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Efficient and Generic Methods to Achieve Active Security in Private Information Retrieval and More Advanced Database Search

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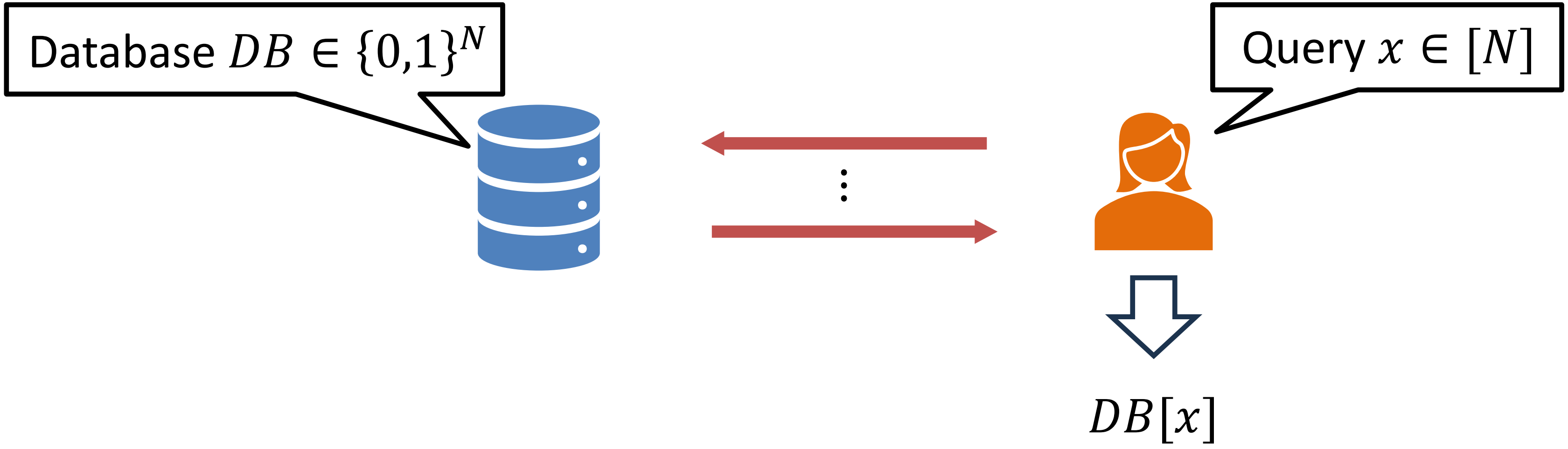
Private Information Retrieval



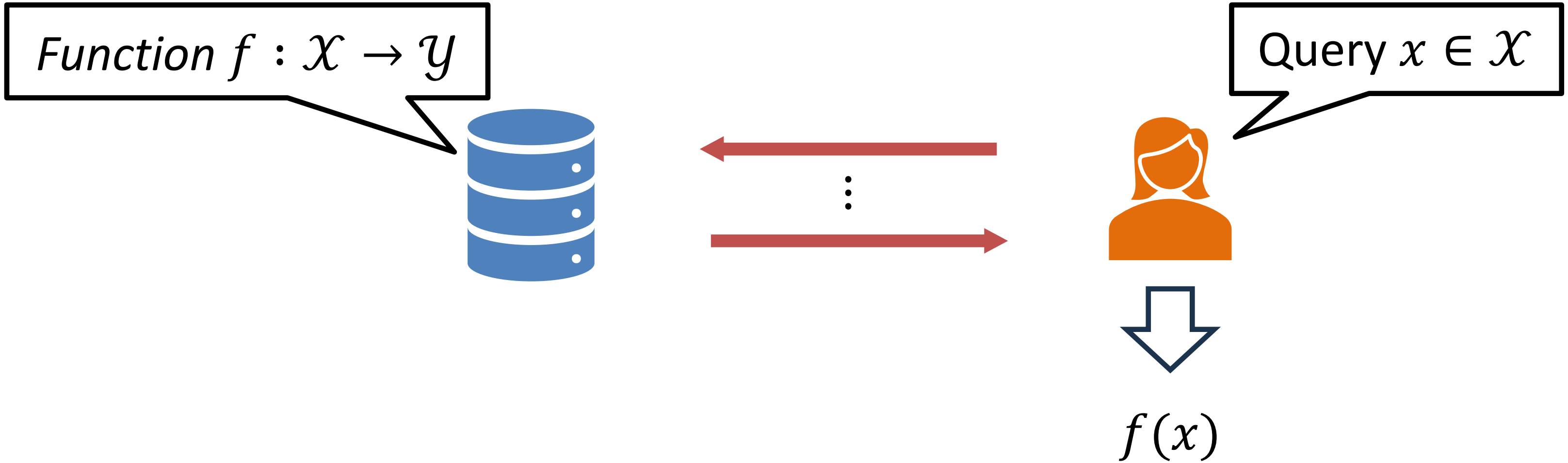
Privacy

Servers learn no information on the client's query x.

The privacy of DB is not considered.

Secure Database Search

- We consider a more general setting of computing a *function* f.



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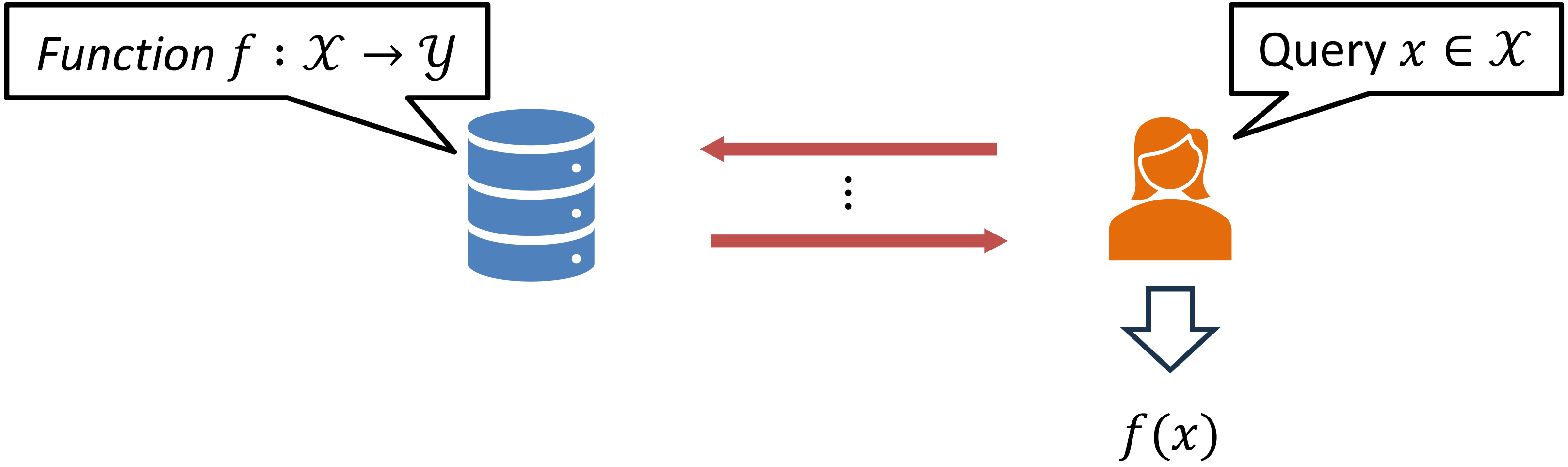


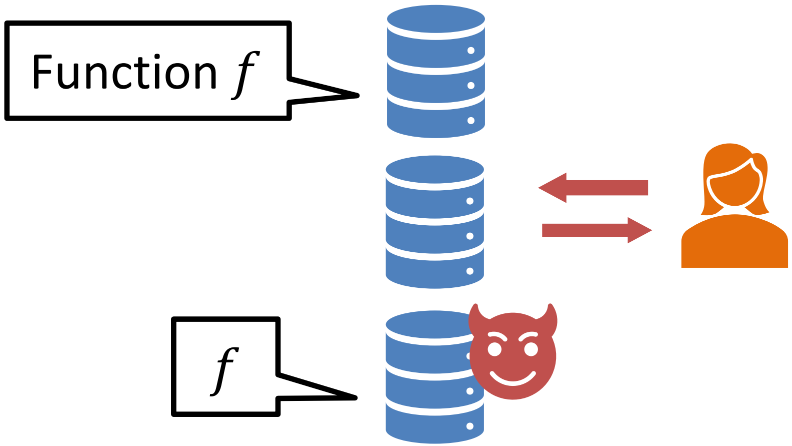
Trivial solution Client can download f and compute $f(x)$ locally.

