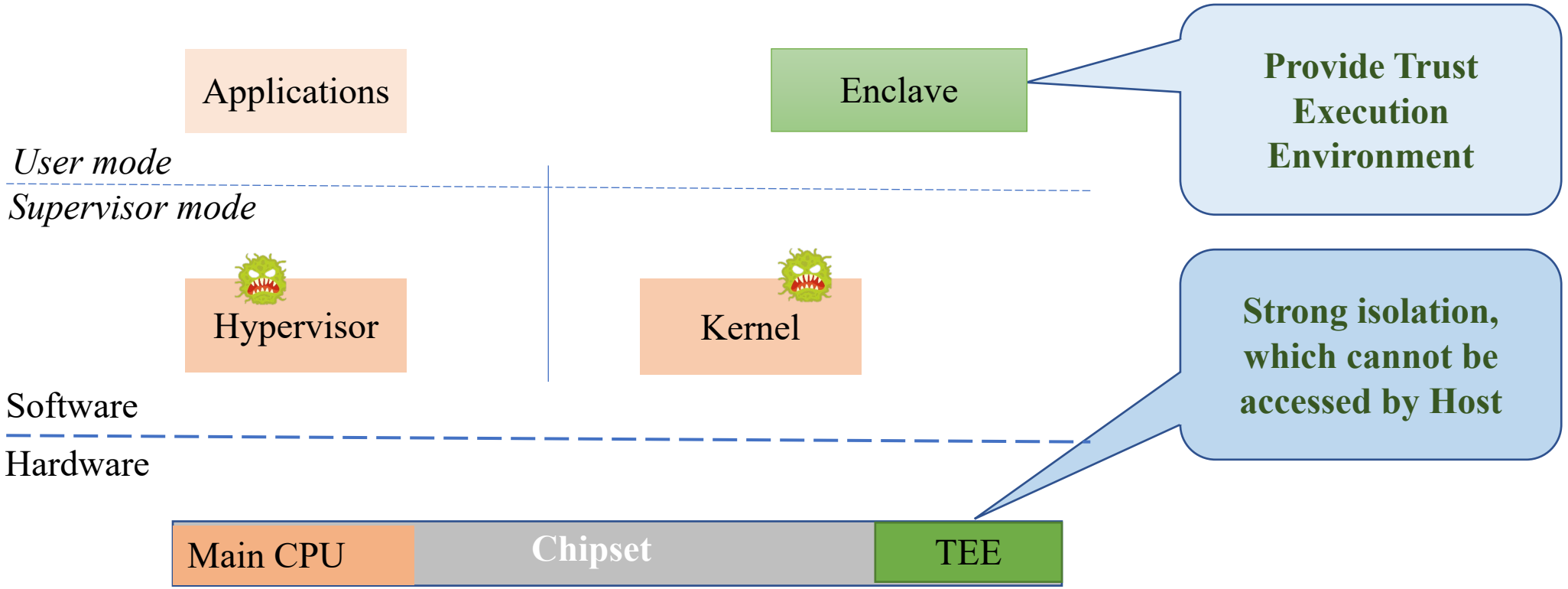
3. Overhead on processing multi-party transactions.

Process multi-party transactions require recursive states update.

Reliable Solution

Using Trusted and Isolated Execution Environment to establish and manage channels without interacting with the main chain!

