Threshcon

Multi-Party Threshold Ascon

NIST Threshold Call - Preview Talk

Categories N3.2, N3.3

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A little dry? I hope not

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2. Ascon (in MPC)
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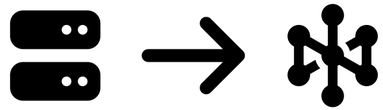
4. Performance & Conclusion

Why Care about Multi-Party Threshold Cryptography?

Generic to Concrete

what do we want to achieve? 

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- **Oblivious decryption**: yield plaintext w/o full key

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- **[C]XOF**: **K**ey **D**erivation **F**unction, **P**seudo-**R**andom **N**umber **G**enerator

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- **Since then → Threshcon package plan:**
  - Formalized as **named crypto-systems** (Threshcon-AEAD128, Hash256, [C]XOF128)
  - Concrete **I/O secret-sharing interfaces**
  - **Rust reference implementation** in active development
  - Full **security characterization**

Scope

Element	**Threshcon Plan**
Class / Categories	**N3.2** (Ascon-AEAD Enc/Dec), **N3.3** (Hash, XOF, CXOF)
Reference primitive	**Ascon** (NIST SP 800-232)
Interoperability	**Strictly Interchangable**

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  - Ascon-AEAD128 $\rightarrow$ **`Threshcon-AEAD128`**
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  - Ascon-Hash256 $\rightarrow$ **`Threshcon-Hash256`**
  - Ascon-XOF128 $\rightarrow$ **`Threshcon-XOF128`**
  - Ascon-CXOF128 $\rightarrow$ **`Threshcon-CXOF128`**
- **Unifying technique:** Ascon permutation eval via RMFE-packing over optimized Bool. circuit

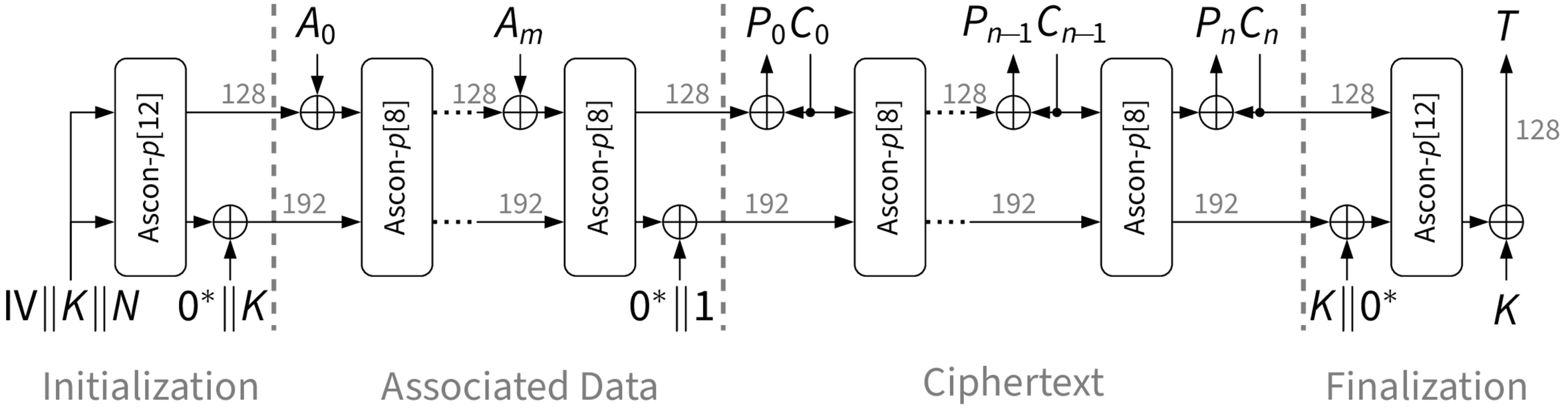
System & Threat Model

Aspect	**Threshcon Model**
Adversary behavior	**Active-malicious**
Corruption threshold	$t < n/3$ (honest supermajority)
Security type	**Information-theoretic**
Setup assumption	**Preprocessing model**
Network model	Synchronous; complete network of secure, authenticated channels