However, Client-side computation/communication is proportional to $|f|$.

Question Protocols whose computation/communication is $\ll |f|$.

Multi-server vs Single-server

Multi-server setting



- ✔ Better efficiency
- ✔ Weaker assumption
- ✘ # of corrupted servers $\leq t$

This work

Single-server setting

- ✘ Heavy computation
- ✘ Stronger assumption

(Unconditional security cannot be achieved)

Passively Secure Protocols

- **Passive t-security**: Semi-honest adversary corrupts t servers.
- Private information retrieval (PIR)

  2^t-server protocol from OWF [BGI16]+[BIW10],

  3^t-server protocol (unconditional) [BIKO10]+[BIW10],…

- Degree-D polynomial

  $\Theta(tD)$-server protocol [WY07],

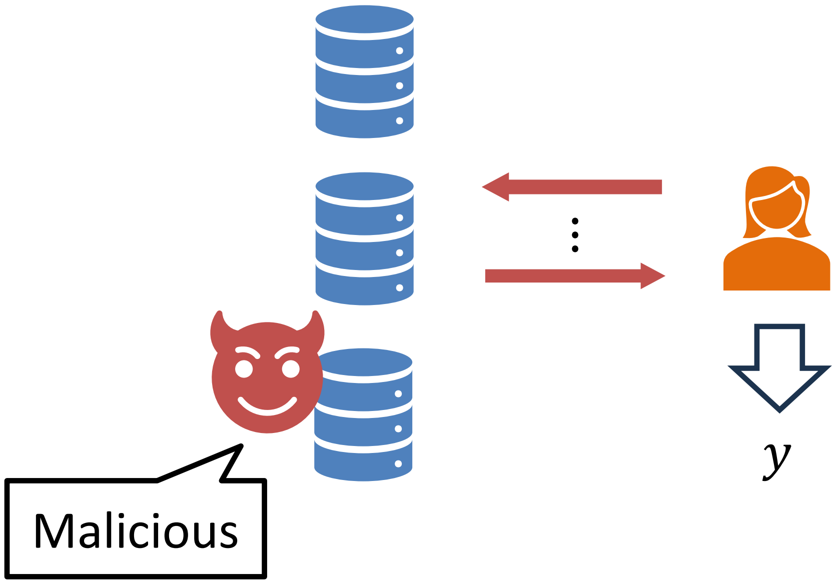
  $(t+1)$-server protocol for $D = o(\log \lambda)$ from sparse LPN [DIJL23]

- Constant-depth circuits of size M

  $(t \cdot \mathrm{polylog}\, M)$-server protocol [BI05]

Active Security

- Corrupted servers may deviate from a protocol.



<u>Privacy</u>

Corrupted servers learn no information on x.

<u>Byzantine-robustness</u>

$y = f(x)$ with high probability.

cf. <u>Verifiability [CNC+23,ZW22]</u>

$y \in \{f(x), \perp\}$ with high probability.

Previous Works

- Passive-to-active compilers were proposed for *PIR* [BS07], [EKN22].

1-round **passively t-secure** k-server protocol → **Actively t-secure** m-server protocol

Compiler	# servers	# rounds	Function
[BS07]	$m = k + 2t$	1	PIR
[EKN22]	$m = k + t$	1	PIR

✘ $\binom{m}{t} = m^{O(t)}$ computation/communication overhead.

✘ Do not consider general functions.

Our Results

- We propose **generic** passive-to-active compilers with **polynomial overheads**.

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[BS07]	$m = k + 2t$	1	PIR
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Ours-1	$m = k + t$	$O(m^2)$	Any
Ours-2	$m = \Theta(k \log k) + 2t$	1	Any

✔ General f

✔ $\mathrm{poly}(m)$ computation/communication overhead

Techniques of Our Compilers

1-round
passively t-secure
k-server protocol

→

Actively t-secure
m-server protocol

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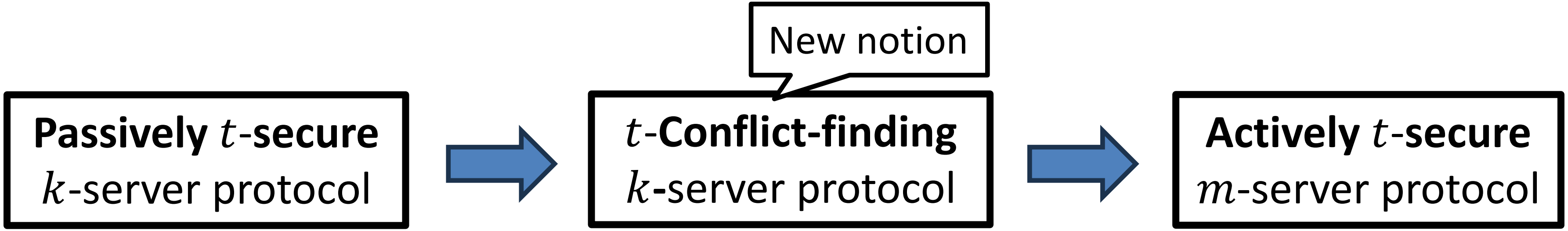
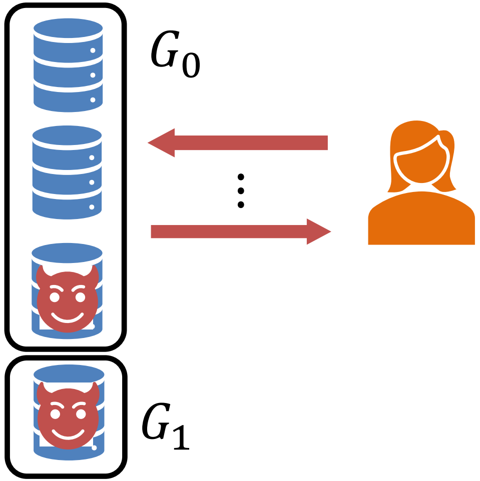
Conflict-finding Protocol



Conflict-finding Protocol

New notion

Passively t-secure k-server protocol → **t-Conflict-finding** k-server protocol → **Actively t-secure** m-server protocol



Privacy Same

Conflict-finding

Client outputs either
(1) $f(x)$, or
(2) a partition (G_0, G_1) such that $H \subseteq G_0$ or $H \subseteq G_1$.

Set of honest servers

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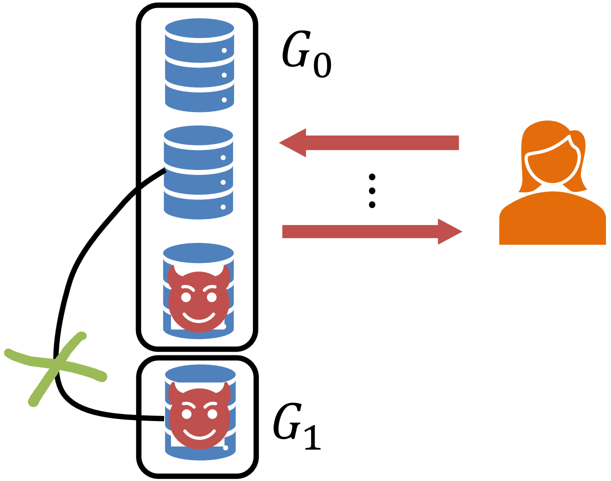

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For any pair (S_i, S_j) with $S_i \in G_0, S_j \in G_1$, we have that S_i or S_j is malicious.

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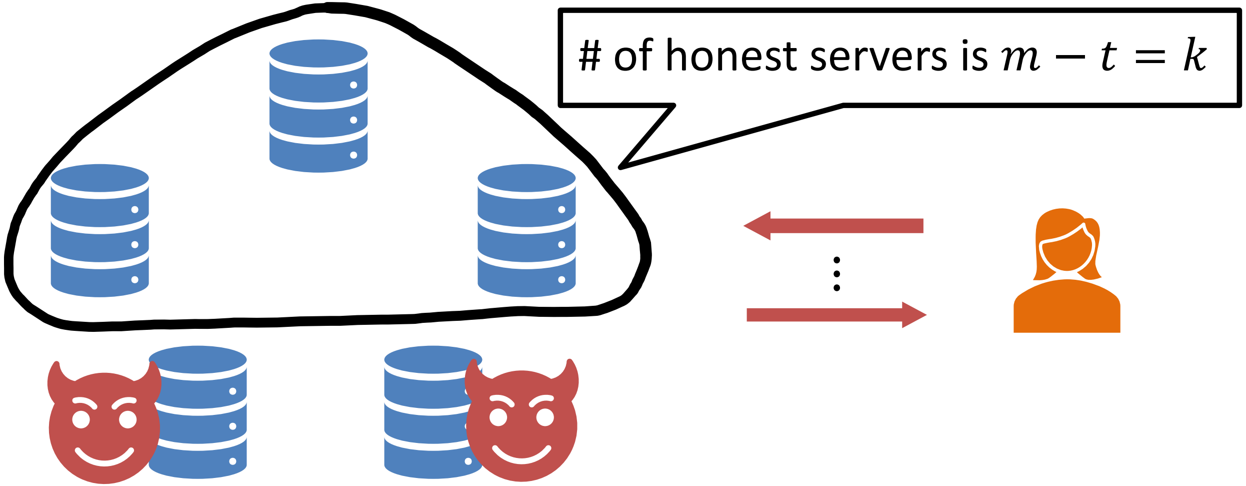
From Conflict-finding to Actively Secure

- There are m servers out of which t are malicious.



