



NuCypher

<presenter name(s), role(s)>

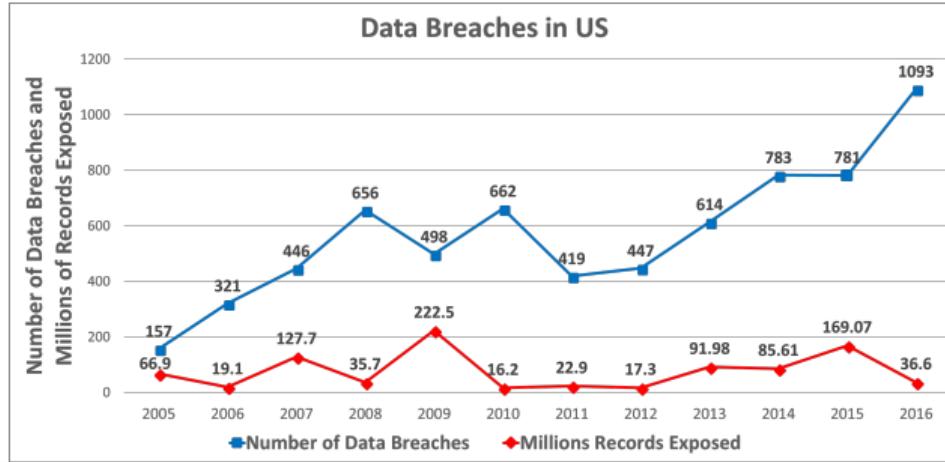
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NuCypher Overview

- Use cryptography to build the tools & infrastructure to preserve data privacy
- Privacy-preserving solutions for distributed applications
 - ▶ Proxy Re-encryption (PRE)
 - ★ Secure data-sharing and access control of encrypted data
 - ▶ Fully Homomorphic Encryption (FHE)
 - ★ Perform arbitrary operations on encrypted data
- Blockchain & Private Deployments

Problem

Data Breaches

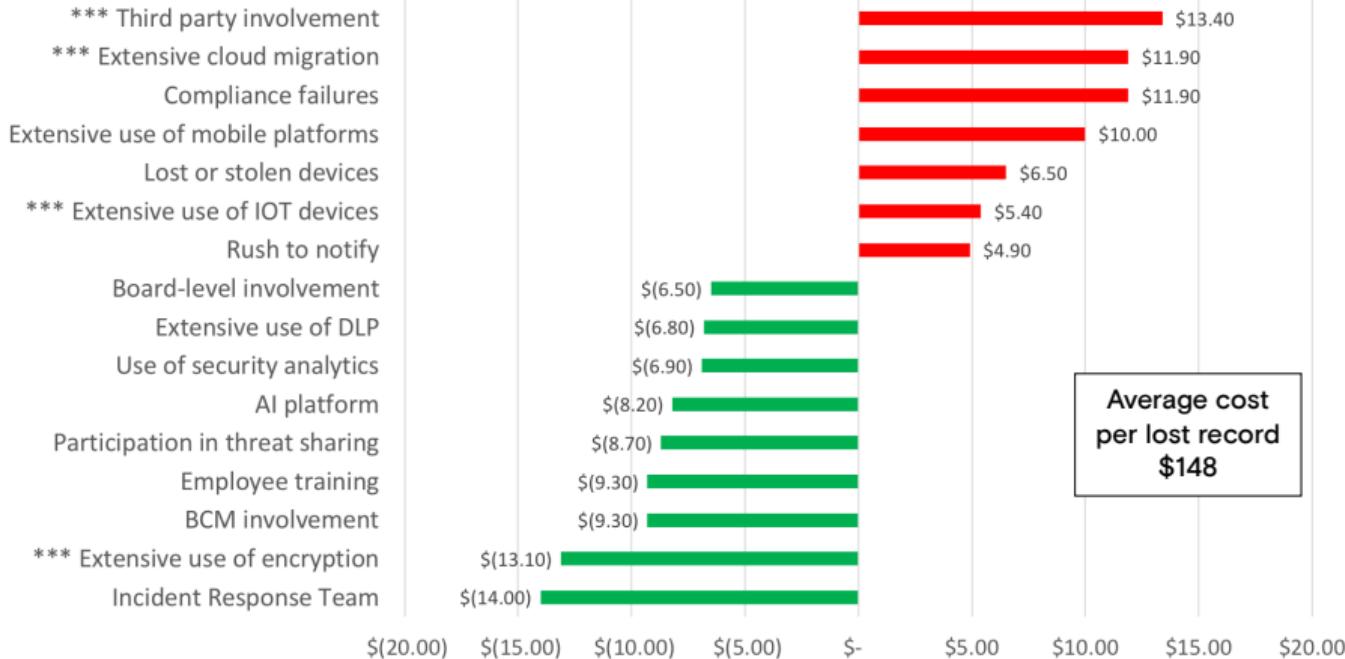


Source:

<https://www.statista.com/statistics/273550/data-breaches-recorded-in-the-united-states-by-number-of-breaches-and-records-exposed/>

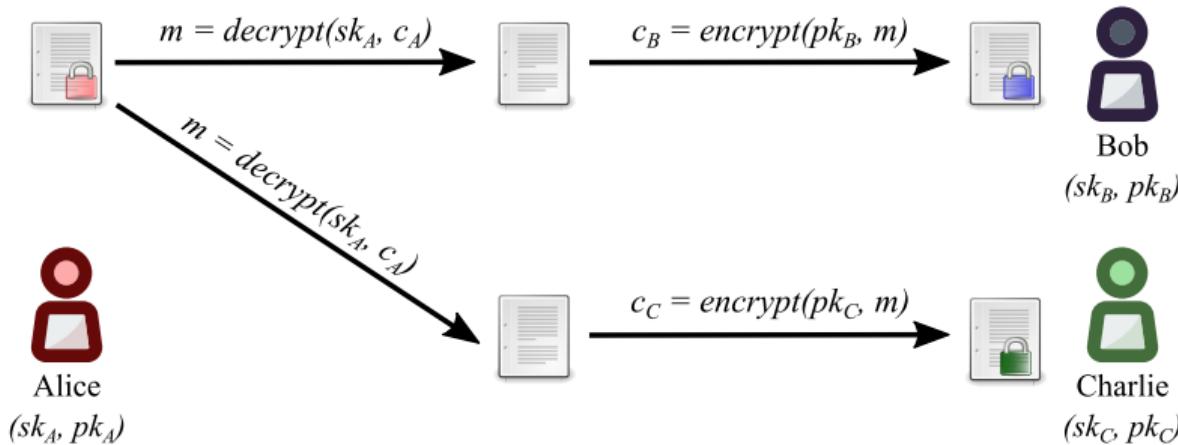
Impact of Data Breaches

Impact on Per Lost Record Cost (US\$)



Source: IBM 2018 Cost of a Data Breach Study: Global Overview, <https://www.ibm.com/security/data-breach>

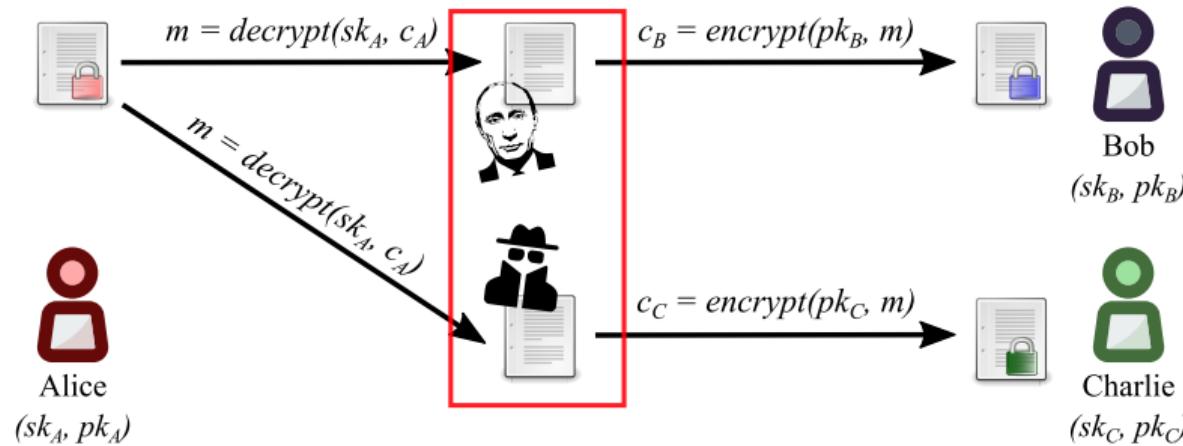
Public Key Encryption (PKE)



