On Error Correction in the Exponent

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MIT Computer Science and AI Laboratory

Theory of Cryptography Conference

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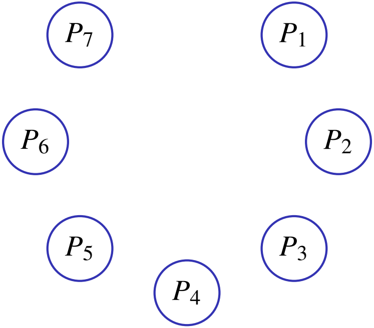
Error Correction (in the Exponent)

Sharing Secrets (mod q)

- Random $\mathbf{p}(\cdot)$, $\deg(\mathbf{p}) < k$, s.t. $\mathbf{p}(0) =$ secret.
- P_i gets share $x_i = \mathbf{p}(i)$.

$(x_1, \ldots, x_n)$ is Reed-Solomon codewd.



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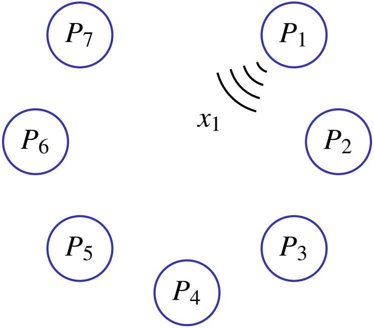

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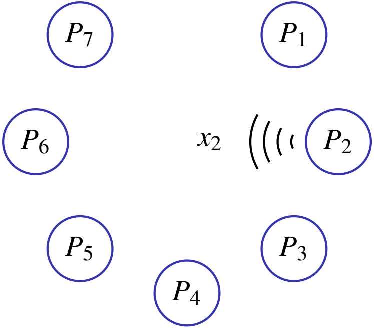

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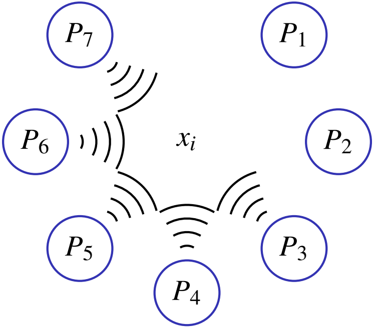

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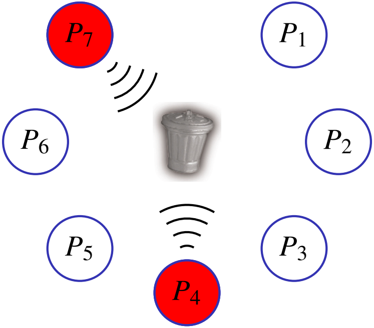
Error correction: [BeWe86, GuSu98]



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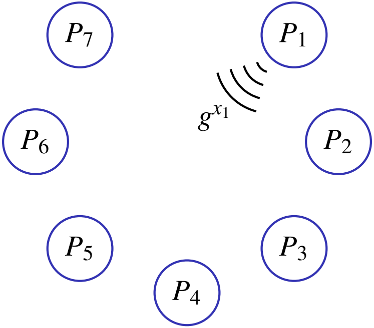

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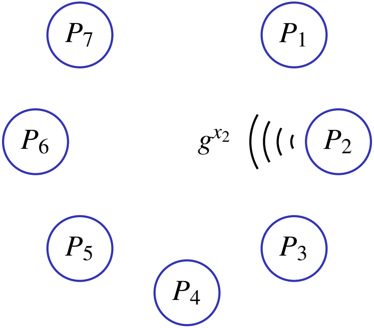

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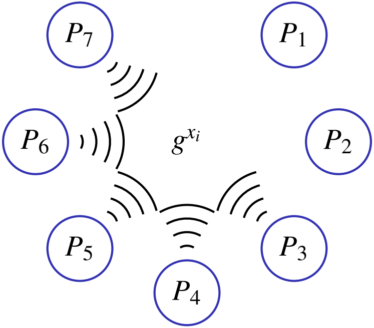

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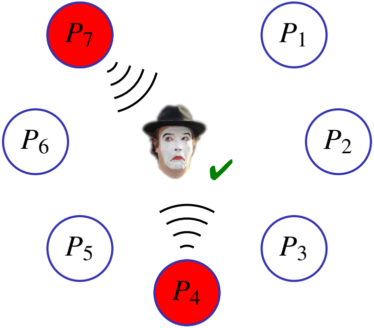

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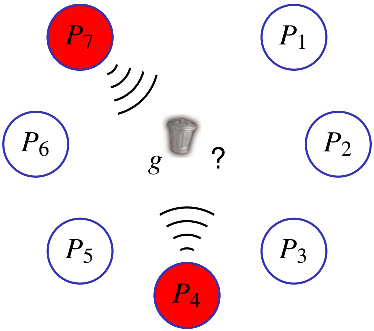
ERROR CORRECTION: ???