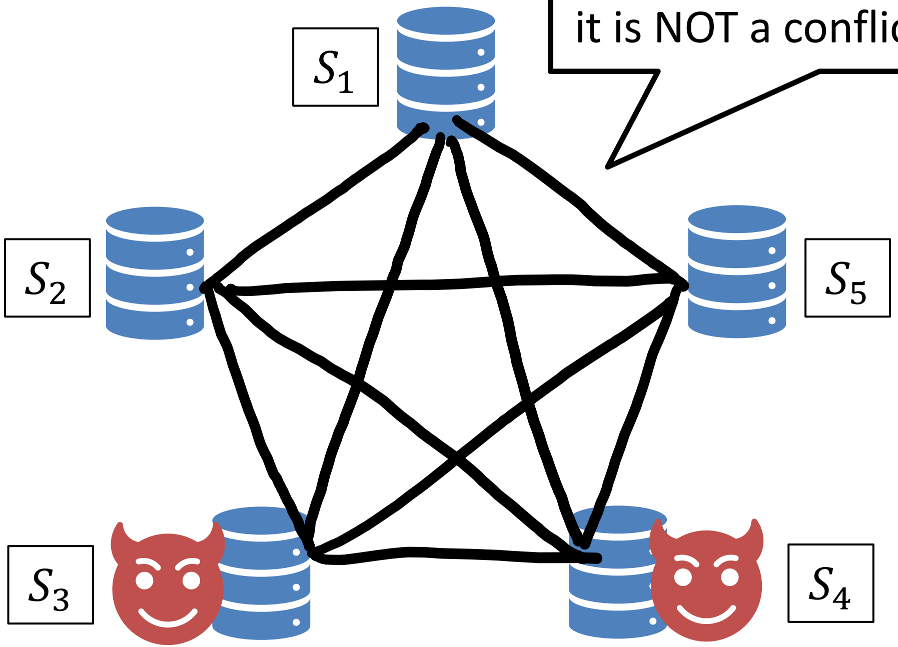
- If a k-server protocol is executed with the set of honest servers,
  Client obtains a correct result $f(x)$.

Strategy | Find sufficiently many conflicting pairs to determine k honest servers

From Conflict-finding to Actively Secure

- We consider a graph whose nodes represent servers.
  - An initial graph is a complete graph.

(S_i, S_j) is an edge if and only if it is NOT a conflicting pair.



From Conflict-finding to Actively Secure

- The client iterates the following:
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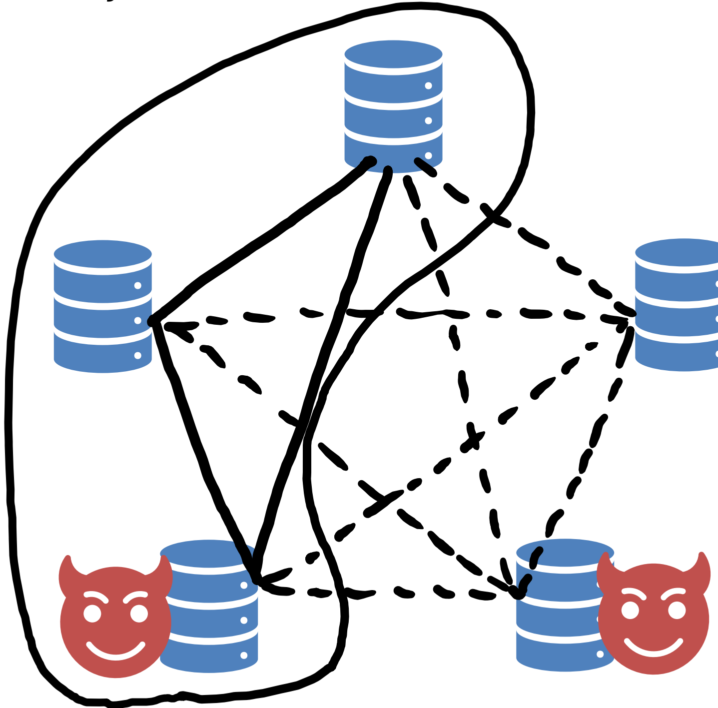

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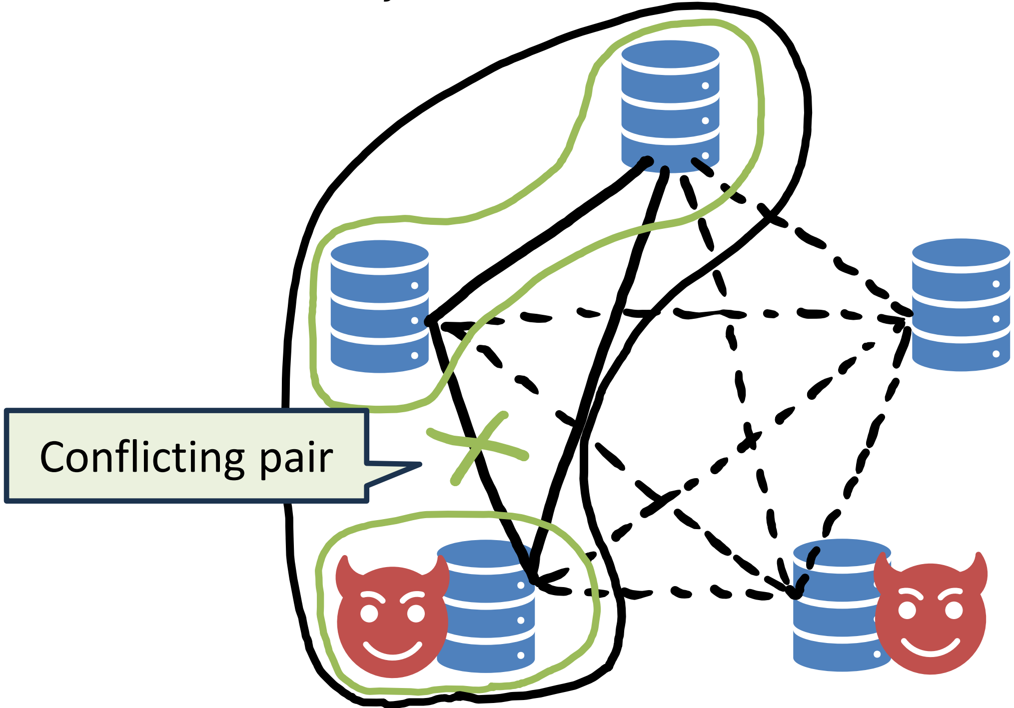

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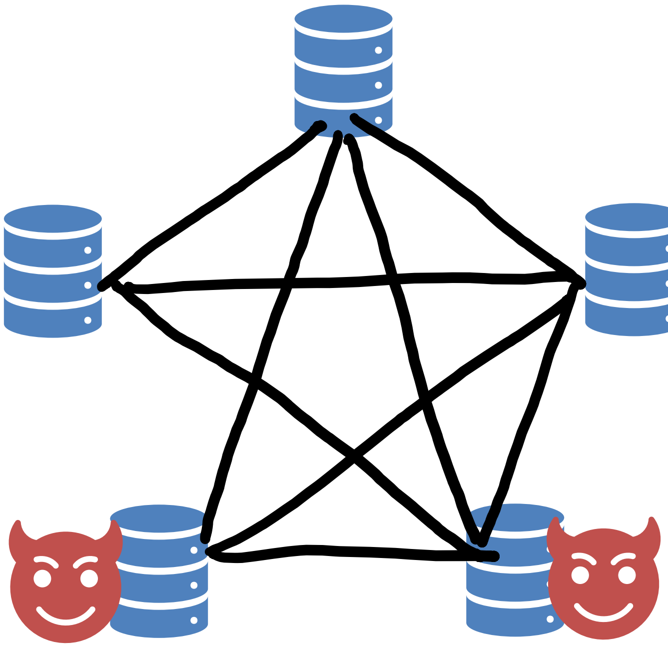