Security System In TEE Architecture



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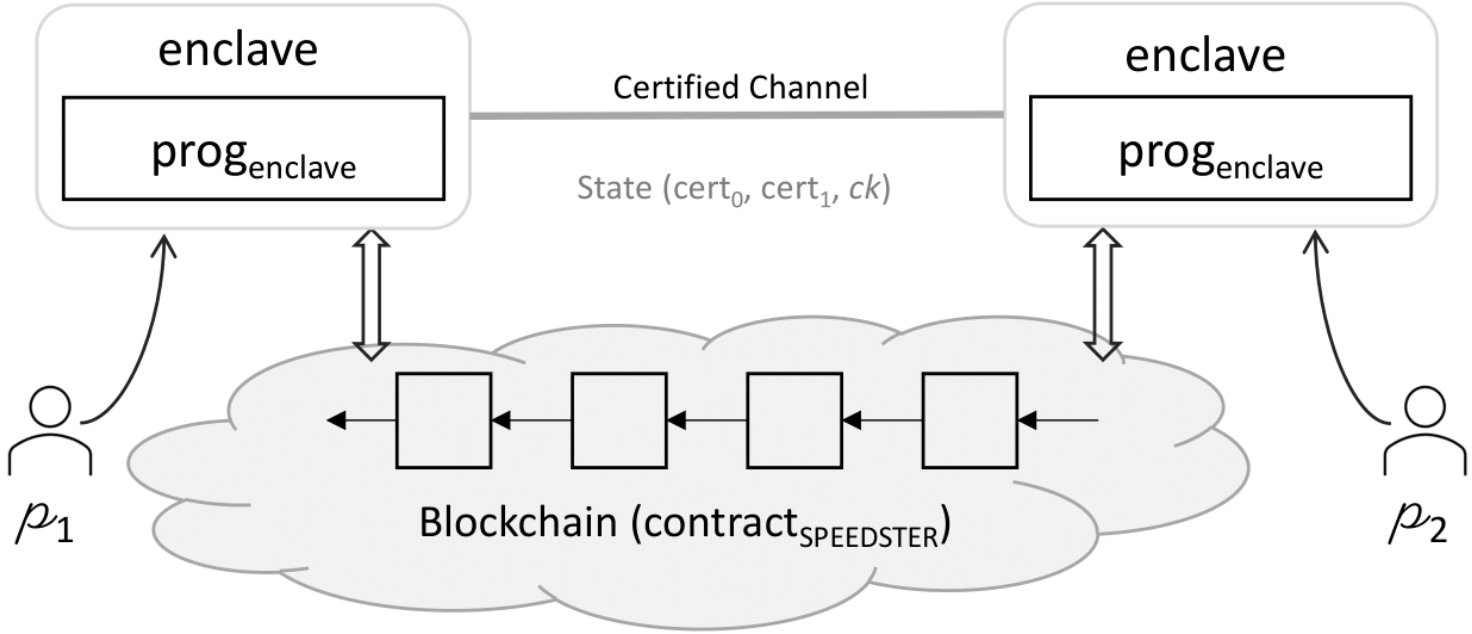
High-level Architecture of the Speedster



Speedster architecture.

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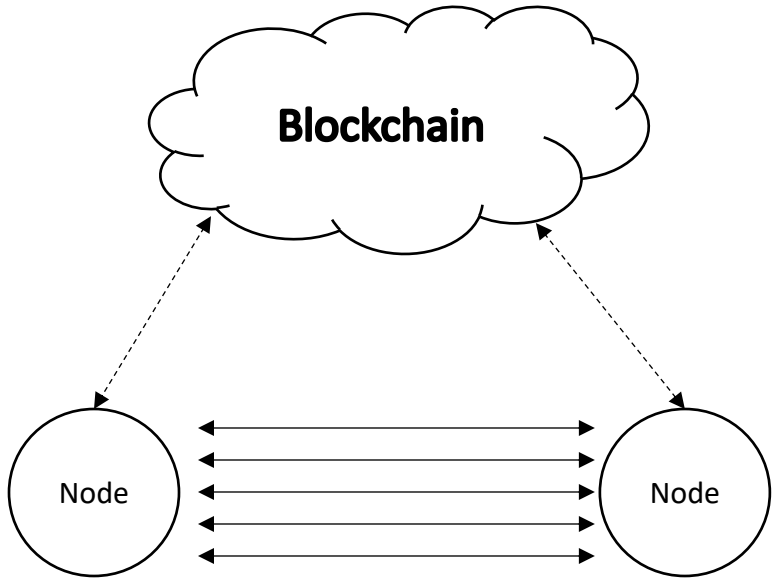
Speedster Design & Implementation

- *Certified Channel*
- Peer-to-Peer Channel Network
- Multi-Party State Channel
- Cross-platform
- TEE Security

Certified Channel

Definition (Certified Channel). A Speedster channel is called a Certified Channel if it is established between two attested enclave accounts and both participants have the channel certificate issued by the other party.

Account Based Channel System



Off-chain Channel Open/Close

1: Node create a TEE account.
2: Node register the account to blockchain,
2: Nodes interact with other nodes off-chain
(attestation, channel creation, transaction)

Transactions in channels are encrypted with AES-GCM instead of ECDSA.

