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Percival: Secure Data Archival Using Secret Sharing

Thomas M Kroeger, Joel C Frank, Ethan L Miller

Sandia National Laboratories and University of California, Santa Cruz

Sandia National Laboratories

Threats to Long Term Data Archives

- **Insider Threat:** *Insiders can be put into one of three categories:*
  1. *Users*--those with legitimate operational need for the data
  2. *System administrators*--system administrators with digital and usually physical access
  3. *Facilities personnel*--those with physical access (e.g. janitorial staff, security guards etc...)

Resilient to 2 & 3 and new capabilities to mitigate abuses by legitimate users.

- **Compromised Repositories:** The rate of security events these days necessitates that any wise system designer plan for parts of their system being compromised.
- **Central Point for Attack:** The central design of most archives provides a clear, single target for attackers.

Secure Foundation: Shamir Secret Sharing

Shamir's Secret Sharing provides a data protection that goes far beyond just splitting the data into parts. It is **information theoretically secure** and uses the fact that one can uniquely define a polynomial curve of order *O* with *O+1* points.

Example: Any 3 of 5 Secret $S = 1234$

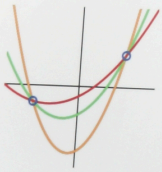
1. Create a polynomial of degree 2 by generating 2 random coefficients, e.g

$$f(x) = S + 166x + 94x^2$$

2. Generate 5 points along that curve:
   (1,1494); (2,1942); (3,2578);
   (4, 3402); (5,4414)

Any three enable me to solve for S.

All I know is S is a value on the Y-axis.
If I steal two points, I don't learn anything new.



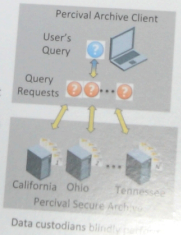
One can draw an infinite number of polynomials of degree 2 through 2 points.

Searching a Percival Archive

- Data is vulnerable when on the client.
- Create ability to operate on the data without needing to reassemble the shares.

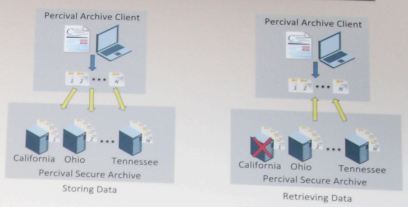
Keyword Search

- Recent research has explored protocols that enable keyword search across our archive.
- We use pre-indexing, key hashes, and bloom filters to provide a blinded search.
- The custodians do the searching but are blinded to the terms searched and the results of the query.
- Initial results with data from the Guttenberg project and Wikipedia have shown promise.



Data custodians blindly [illegible] the search

Percival: Using Secret Sharing for Resilient Data Archive



- Splits a 1K document into *N* shares of 1K that are stored by data custodians creating a distributed archive.
- To retrieve a document, the client gets and combines *T* shares.

- **Resilient to insider threat**. *T* different sites would have to collude.
- **Resilient to component compromise**. Able to operate with integrity and data protection in the presence of *T-1* compromised sites.
- **Resilient to crypto analytical attack**. *T-1* shares are information theoretic in their protections and are not susceptible to brute force decryption attacks.
- **Keyless**. Issues such as key rotation and revocation are moved to authentication.
- **Secure backup**. Beyond the data privacy protections, this system also provides a platform that, by design, securely protects from data loss due to equipment failure.

Potential Uses of Percival

Percival's architecture enables a broad range of capabilities for archive designers:

NNSA Data Archive

- Repositories at 9 sites, any 5 of which can be used to recover data (*N=9, T=5*).
- Secure operations with up to 4 sites compromised.
- Sites disconnecting from the internet because of internal compromise would not impact the archive's secure operations or data integrity.
- For OUO Archives, users could use a keychain for one sign-on to many repositories. For higher level data, multi-person access requirements could provide greater security.