Limitations

- Decryption required before sharing
- Not scalable
- Complex access revocation

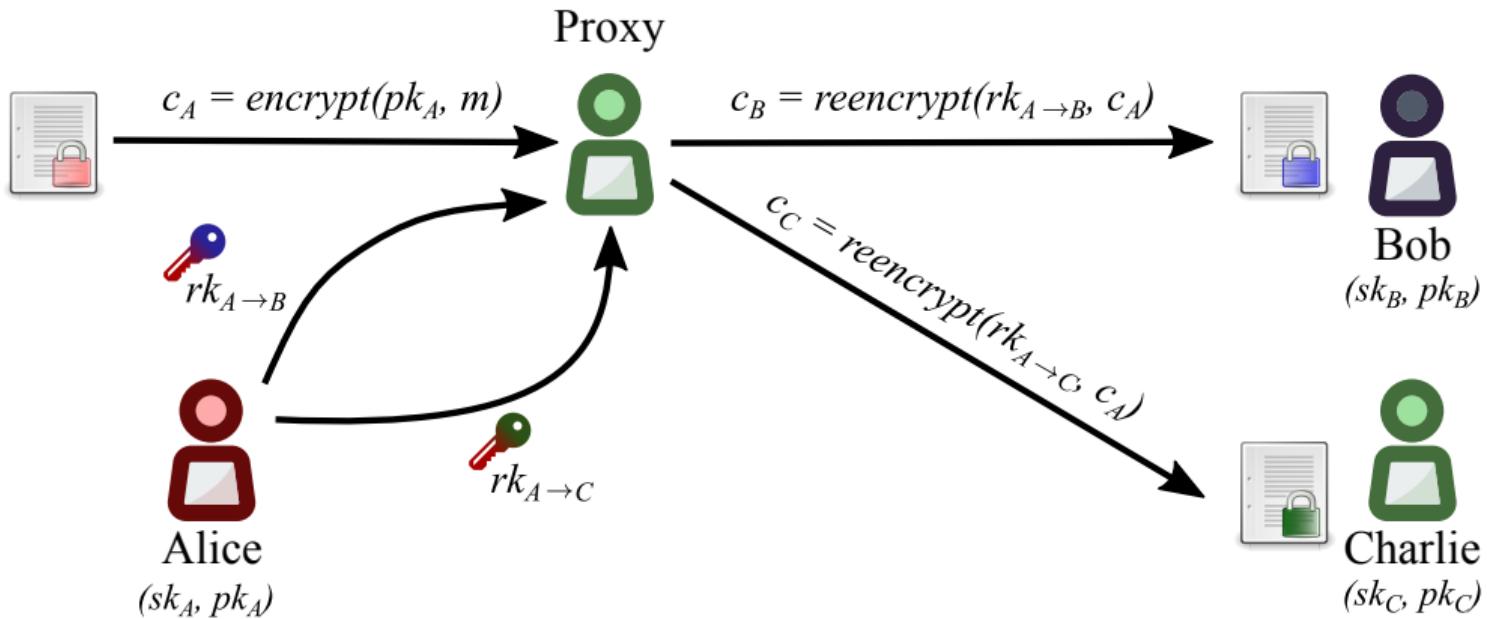
Public Key Encryption (PKE)



Limitations

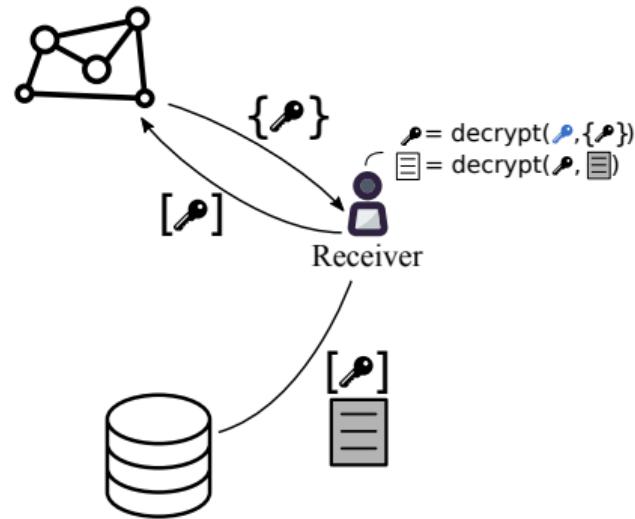
- Decryption required before sharing
- Not scalable
- Complex access revocation

What is proxy re-encryption (PRE)



Solution

Proxy Re-encryption + Key Management

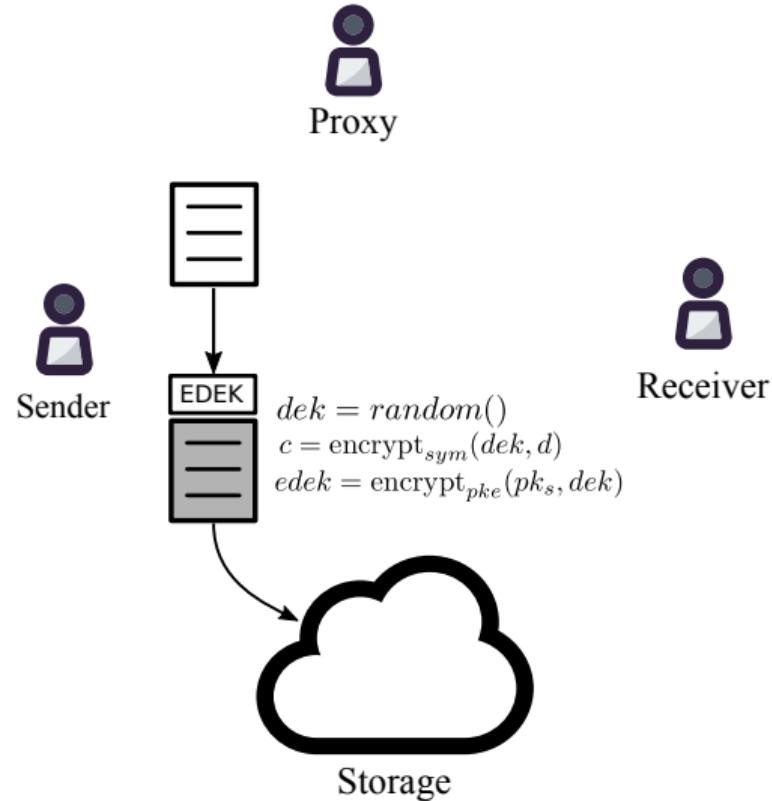


Advantages

- Data not decrypted to facilitate sharing
- Scalable and performant
- Access revocation through re-encryption key deletion
- Secure use of data storage providers