Speedster Design & Implementation

- Certified Channel
- ***Peer-to-Peer Channel Network***
- Multi-Party State Channel
- Cross platform
- TEE Security

Peer-to-Peer Channel Network

Definition (Peer-to-Peer Channel Network). A payment/state channel network in which a node can establish direct channel connections with other nodes efficiently off-chain and process transactions without relying on intermediaries.

- Direct channel connection.
- Off-chain channel open and close at anytime.
- Minimum fee cost.

Speedster Design & Implementation

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- ***Multi-Party State Channel***
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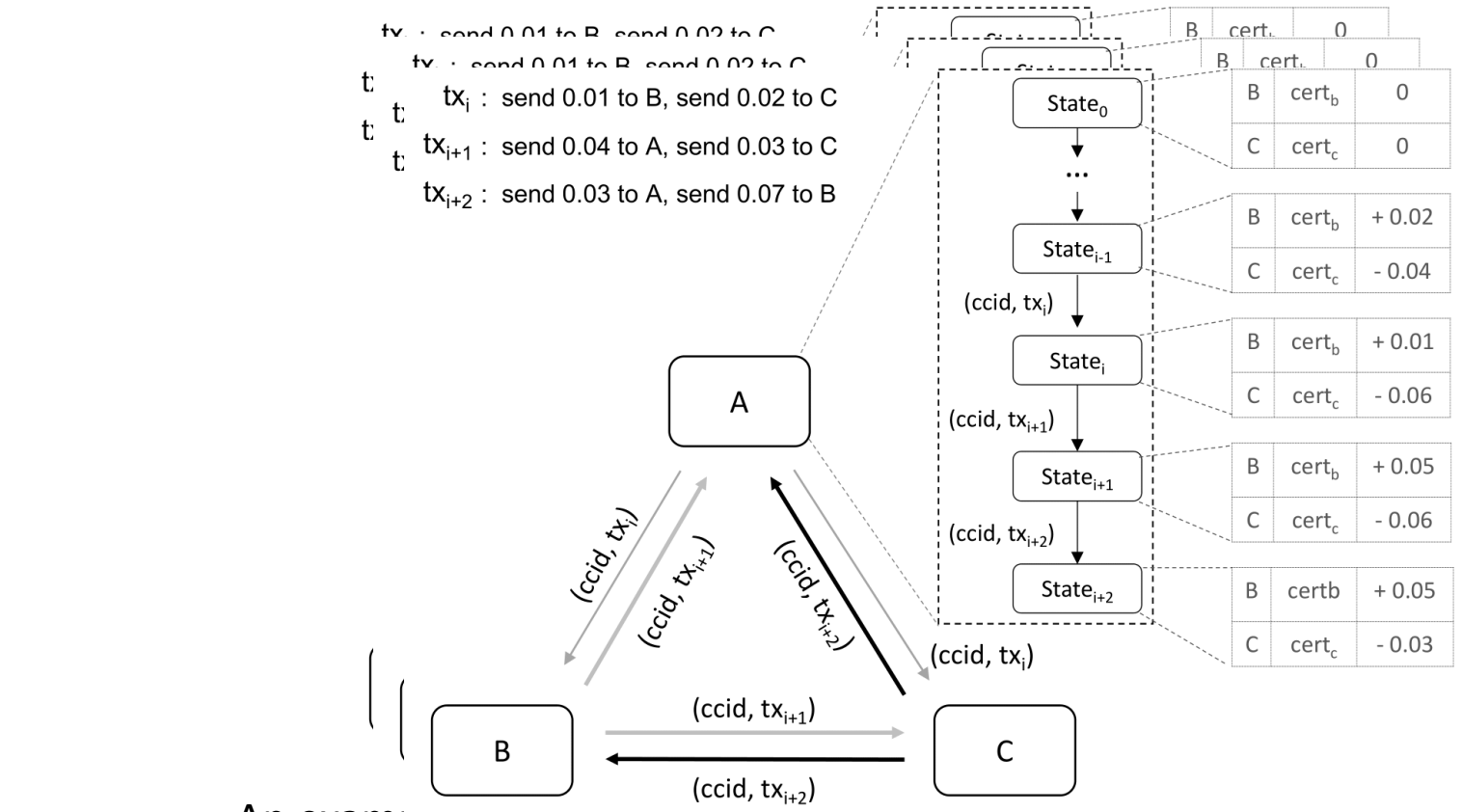
- TEE Security

Multi-Party State Channel



An example of executing a multi-party transfer contract among A, B and C, assuming SORT(pk_A)>SORT(pk_B)>SORT(pk_C). (+) and (-) in the tables represent the balance change after each respective Certified Channel transaction.