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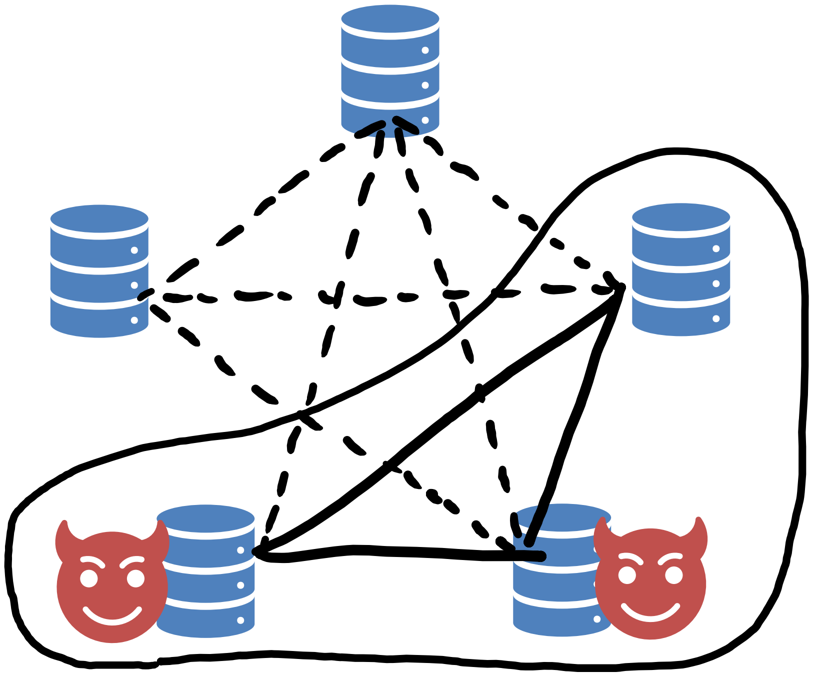

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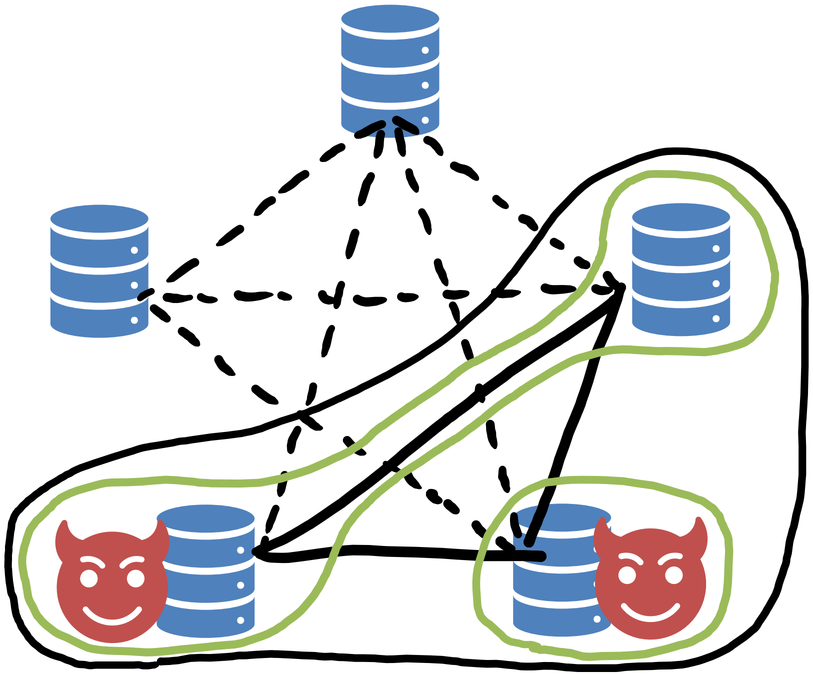

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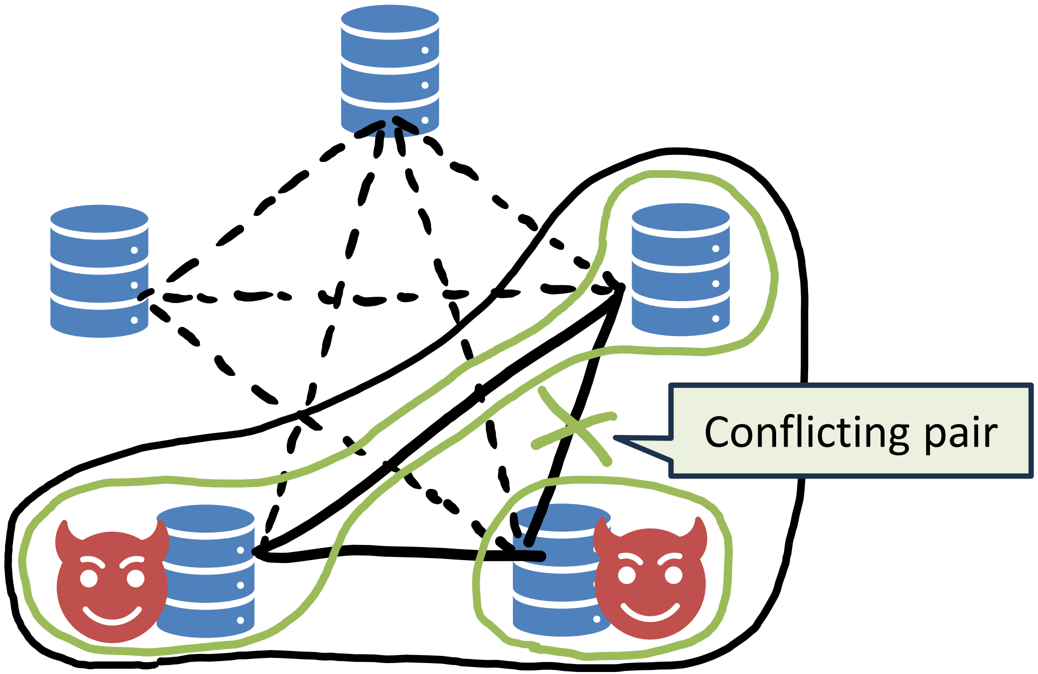

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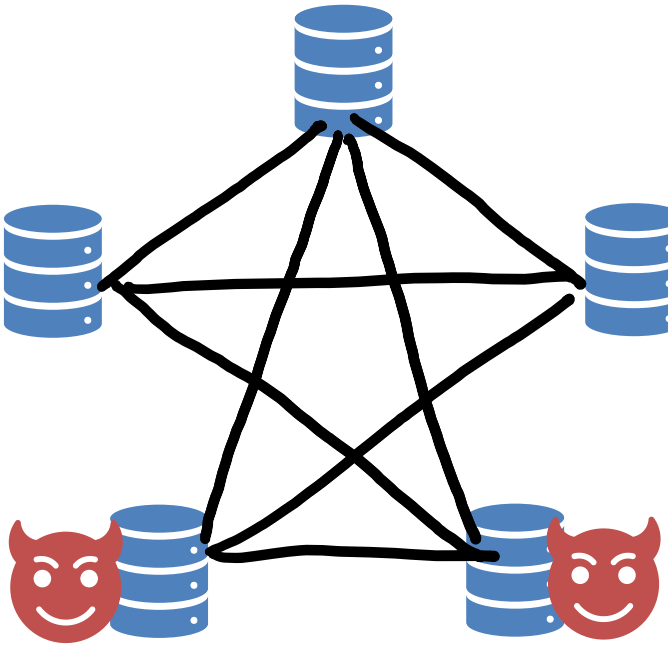