Background - Ascon Structure

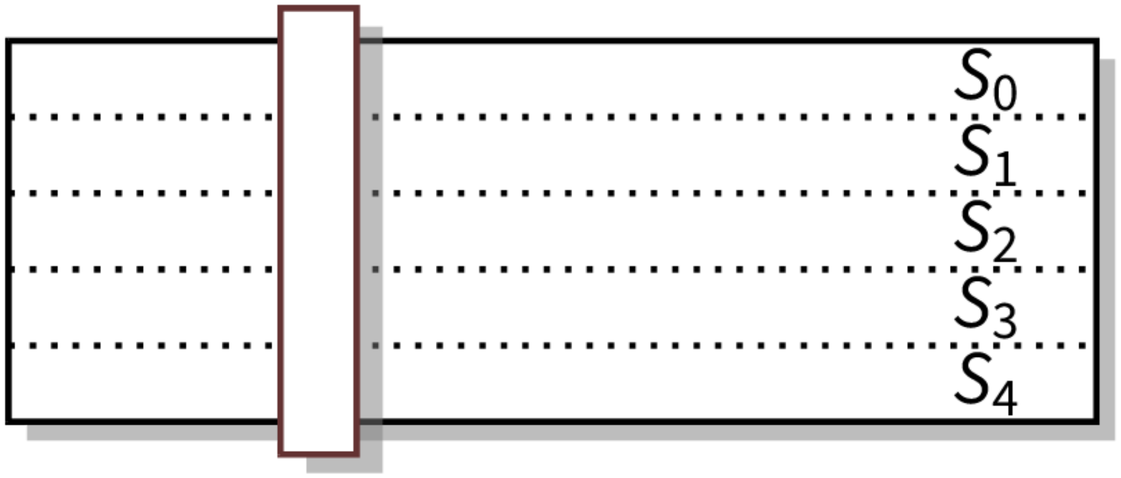
Built around Permutation: $p = p_L \circ p_S \circ p_C$

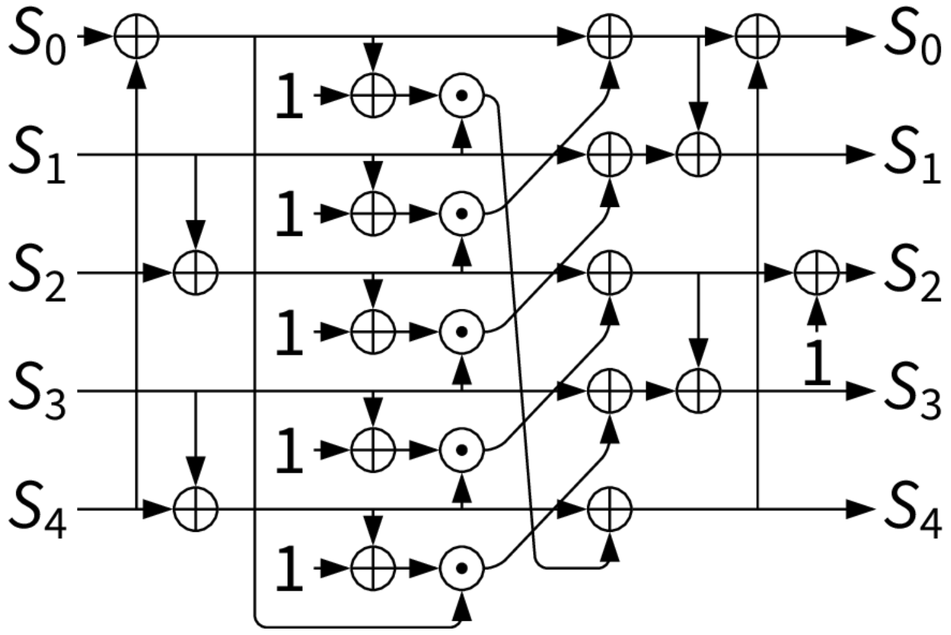
Ascon-AEAD128 authenticated decryption mode:



Background - Ascon Structure

Substitution layer, state structure and function:





Linear layer:

$$\Sigma_0(S_0) = S_0 \oplus (S_0 \ggg 19) \oplus (S_0 \ggg 28)$$

....

Background - Reverse-Multiplication Friendly Embeddings (RMFEs)

A Set of ϕ, ψ mappings called a $(k, m)_q$ RMFE "imitates" a homomporhism between vectors and field elements.

Core Approach: RMFE-Packed Ascon (Recap)

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  - With $(3, 5)_2$ RMFE: **3 packed S-boxes per field multiplication**
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- *Full details: WPES'25 Paper (**ia.cr/2025/1538**)*

Specification Strategy

Component	**Approach**
Security definition style	Ideal functionality for Ascon permutation; game-based for composite modes
Modularity	Layered architecture (RMFE → MPC → Ascon → Modes)
Parameterization	Configurable $(k, m)_2$ RMFE parameters; threshold profile (t, n)

I/O Secret-Sharing Modes

Per NIST Call Requirements (§10.3, Req. 10.9)

AEAD Mode	**Key K**	**Nonce N**	**Assoc. Data A**	**Plaintext PT**	**Ciphertext CT**	**Tag T**
Encryption	→ ■	→ □	→ □	→ □	← □	← □
Decryption	→ ■	→ □	→ □	← □	→ □	→ □

Hash Mode	**Message M**	**Length L**	**Customization Z**	**Output H**
Hash	→ ■	-	-	← □
XOF	→ ■	→ □	-	← □
CXOF	→ ■	→ □	→ □	← □

Legend: ■ = shall be secret-shared - □ = may be secret-shared - → input - ← output

Threshcon-AEAD128

Function Interface (Category N3.2)

Core operations:

- $\texttt{Threshcon-AEAD128.enc}([K], N, A, PT) \rightarrow (CT, T)$ or $([CT], [T])$
- $\texttt{Threshcon-AEAD128.dec}([K], N, A, CT, T) \rightarrow PT$ or $[PT]$

Sharing functions:

- $\texttt{ShareKey}(K, P_i) \rightarrow [K]$; $\texttt{ShareNonce}(N, P_i) \rightarrow [N]$; $\texttt{ShareAssoc}(A, P_i) \rightarrow [A]$; $\texttt{SharePT}(PT, P_i) \rightarrow [PT]$; $\texttt{ShareCT}(CT, P_i) \rightarrow [C]$; $\texttt{ShareTag}(T, P_i) \rightarrow [T]$
- **Design principle:** Minimal required signature + flexibility

Threshcon-Hash256 & [C]XOF128

Function Interface (Category N3.3)

Core operations:

- $\texttt{Threshcon-Hash256}([M]) \to H$ or $[H]$
- $\texttt{Threshcon-XOF128}([M], L) \to H$ or $[H]$
- $\texttt{Threshcon-CXOF128}([M], L, Z) \to H$ or $[H]$

Sharing functions:

- $\texttt{ShareMsg}(M, P_i) \to [M]$; $\texttt{ShareLen}(L, P_i) \to [L]$; $\texttt{ShareCust}(Z, P_i) \to [Z]$
- Hash/XOF modes keyless, but **message is SSI** per Req. 10.9
- CXOF's customization parameter Z, length may be secret-shared (domain separation secrecy)

Protocol Modules

Layered Architecture (Spec Organization)