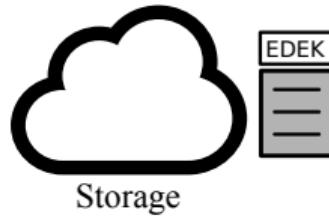
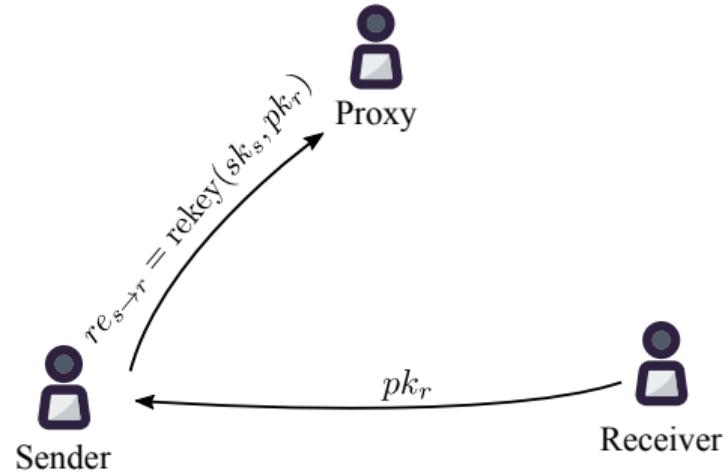
Centralized KMS using PRE

Encryption



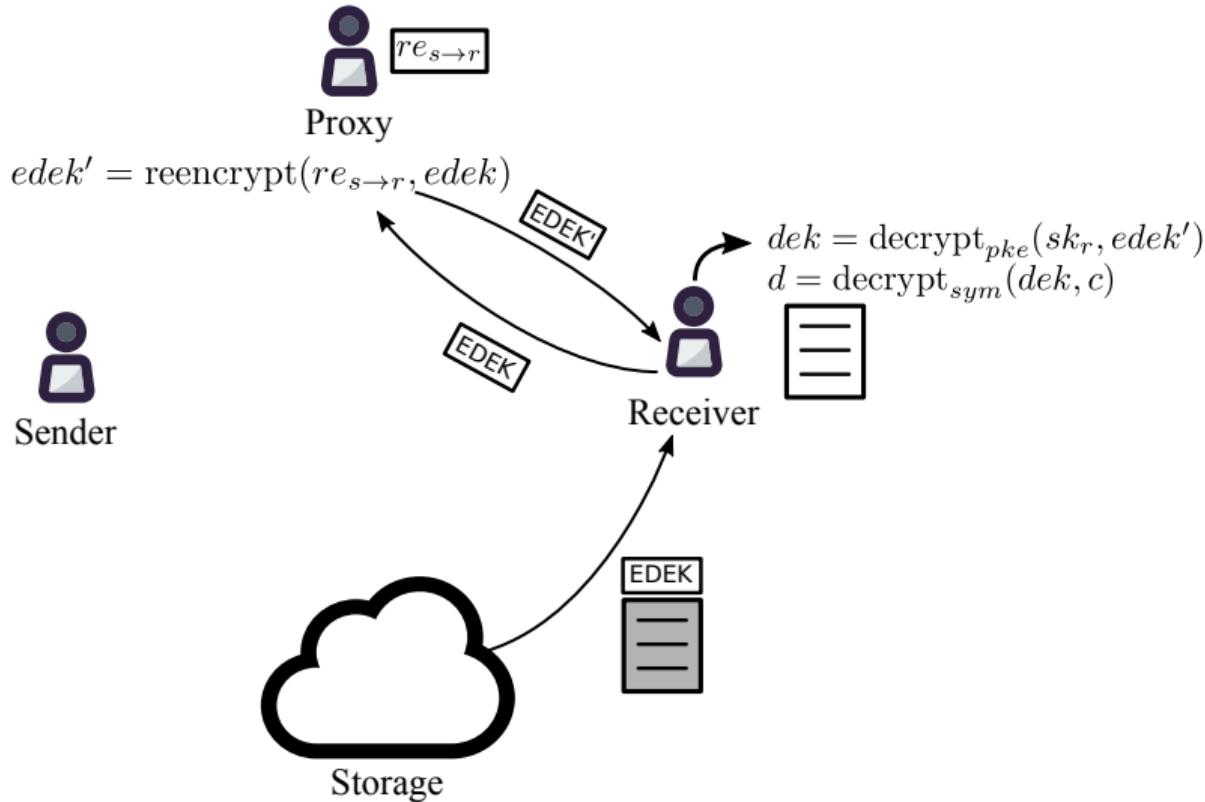
Centralized KMS using PRE

Access delegation



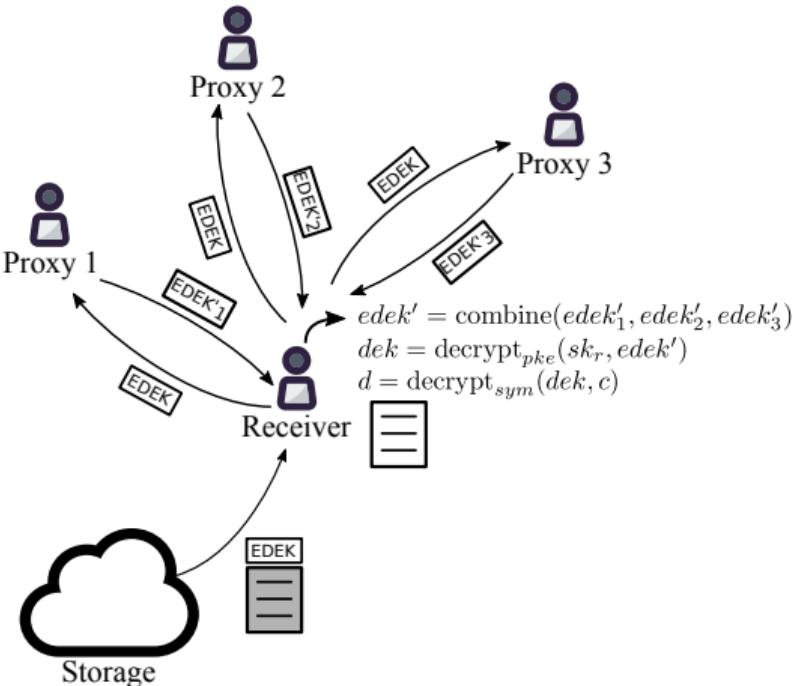
Centralized KMS using PRE

Decryption



Decentralized KMS using PRE

Using threshold split-key re-encryption (Umbral)



NuCypher PRE Properties

- Unidirectional
- Single hop
- Non-interactive

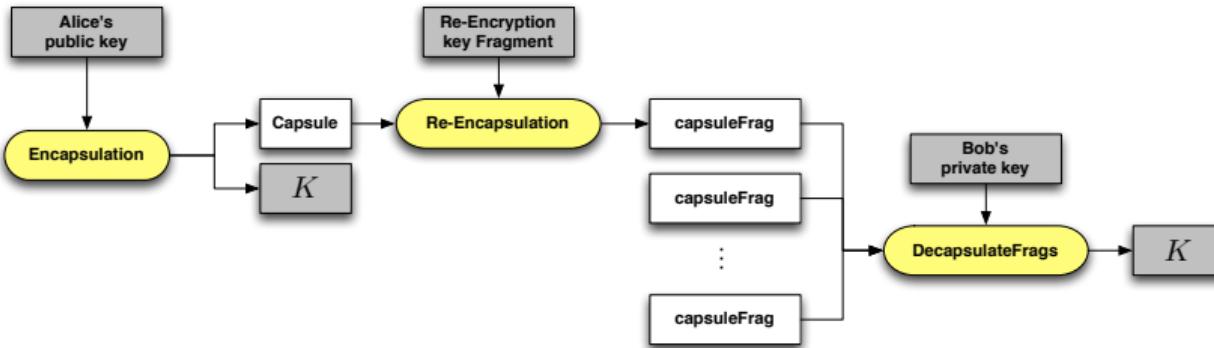
KEM/DEM Approach

- Umbral KEM for threshold re-encryption
- ECIES for key encapsulation
- DEM can be any AE (ChaCha20-Poly1305)