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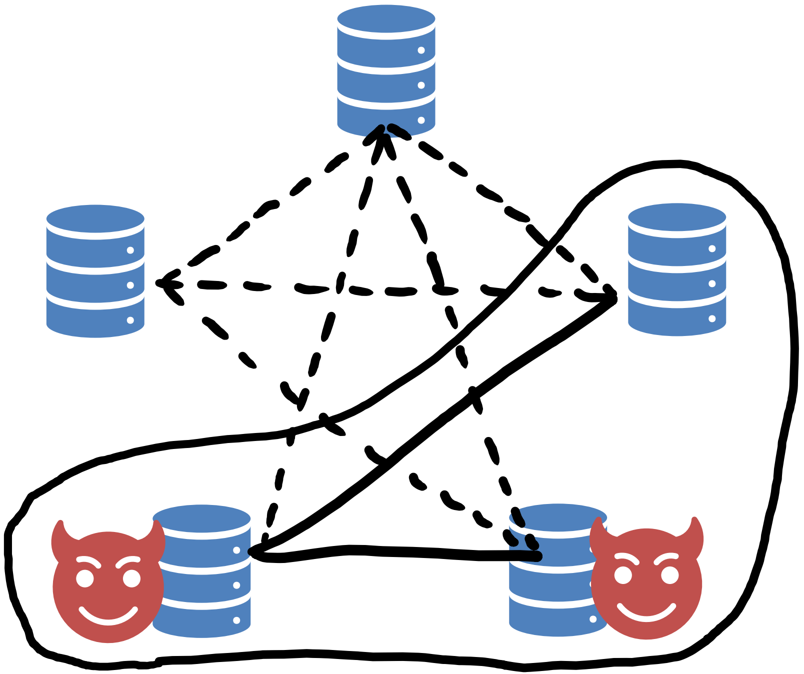

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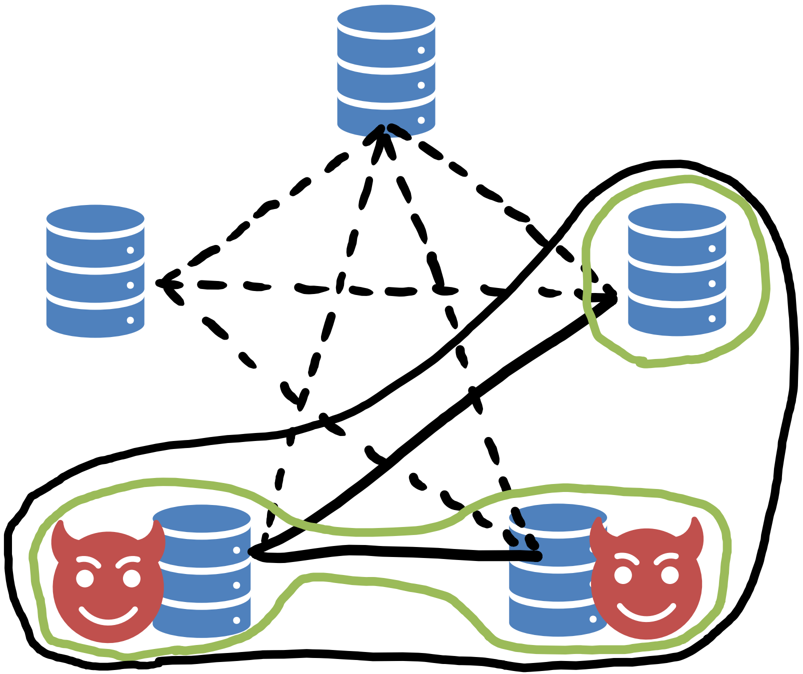

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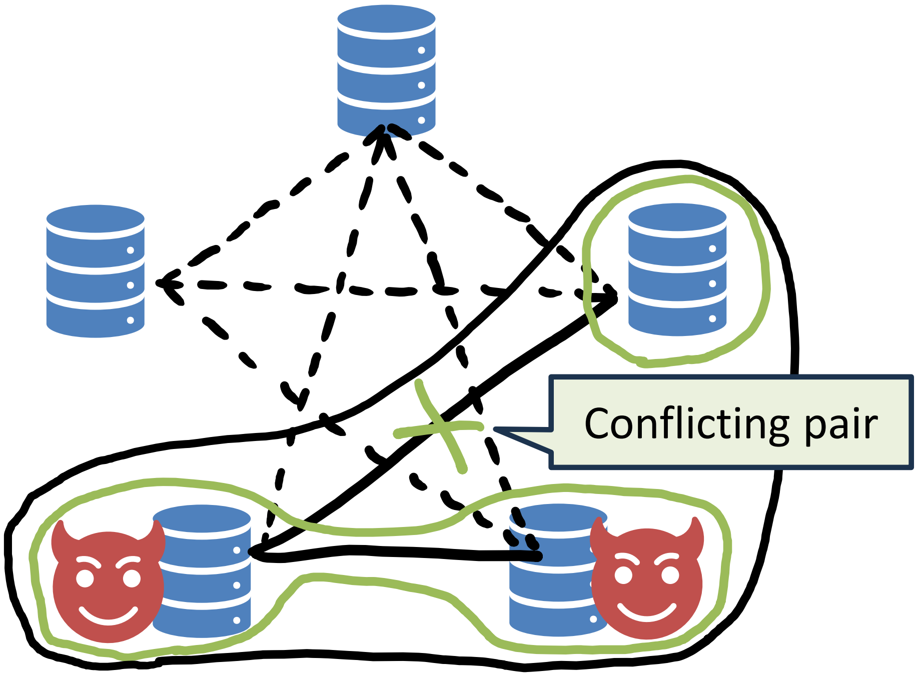

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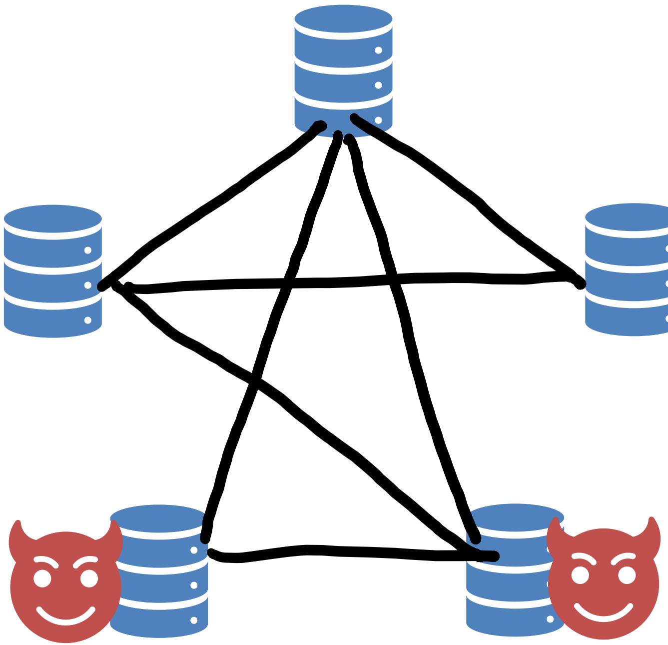

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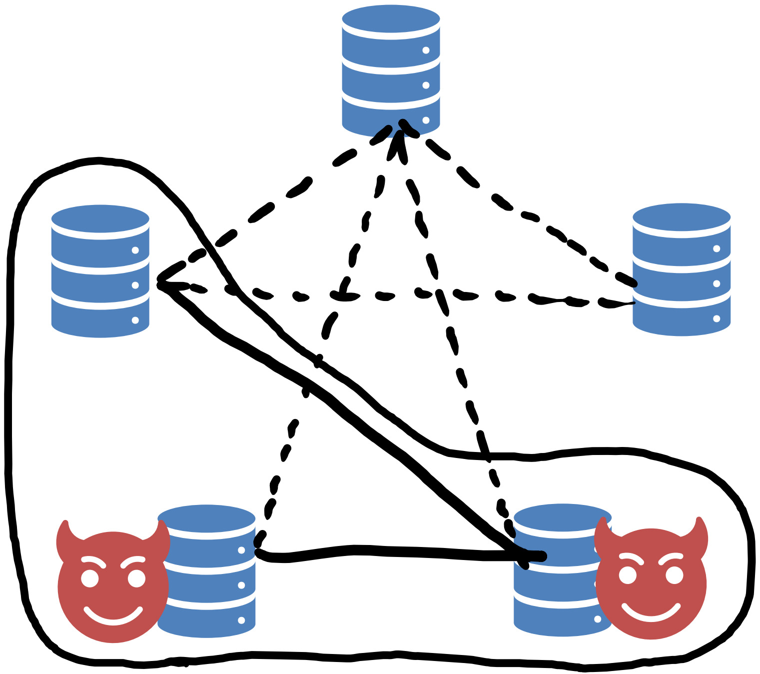