Agency's Credit Card Data

- Many agencies (e.g. FEMA) have a large set of credit card records.
- All must be kept but most are never examined.
- Use Percival to split data into three shares (*N=3*).
- Outsource data repositories to 3 different cloud providers.
- Require two people to recover any credit card records; this inhibits insider abuse of credit card data. *(T=2)*

Percival Directions

Applied Research – Prototype development & Testing

- Expand initial proof of concepts to pursue a detailed prototype
- Exploring and testing searching across the prototype
- Explore adversarial models
  - Denial of service
  - Data integrity ECC type models to offer verification
  - Rebuilding after compromise
  - Detection of compromise
  - Man-in-the-middle threats

Open Research Questions

- Better search models
- Other transactions on split data
- More efficient transforms to split data
- Improved client side operations

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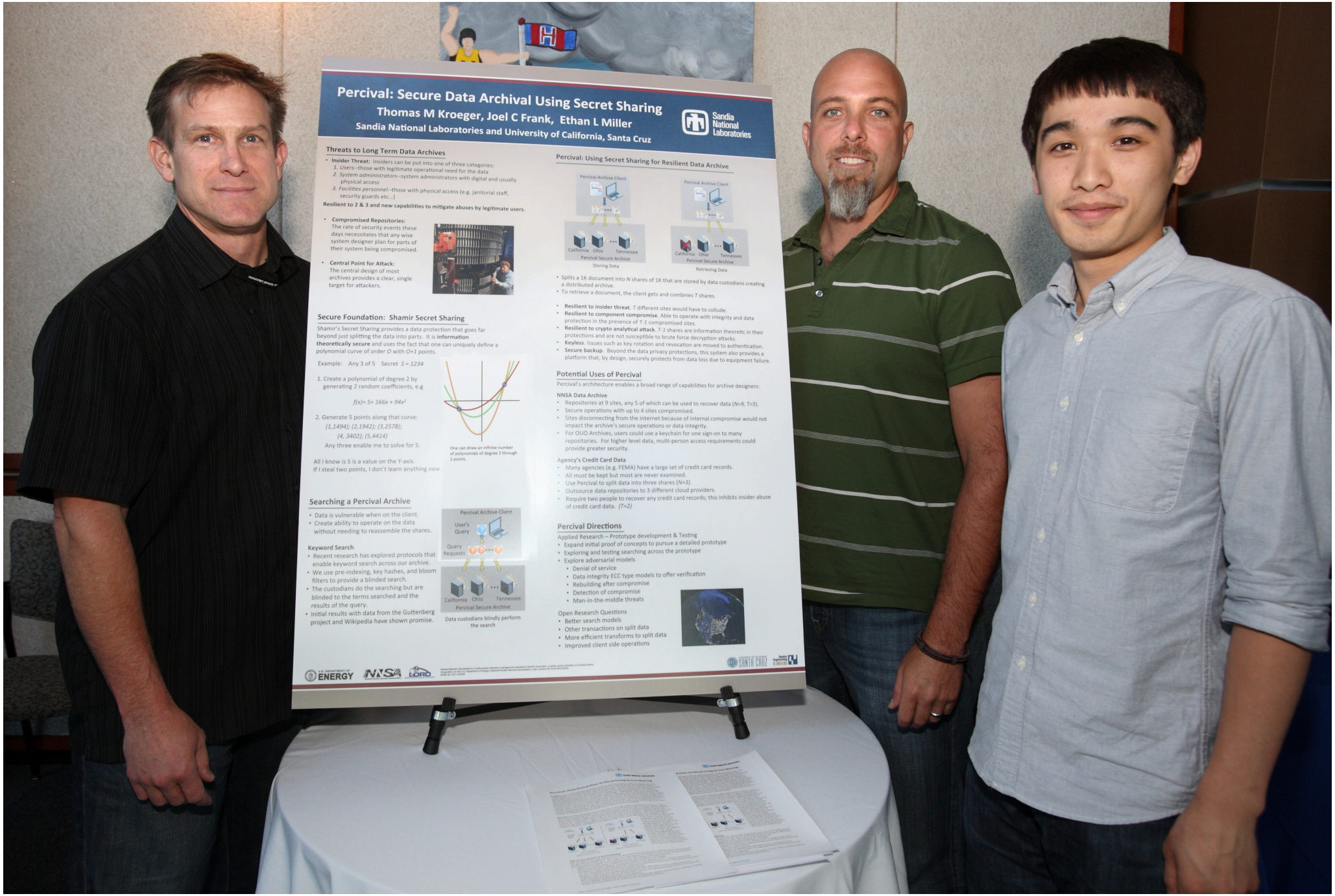
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Percival Archive Client
User's Query
Query Requests
California Ohio Tennessee
Percival Secure Archive
Data custodians blindly perform the search
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