Speedster Design & Implementation

- Certified Channel
- Peer-to-Peer Channel Network
- Multi-Party State Channel
- ***Cross-platform***
- TEE Security

Cross-platform

Prototype of Speedster is cross-platform:

- Intel SGX:
  - Linux-SGX SDK
  - OpenEnclave
- AMD SEV:
  - Qemu
  - Vm:Ubuntu18.04
- ARM TrustZone
  - OPTEE
  - OpenEnclave

Speedster Design & Implementation

- Certified Channel
- Peer-to-Peer Channel Network
- Multi-Party State Channel
- Cross-platform
- ***TEE Security***

TEE Security

TEE Attacks:

- Replay/Rollback attacks.
- Side-channel attacks.
- Denial-of-service attacks.

Solutions:

- A generalized TEE abstraction.
- SEV-SE, Monotonic Counter, RPMB Secure Storage.
- Side-channel-attack resistant cryptographic library.
- Committee enforcement design.

TEE Security

TEE Attacks:

- Replay/Rollback attacks.
- Side-channel attacks.
- Denial-of-service attacks.

❑ TEE Security is another research topic, we can not cover all attacks here!!!

Solutions:

- A generalized TEE abstraction.
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Evaluation

The test environment platform:

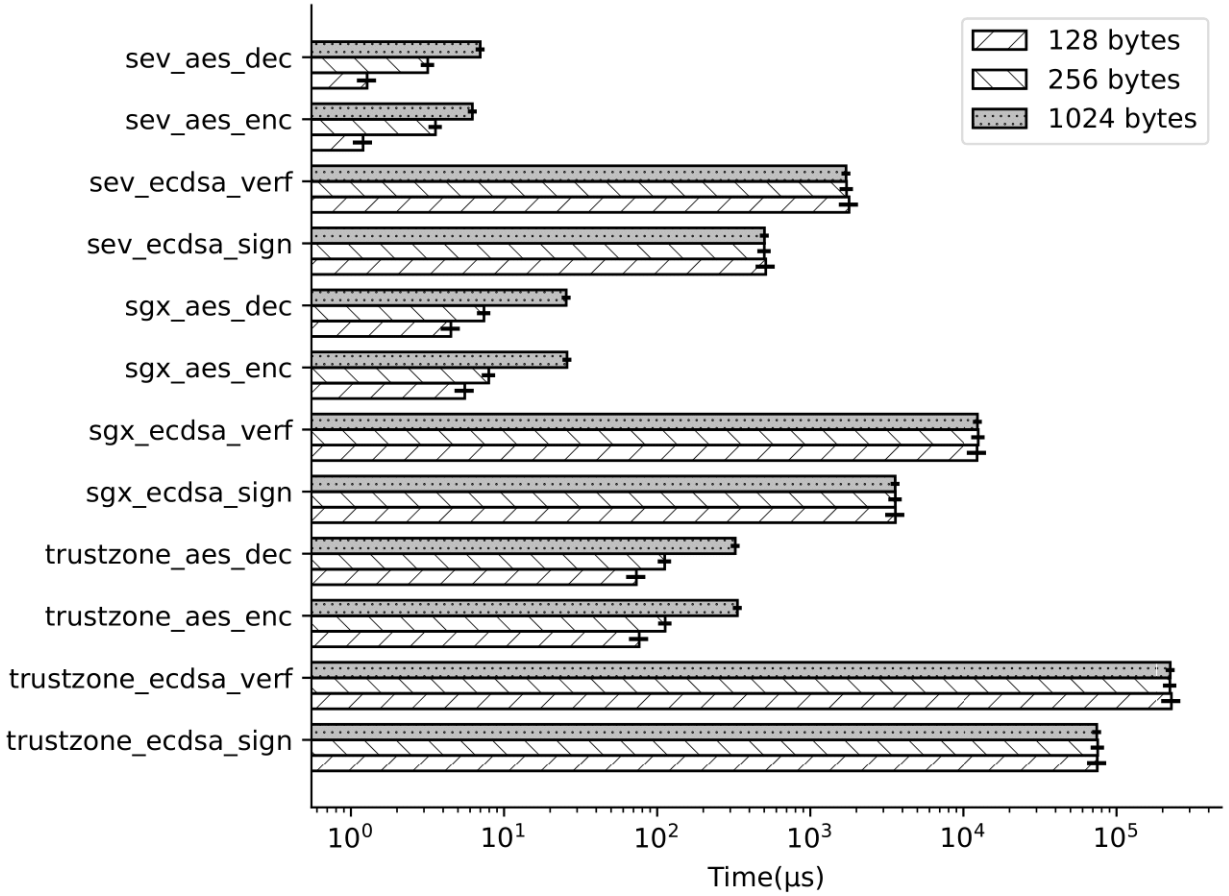
- ✓ Intel SGX: quad-core 3.6 GHz Intel(R) E3-1275 v5 CPU with 32 GB memory.
- ✓ AMD SEV: 64 GB DRAM and an SEV-enabled AMD Epyc 7452 CPU, which has 32 cores and a base frequency of 2.35 GHz.
- ✓ ARM TrustZone: QEMU cortex-a57 virtual machine with 1 GB memory and Linux buildroot 4.14.67-g333dc9e97-dirty as the kernel.
- ✓ Real world: Azure Standard DC1s_v2 (1 vCPUs, 4 GB memory) virtual machines.