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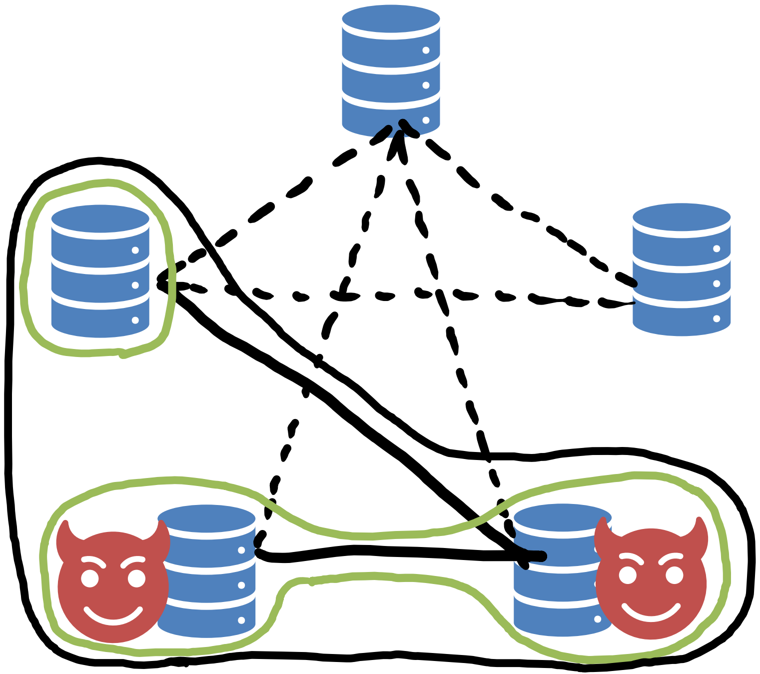

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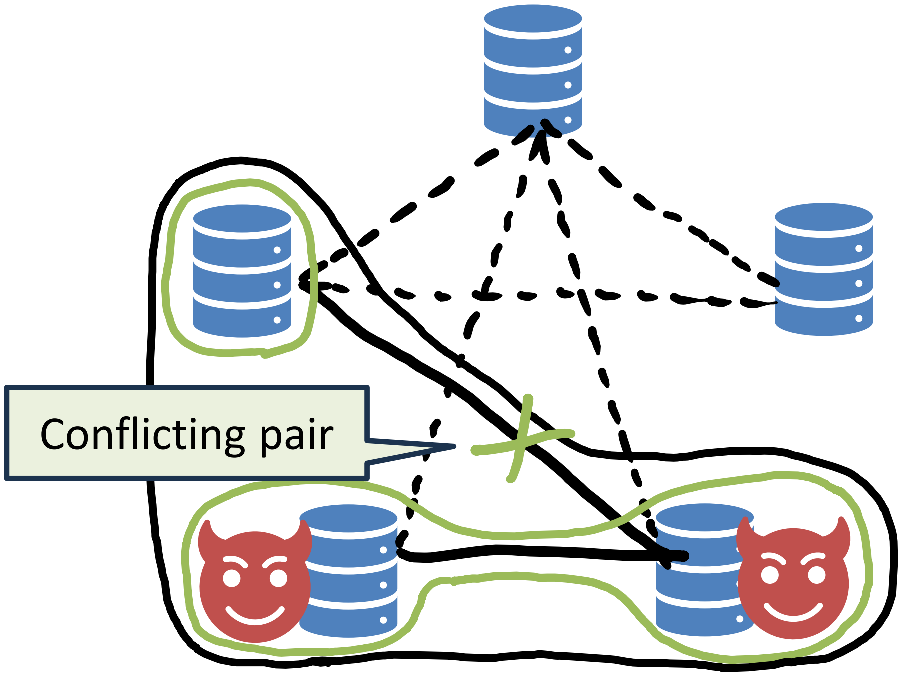

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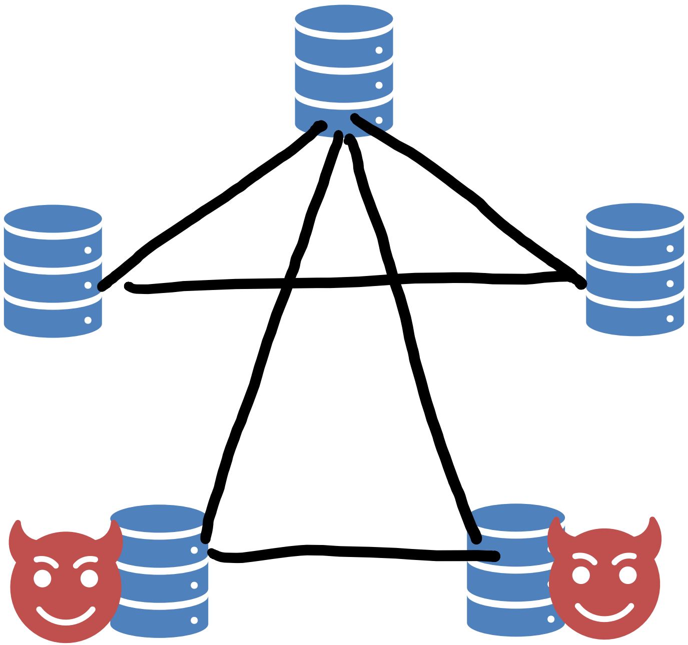

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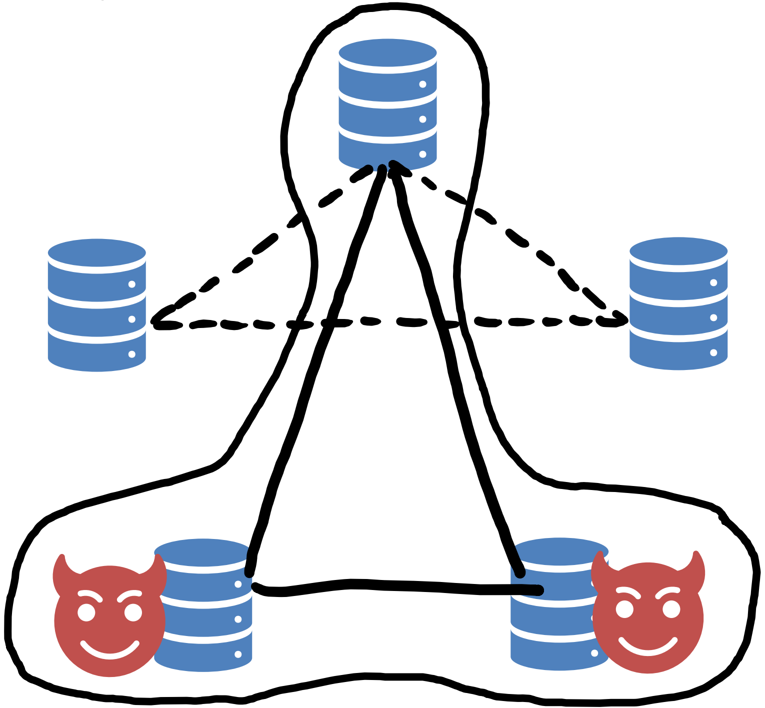

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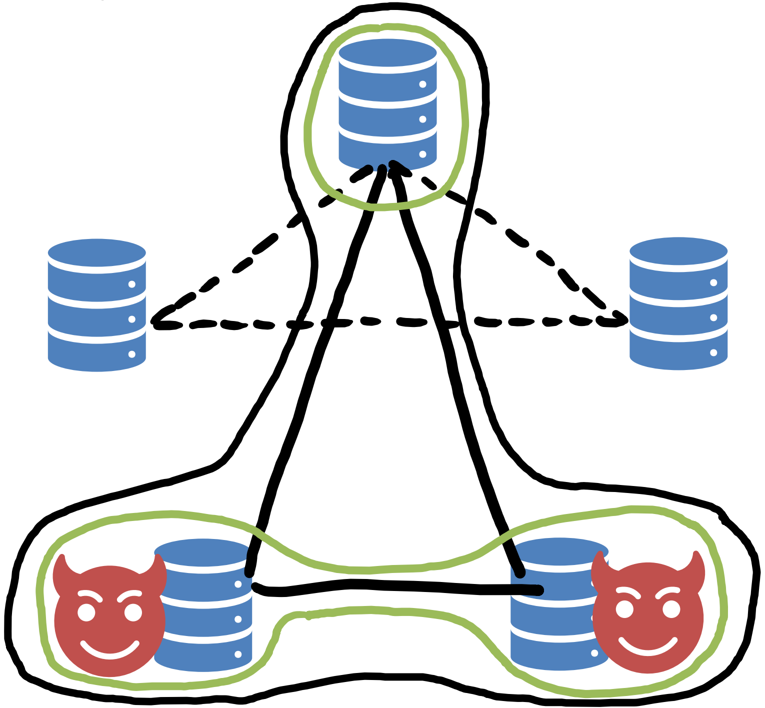