Verification of Correctness

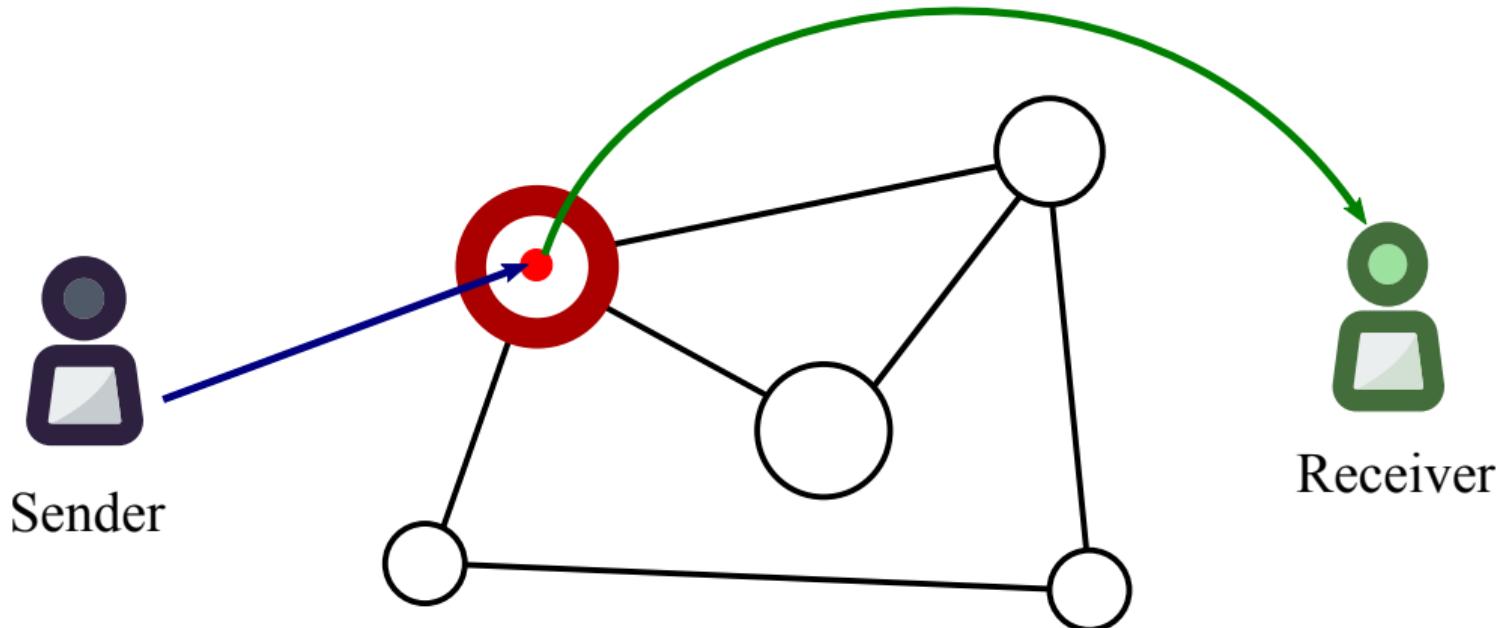
- Verification through non-interactive ZK proof
- Incentive layer via NU staking token
- Re-encryption validated by challenge protocol

Umbral Flow Diagram



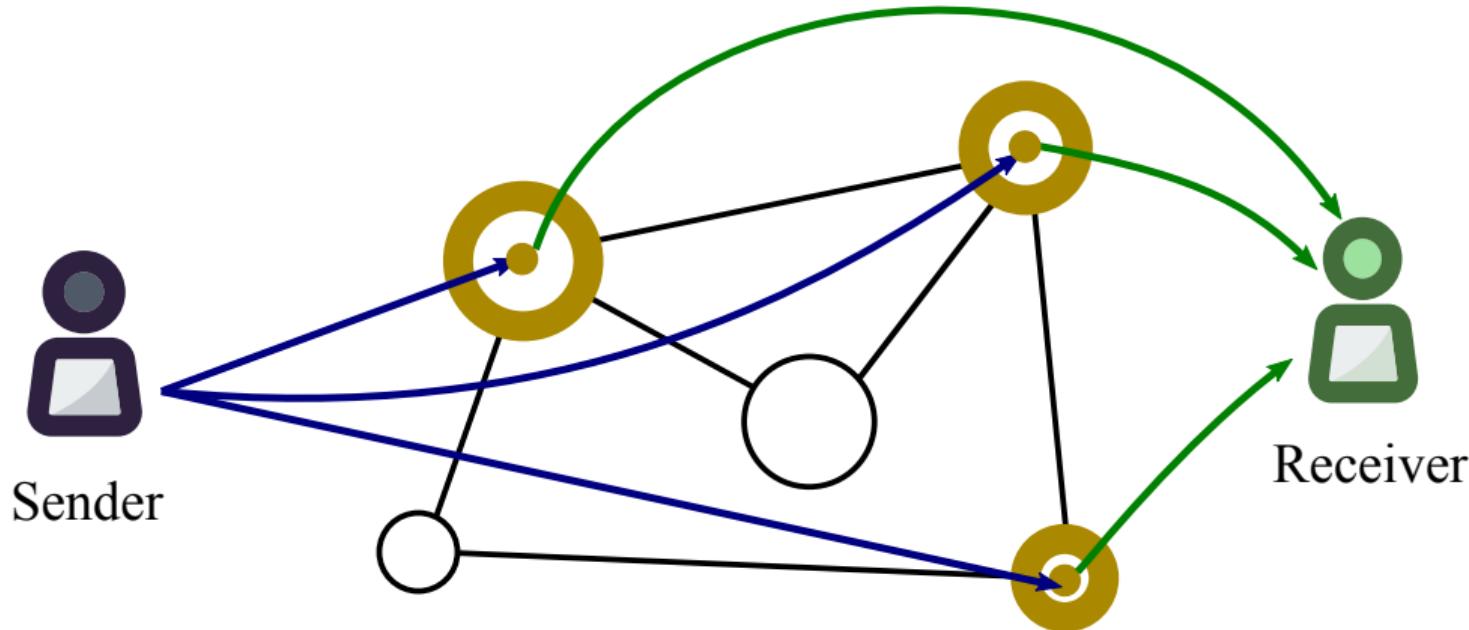
- Reference implementation: <https://nucypher.dev/pyUmbral>
- Documentation: <https://nucypher.dev/umbral-doc>