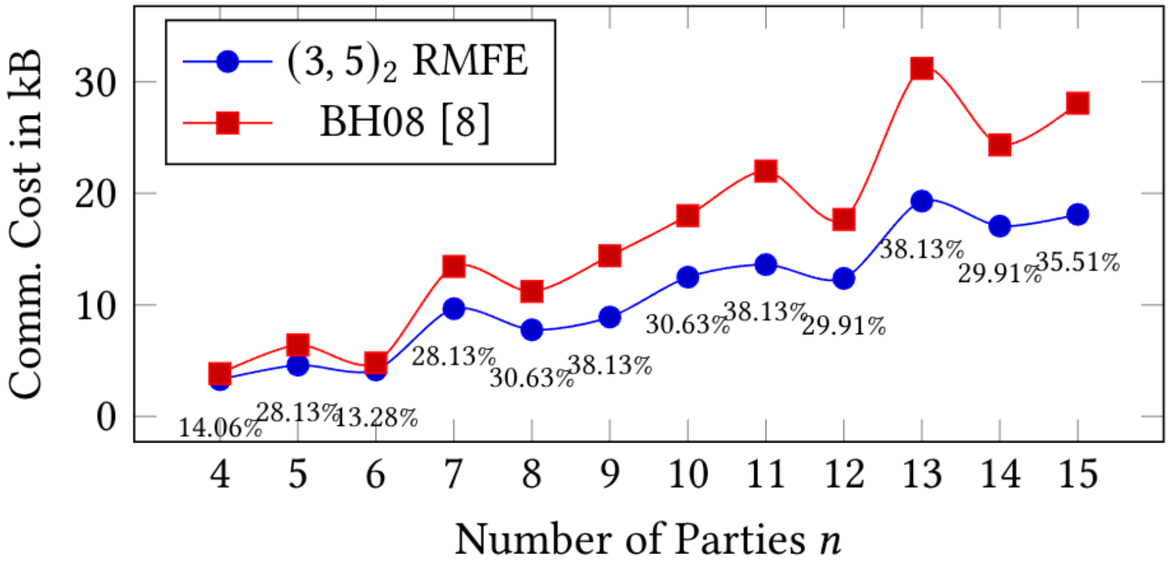
Layer	Component	Basis
Foundation	RMFE encoding/decoding	CCXY18 (Cascudo et al., CRYPTO'18)
MPC Framework	Arithmetic MPC with player elimination	BH08 (Beerliová-Trubíniová & Hirt, TCC'08)
Ascon-specific	Permutation, Packed linear layer (bit rotations)	SPAP25 (Schwarz et al., WPES'25)
Mode adaptation	AEAD / Hash / XOF / CXOF circuits	New (this package)

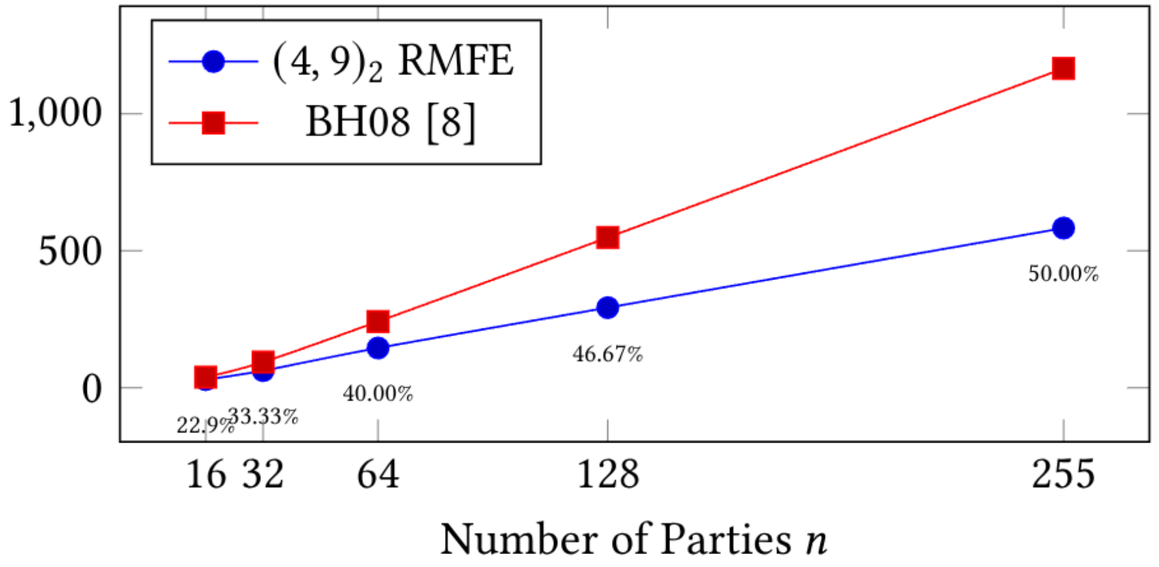
Sub-protocols: `ReconsPriv`, `ReconsPubl`, `Input`, `XOR`, `AND`, `MultiRightRotate`