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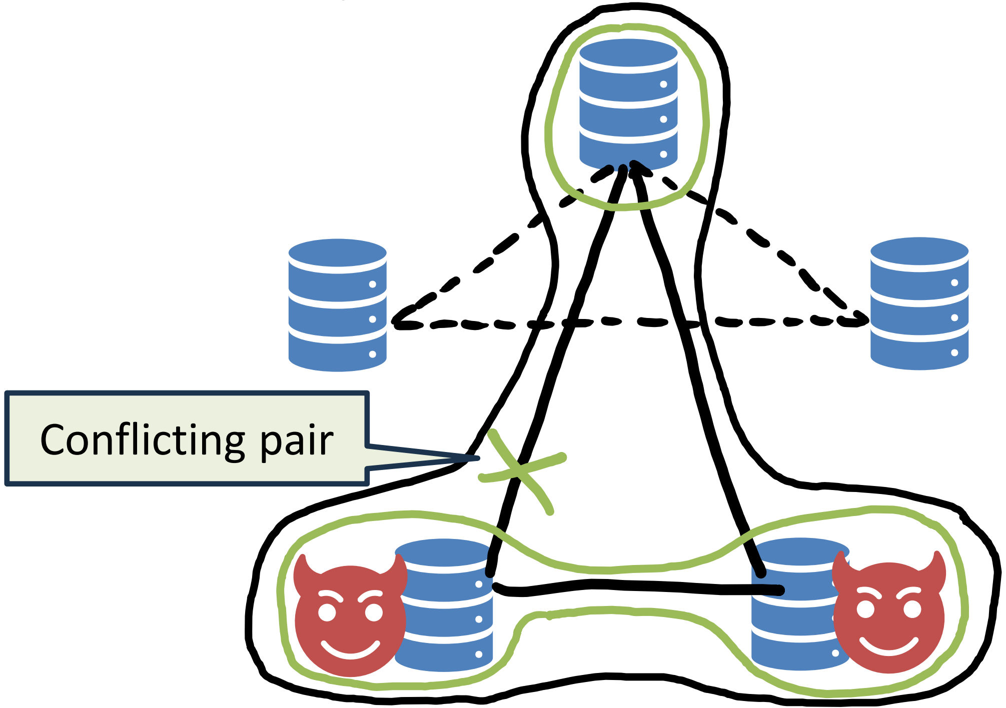

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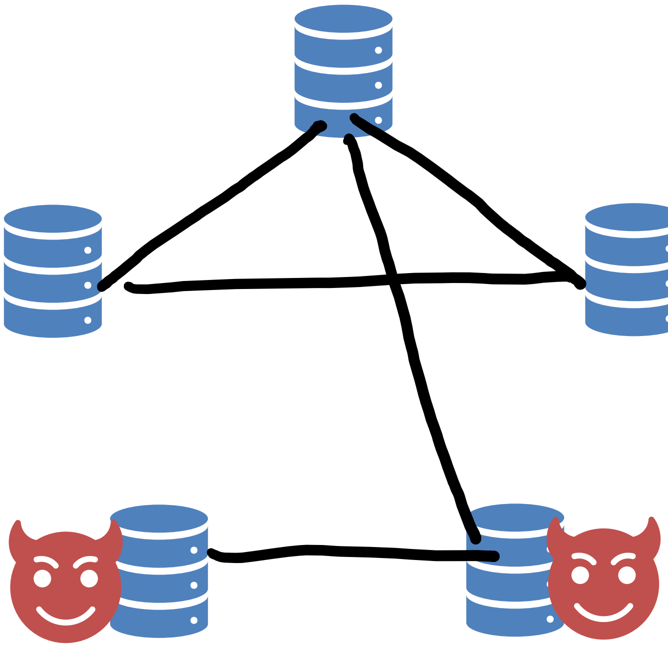

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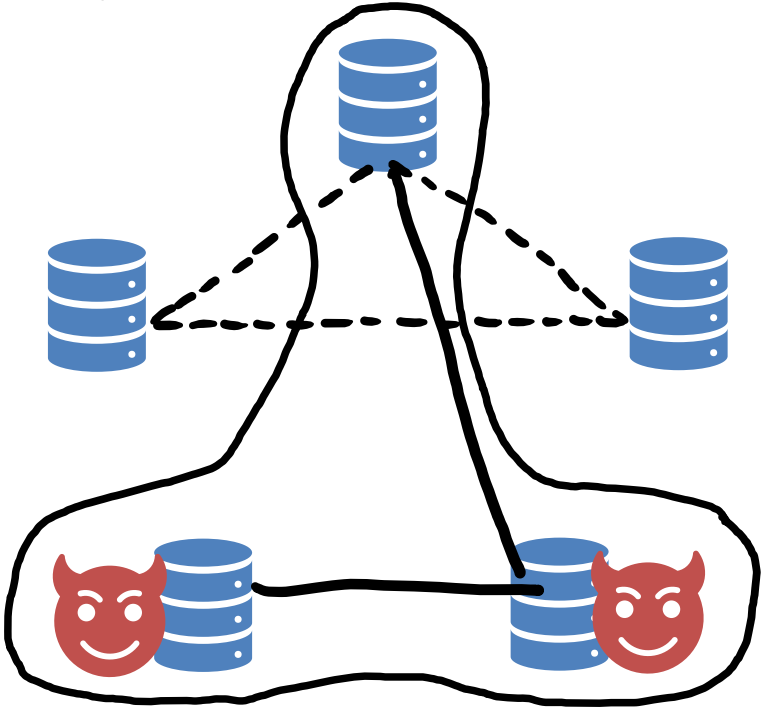

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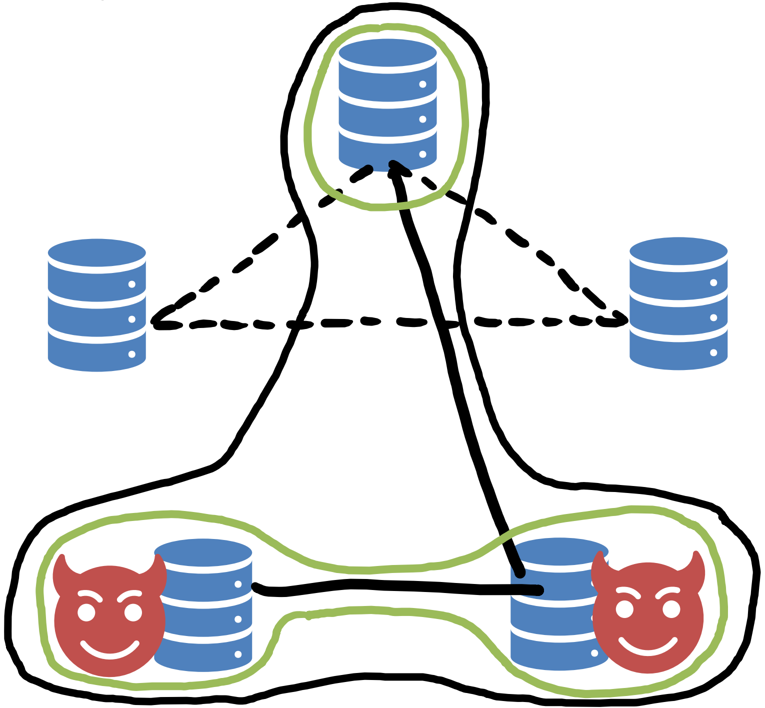