KMS Network: Data Sharing + PKE



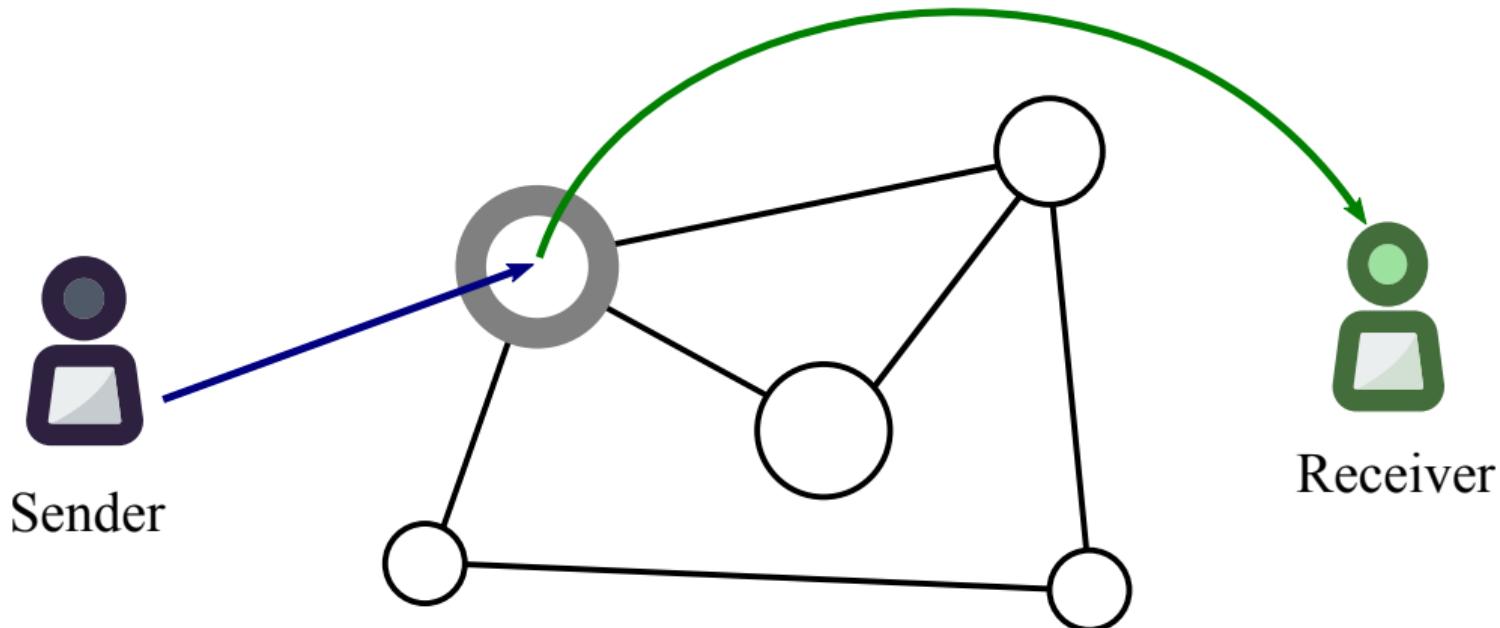
- Single node has access to data
- Single node can deny to do work

KMS Network: Data Sharing + PKE + Shamir Secret Sharing



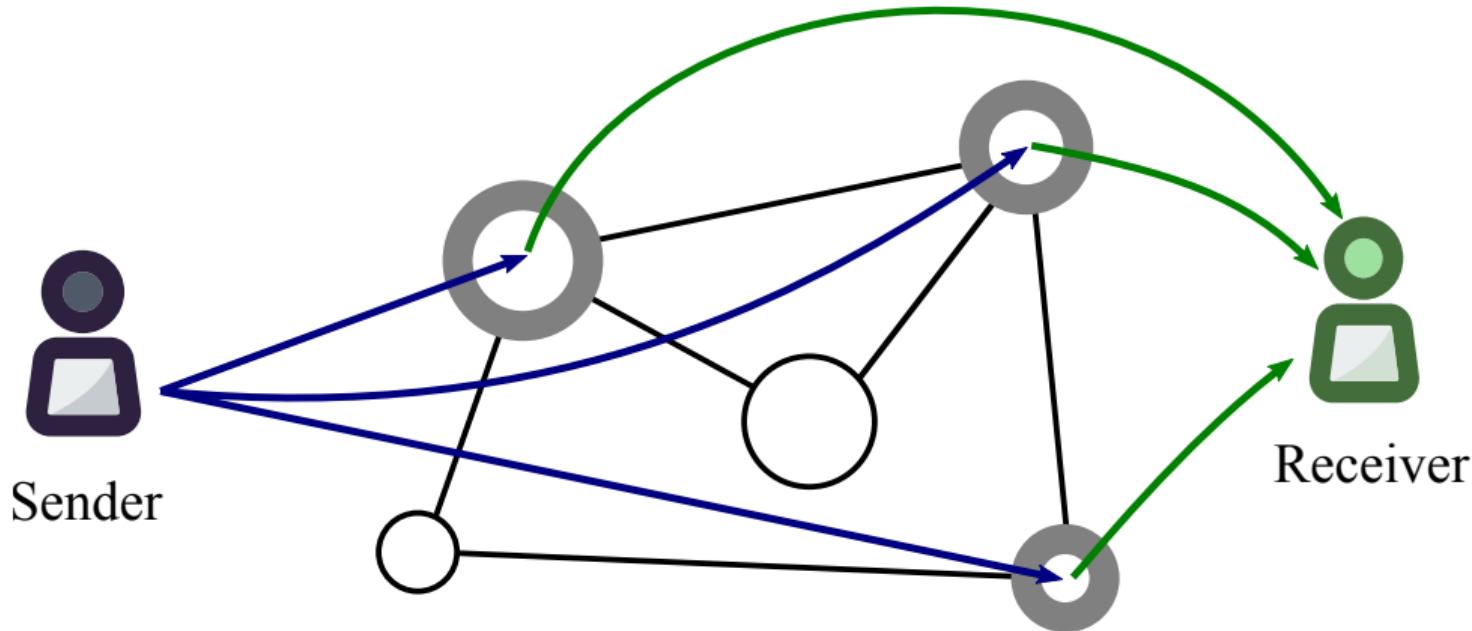
- Nodes can collude to gain access to data

KMS Network: Data Sharing + PRE



- Single node collusion with receiver possible
- Single node can deny to do work

KMS Network: Data Sharing + Threshold PRE (Umbral)



- Collusion now requires m nodes + receiver

NU Token

Purpose

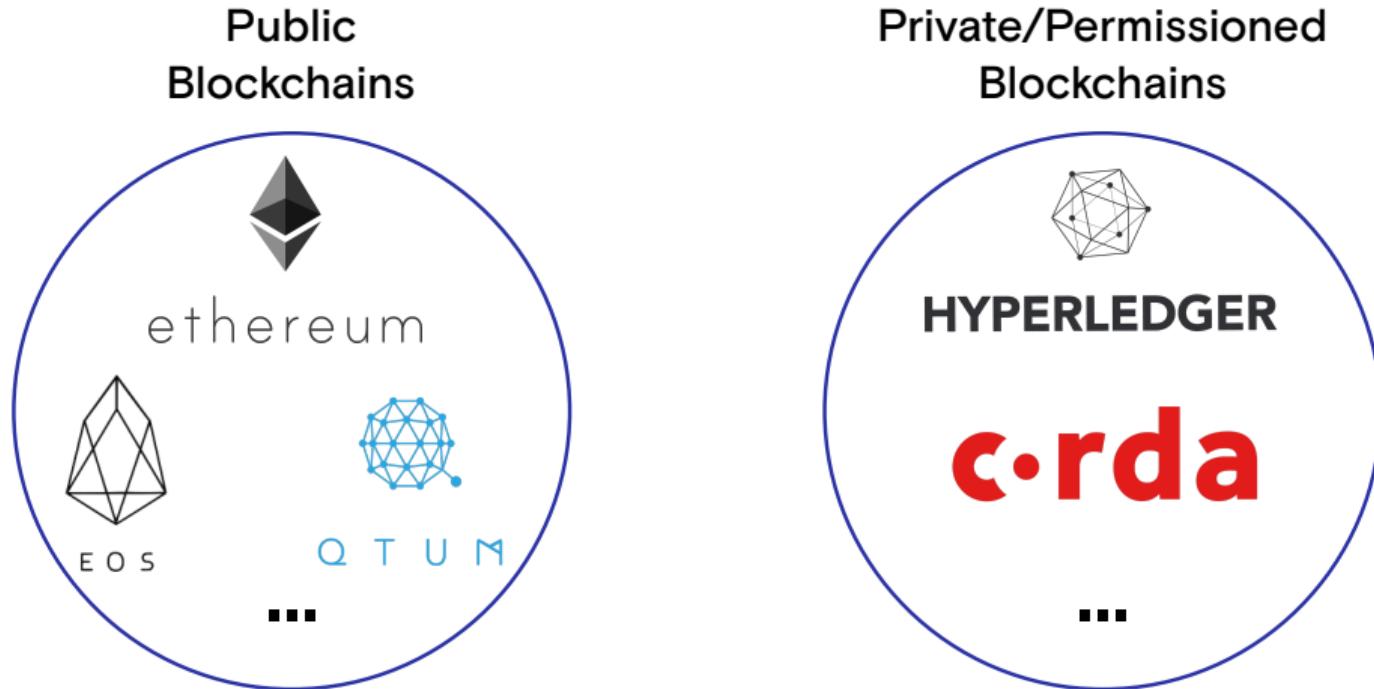
- Splitting trust across re-encryption nodes
 - ▶ More tokens = more trust, more work, and more compensation
- Proof of Stake for minting new coins according to the mining schedule
- Security deposit at stake against malicious behavior of nodes