Evaluation

Applications:

- Instant State Sharing
- Faster Fund Exchange (ERC20 transaction)
- Sequential Contract Execution (Gomoku)
- Parallel Contract Execution (Rock-Paper-Scissors)
- Multi-party Applications (Monopoly)

Evaluation: Time Cost for Transaction Authentication



- AES-GCM is 3-4 orders faster than ECDSA.

Evaluation: Transaction Performance

- We use the popular layer-2 network, the LN, as a baseline.
- The experiment results are averaged from 10,000 trials.

	Payment	ERC20	Gomuku	RPC
LN	192.630	N/A	N/A	N/A
SEV:AES-GCM	0.1372	0.1382	0.6667	0.1365
SGX:AES-GCM	0.0205	0.3500	0.4500	0.1930
TZ:AES-GCM	20.496	40.148	95.092	37.215

Local time cost for end-to-end transaction (ms)

	LN (lnd)	**Speedster**			
	Payment		ERC20	RPC	Gomoku
Throughput (tps)	14 ±9 %	72,143 ±4 %	30,920 ±10 %	53,355 ±7 %	2,549 ±15 %
Latency (ms)	548.183 ±7 %	80.483 ±1 %	82.490 ±1 %	80.743 ±1 %	82.866 ±1 %

Channel performance in real-world Evaluation

Speedster has better performance than LN in payment processing.

Evaluation: Channel System Comparison

Features	Channel Projects							
	LN [68]	TeeChan [65]	TeeChain [66]	DMC [37]	SFMC [24]	Perun [40]	Celer [38]	Speedster
Direct Off-chain Channel Open	✗	✓	✓	✗	✓	✓	✗	✓
Direct Off-chain Channel Close	✗	✗	✓	✗	✓	✓	✗	✓
Dynamic Deposit	✗	✗	✓	✗	✓	✗	✗	✓
Off-Chain Contract Execution	✗	✗	✗	✗	✗	✗	✓	✓
P2PCN	✗	✗	✗	✗	✗	✗	✗	✓
Multi-Party State Channel	✗	✗	✗	✗	✓	✗	✗	✓
Dispute-Free	✗	✗	✓	✗	✗	✗	✗	✓
Duplex Channel	✗	✗	✓	✓	✓	✗	✗	✓

Feature comparison with other channel projects.

Speedster is the only project that provides all features.

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- **Conclusion**

Conclusion

- **Speedster** – efficient multi-party state channel system
  - — Leverage TEE.
  - — Use AES-GCM to encrypt transaction.
  - — Off-chain channels can be freely opened/closed.
  - — Dispute free.
  - — Support multi-party state channels.
  - — Cross-platform.

Thank you!

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https://fengweiz.github.com/