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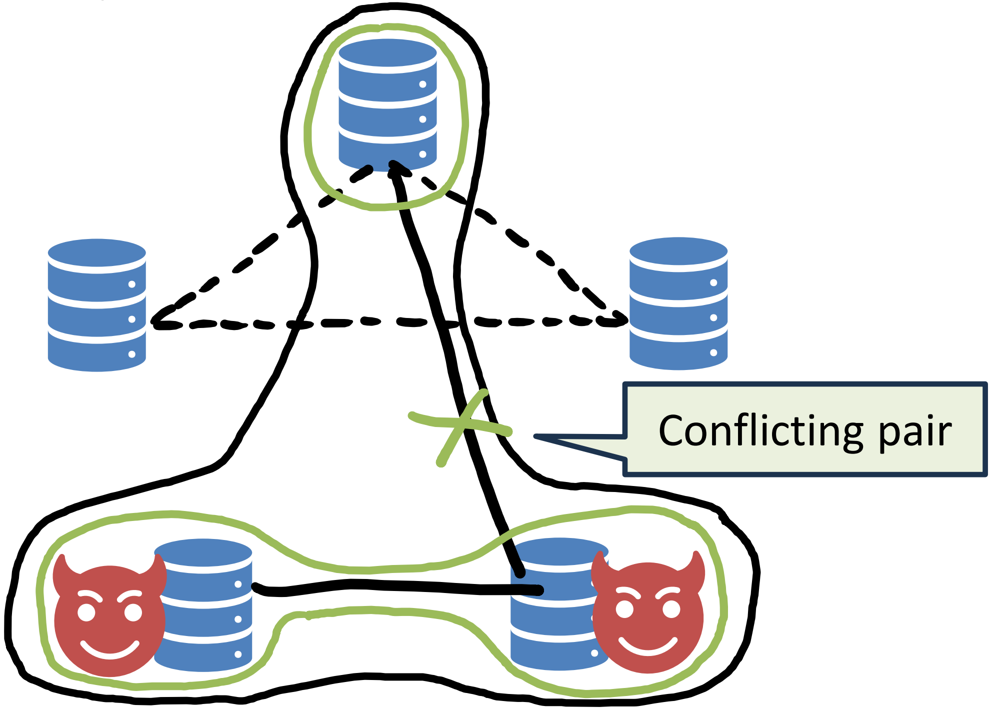

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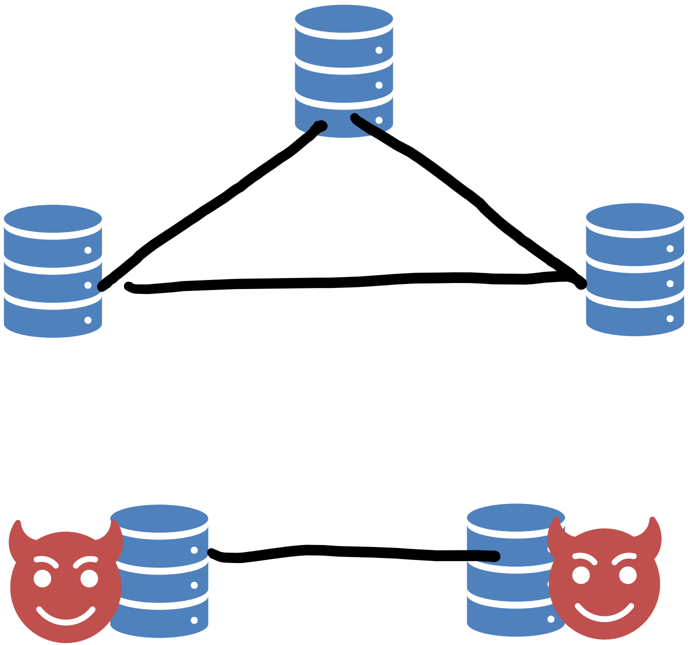

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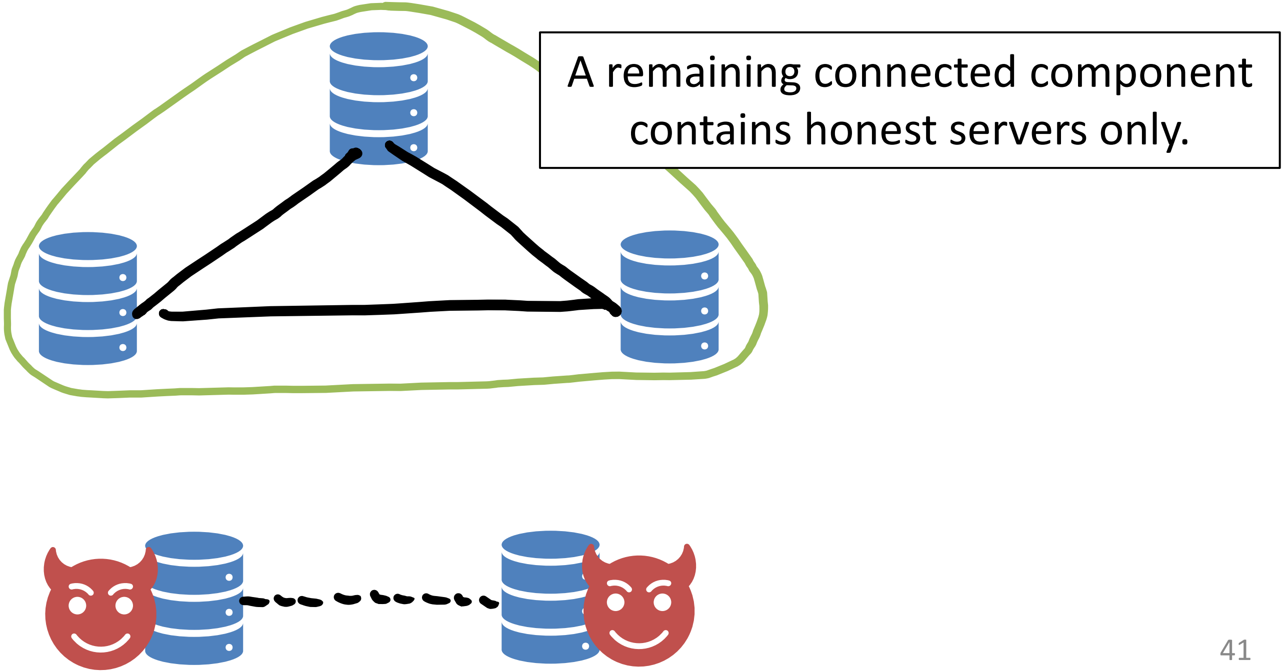

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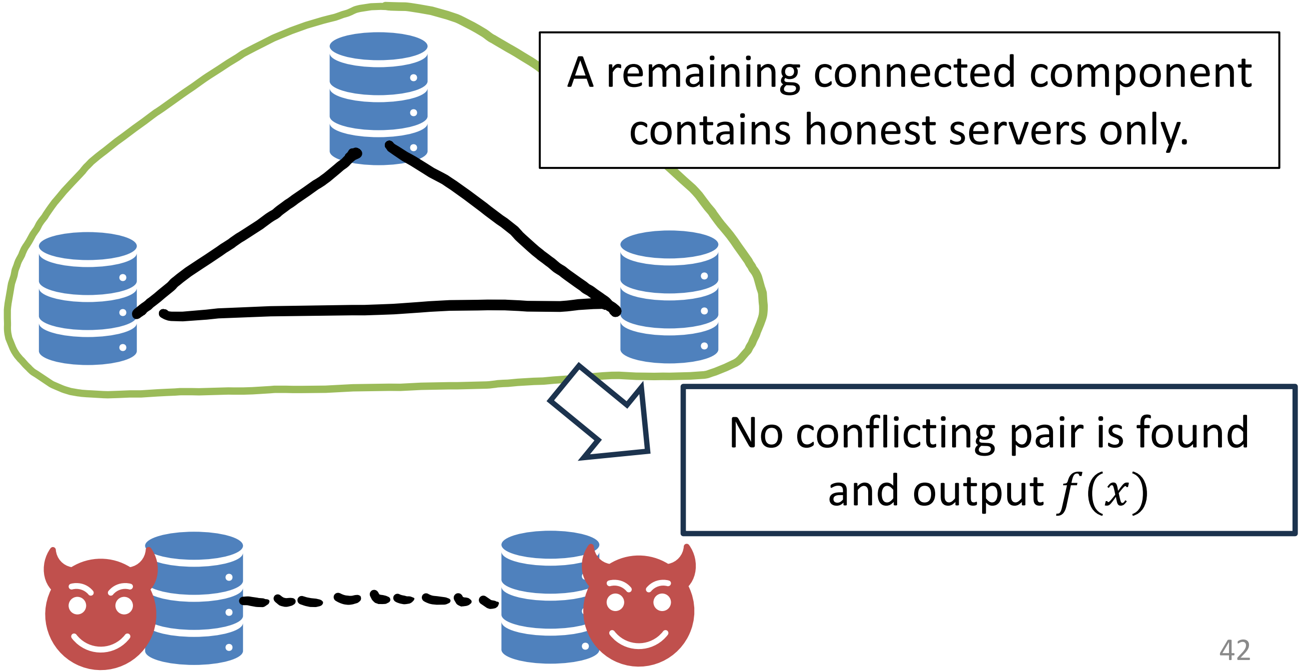

Summary

- Passive-to-active compilers for secure database search protocols with $\text{poly}(m)$ overheads.

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- Future work
  - Is it possible to achieve $O(1)$ rounds while keeping $m = k + t$?

Reference

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Thank you!