Data Sharing Policies

- Time-based
- Conditional on payment
 - ▶ “Grant access once paid, continue granting while paying”
- Smart contract (public) method

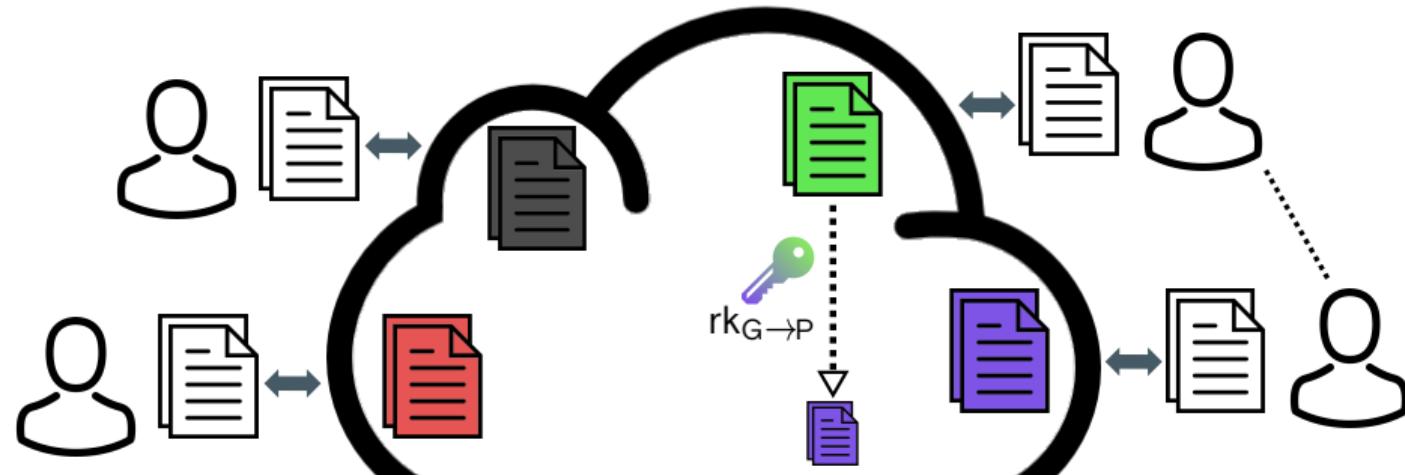
Decentralized re-encryption nodes (Ursulas) relied on to apply conditions without having the ability to decrypt data