Reference Implementation Status

Aspect	Status
Language	**Rust** (cargo build system)
Repository	**Active development**; public release planned with package submission
License	EUPL v1.2
Architecture	**Crypto** engine (Ascon + CCXY18 + BH08) **separated** from networking (QUIC/TLS)
Key dependencies	`tokio` (async runtime), `quinn` (QUIC transport), `rand`, `criterion`
Testing	KATs against Ascon test vectors; malformed-share injection; network fault simulation

Performance: Theoretical Results





- **Baseline:** Boolean BH08 (per-bit Shamir sharing)
- **Gain source:** SIMD amortization - ~~individual AND gates~~ field multiplications
- **Full empirical benchmarks:** Work in progress (see Evaluation Plan)

Preprocessing Communication Costs

Comparing RMFE packing vs. naive Boolean evaluation (BH08) Parameters: $n = 13, t = 4, (3, 5)_2$ *RMFE*

Concrete Communication Sent (Bits):

Workload	Baseline (BH08)	Threshcon (RMFE)	Reduction
1 Permutation (p)	583,680 bits	358,140 bits	**~38%**
1 Block (p^8)	~4.6 MB	~2.7 MB	**~41%**
1 KiB Data ($p^{8 \cdot 64}$)	~298.8 MB	~173.6 MB	**~41%**

- **Why it matters:** RMFE packing amortizes randomness generation for p_S, p_L layers.

Experimental Evaluation Plan

Metric	Target Platform
Online communication (bits/round)	16-core / 64 GB (NIST baseline)
Latency (ms/permutation)	Local loopback, LAN/WAN sim.
Throughput (bits/sec)	Local loopback, LAN/WAN sim.
Scalability (n)	$n \in \{4, 7, 13, 31, 63, 127, 255\}$

- Comparison Baseline: BH08-MP-SPDZ baseline, theoretical eval, pot. N3 submissions
- **Includes:** All-honest configuration + corrupted-party configurations per Call Req.
- **Amortization study:** Multi-block throughput for AEAD (128-bit rate) vs. Hash (64-bit rate)

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- **In progress ⏳:** Full AEAD/Hash/XOF mode circuits; QUIC networking layer; KAT suite; protocol optimizations
- **Outstanding 🚧:** Empirical WAN benchmarks; security proof writeup; spec finalization

Takeaways

1. **Threshcon:** bandwidth-optimized thresholdization of Ascon family (AEAD, Hash, [C]XOF), strictly interchangeable
2. **Info-theoretic active-adaptive security** at $t < n/3$, no computational assumptions, achieved via RMFE-packed Boolean evaluation
3. **Rust-based reference implementation** until October '26

Writeup: Available via NIST-MPTC

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Paper: ia.cr/2025/1538

Questions?