- Guess-and-check: $\frac{n \log n}{k}$ errors



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Unconditional Results

Errors	Complexity
$n - \sqrt{nk}$	EASY AS DH
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- Guess-and-check is optimal — even if DDH is easy.

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Evidence for:

$$\text{DDH} < \text{ECE} \leq \text{DH}$$

A new approach for:

$$\text{DDH} < \text{ECE} = \text{DLOG} = \text{DH}$$

Relation to Discrete Log

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Decoding (in the exponent) to distance $n - k - k^{1-\epsilon}$ is as hard as computing discrete logs in G.

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Proof Sketch

1. Finding a representation on uniform $\mathbf{w} \in G^n$ is as hard as dlog.
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- Representation on $\mathbf{w}$: nonzero $\mathbf{a} = (a_1, \ldots, a_n) \in \mathbb{Z}_q^n$ s.t.

$$\prod_i w_i^{a_i} = 1.$$

- [Bra93] showed hardness.

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We show $\exists\ \ell = k + k^{1-\epsilon}$ points $w_i = g^{x_i}$, with x_i on poly of deg $< k$.

- There are $\binom{n}{\ell}$ distinct events (each very rare).
- These events have limited dependence.

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3. Decoding $\mathbf{w}$ yields a representation on $\mathbf{w}$.
   - Decode $\mathbf{w}$ to $(g^{x_1}, \ldots, g^{x_n})$, where x_i lie on poly of deg $< k$.
   - There are $\gg k$ points $w_i = g^{x_i}$. wlog: $w_1, \ldots, w_{k+1}$.
   - Interpolate in the exponent:

$$w_{k+1} = \prod_{i=1}^{k} w_i^{\lambda_i} \quad \Rightarrow \quad \text{representation!}$$

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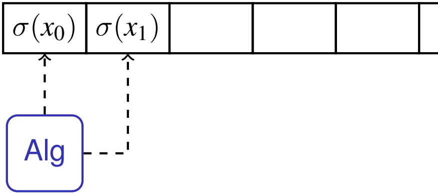

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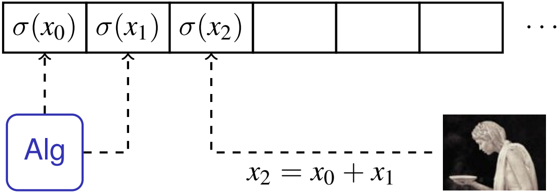

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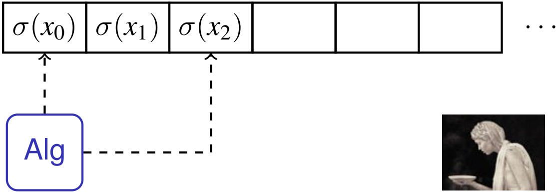

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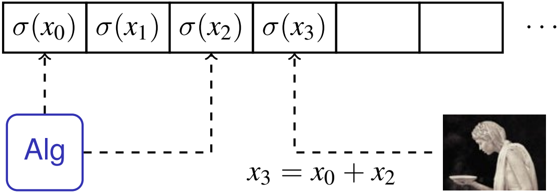

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Alg - - - - → 0/1, $\sigma(x)$, ...

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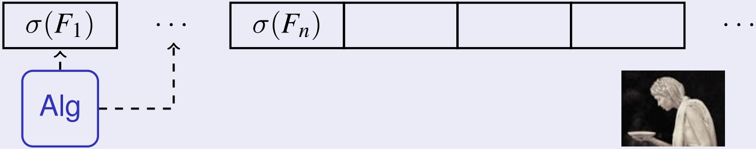

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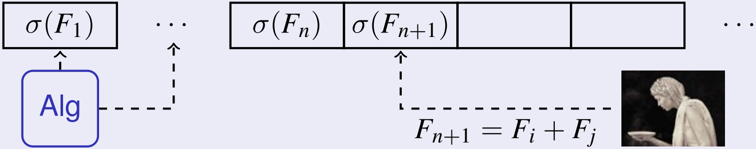

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- Differs from real game only if $\exists\, F_i \not\equiv F_j$, but $(F_i - F_j)(\mathbf{p}, \mathbf{e}) = 0$. Analyze event for "strange" distribution of $\mathbf{p}, \mathbf{e}$.

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   With overwhelming prob, F depends on some uniform e_i.

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2. e variables in $\mathbf{e}$ are uniform (others are zero).
3. F depends on *some* uniform variable (either in $\mathbf{p}$ or $\mathbf{e}$).

   Suppose F doesn't depend on any variables in $\mathbf{p}$.

   Then F depends on $\geq n - k$ positions of $\mathbf{e}$.
   (Dual of Reed-Solomon code.)

   With overwhelming prob, F depends on some uniform e_i.
4. By Schwartz's Lemma, $\Pr[F(\mathbf{p}, \mathbf{e}) = 0]$ small.

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☞ Converse does not appear to hold.
I.e., error correction seems strictly harder than DDH.

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Thank you!