Blockchain & Smart Contract Agnostic



Use Cases

Multi-tenant, Multi-source Encrypted Data Lake

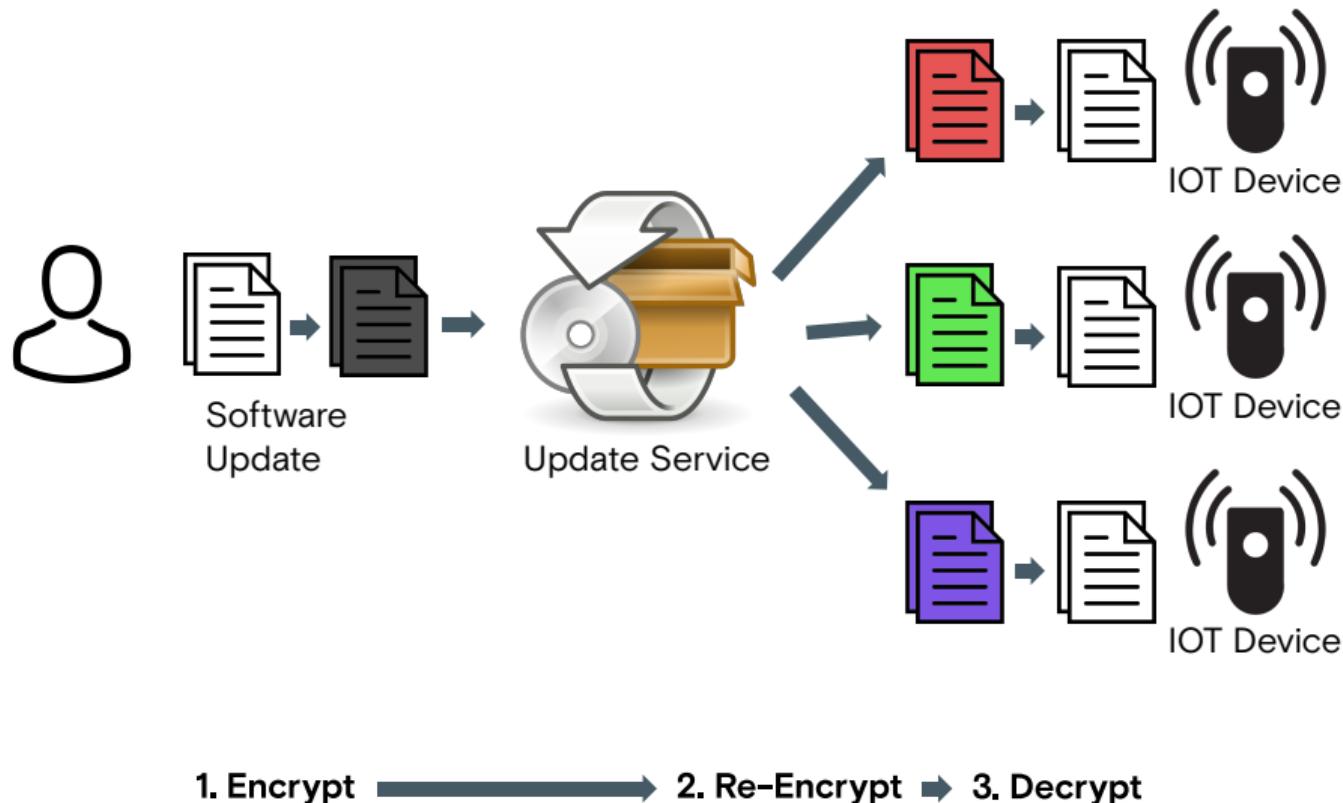


Encrypted Data Lake

1. Encrypt → 2. Re-Encrypt → 3. Decrypt

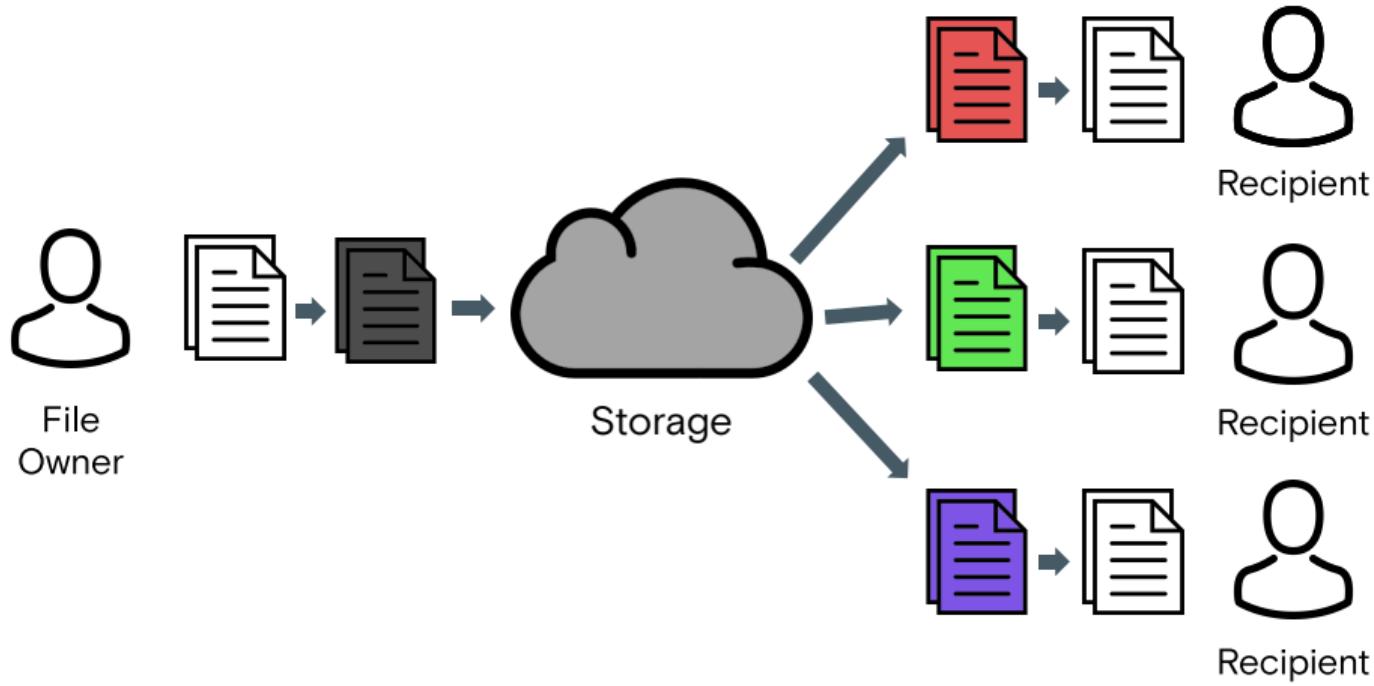
Use Cases

Scalable, Secure IOT Updates



Use Cases

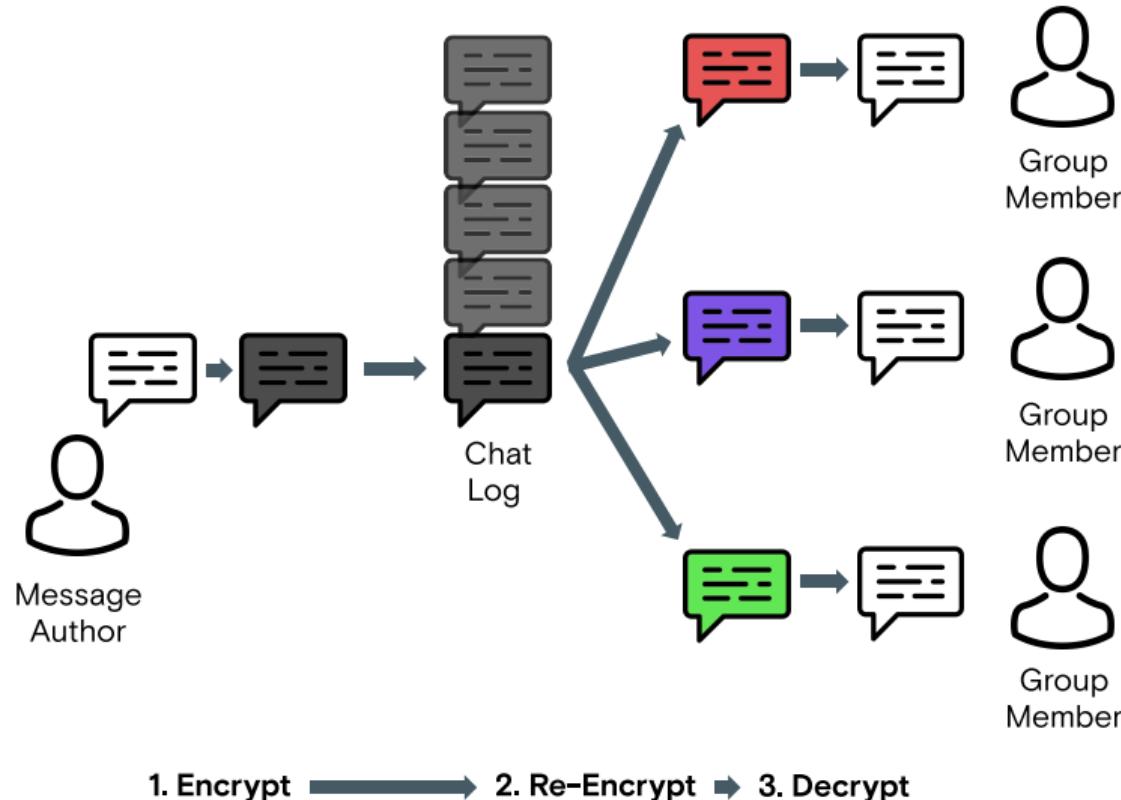
Encrypted file sharing



1. Encrypt → 2. Re-Encrypt ➔ 3. Decrypt

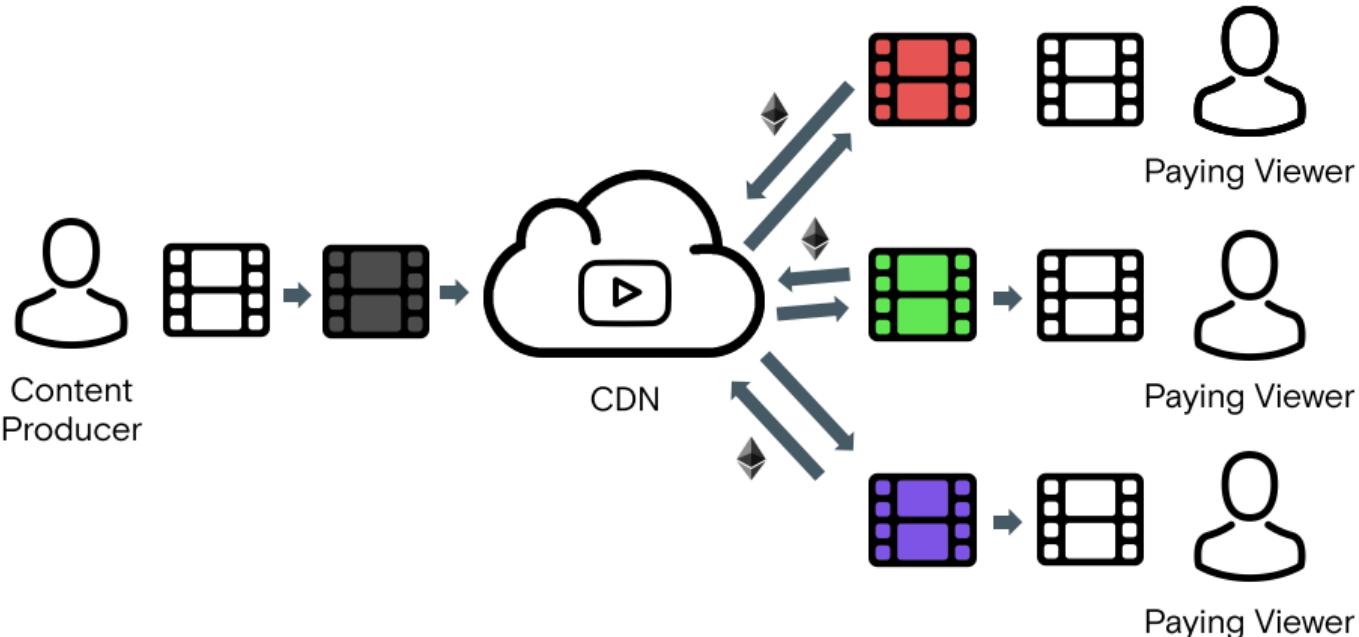
Use Cases

Encrypted multi-user chats



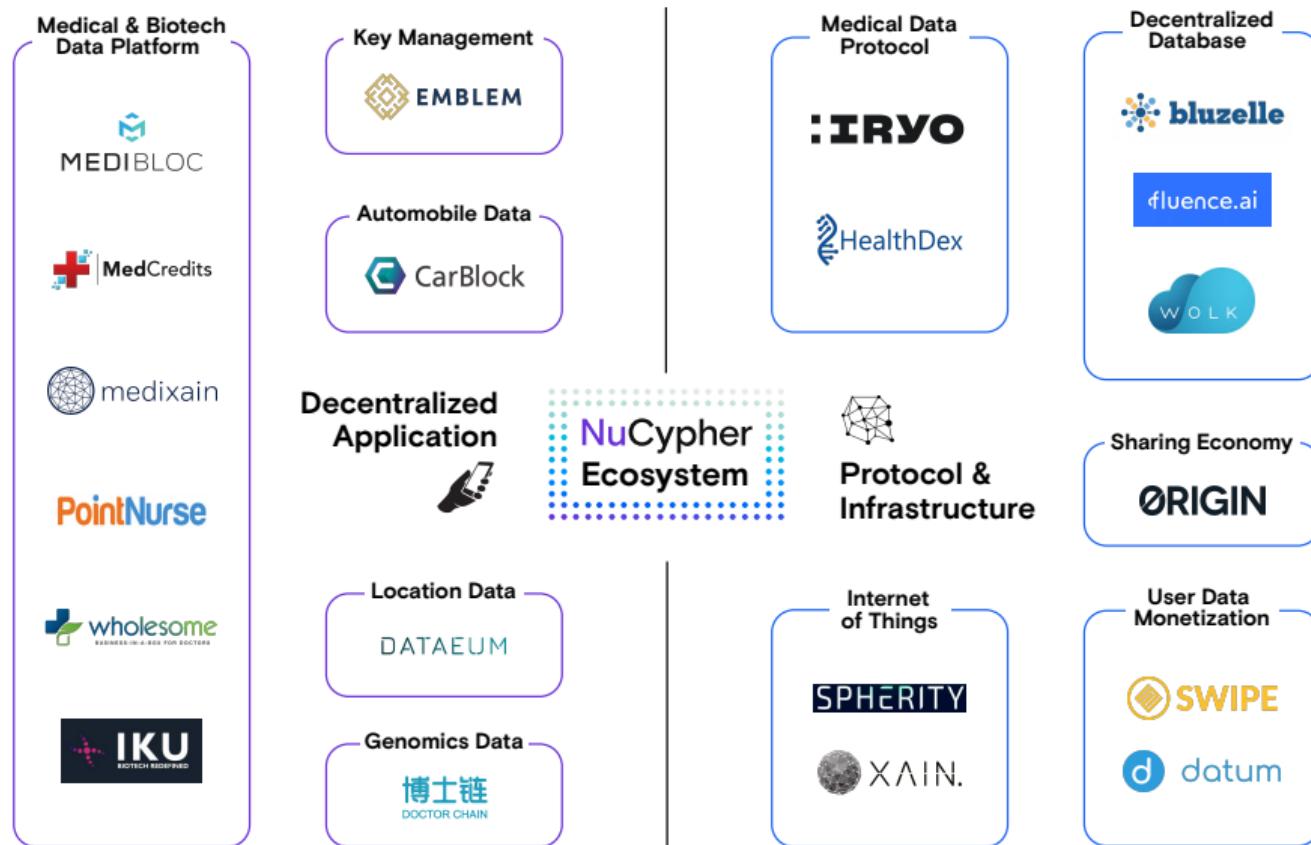
Use Cases

Decentralized access-controlled content



1. Encrypt
2. Conditional Re-Encrypt
3. Decrypt

Early Users



Competing Technology

Data Masking and Tokenization

- Less secure for data with underlying patterns
- Reduce the value of data by obfuscating it

Public Key Encryption

- Data must be decrypted before it is shared
- Not Scalable

Multi-Party Computation

- Interactive protocol
- Slow Performance

Fully Homomorphic Encryption

- Slow Performance
 - ▶ NuCypher has developed a GPU-accelerated FHE library: nuFHE

Fully Homomorphic Encryption

nuFHE library

- GitHub: <https://nucypher.dev/nufhe>
- GPU implementation of fully homomorphic encryption
- Uses either FFT or integer NTT
- Achieved 100x performance over TFHE benchmarks

Platform	Library	Performance (ms/bit)	
		Binary Gate	MUX Gate
Single Core/Single GPU - FFT	TFHE (CPU)	13	26
	nuFHE	0.13	0.22
	Speedup	100.9	117.7
Single Core/Single GPU - NTT	cuFHE	0.35	N/A
	nuFHE	0.35	0.67
	Speedup	1.0	-

FHE Proof of Concept

Sputnik

- GitHub: <https://nucypher.dev/sputnik>
- Assembly language and interpreter for FHE that uses nuFHE
- Commits a merkle root of computation to the blockchain for proof of logic flow
- Used to execute first homomorphic smart contract at ETHBerlin 2018



ETHBerlin
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PLEASE give a round of applause to
Sputnik!!! They are the first winners of our
open track!! They designed A byte code
assembly type language! YAAAAAASSSSS
GUYS #ETHBerlin

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>\$15M in Venture Funding

POLYCHAIN
CAPITAL



compound



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capital

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Co-founder and CTO



David Nuñez, PhD
Cryptographer



John Pacific (tux)
Engineer



Justin Myles Holmes
Engineer



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Ravital Solomon
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Damon Ciarelli
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Advisors



Prof. Dave Evans
University of Virginia



Prof. Giuseppe Ateniese
Stevens Inst. of Technology



John Bantleman
Rainstor



Tony Bishop
Digital Realty

More Information



NuCypher

Website: <https://www.nucypher.com>

Whitepaper: <https://nucypher.dev/whitepaper/blob/master/whitepaper.pdf>

Proxy Re-encryption Network: <https://nucypher.dev/nucypher>

Umbral Reference Implementation: <https://nucypher.dev/pyUmbral>

nuFHE: <https://nucypher.dev/nufhe>

Discord: <http://discord.nucypher.com>

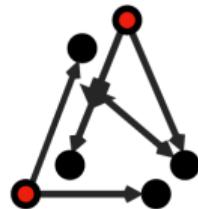
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E-mail: hello@nucypher.com

Appendix: Umbral – Threshold Proxy Re-encryption

- “Umbral” is Spanish for “threshold”
- PRE properties: Unidirectional, single-hop, non-interactive
- Follows a KEM/DEM approach:
 - ▶ UmbralKEM provides the threshold re-encryption capability
 - ▶ Uses ECIES for key encapsulation with ZK proofs of correctness for verifiability on prime order curves (such as secp256k1)
 - ▶ DEM can be any authenticated encryption (currently ChaCha20-Poly1305)
- IND-PRE-CCA security
- Key splitting is analogous to Shamir Secret Sharing
- Verification of re-encryption correctness through Non-Interactive ZK Proofs
- Reference implementation: <https://nucypher.dev/pyUmbral>
- Documentation: <https://nucypher.dev/umbral-doc>

Appendix: Security Audits



Least Authority
Freedom Matters

Appendix: Fully Homomorphic Encryption

