Hu-Fu: Efficient and Secure Spatial Queries over Data Federation

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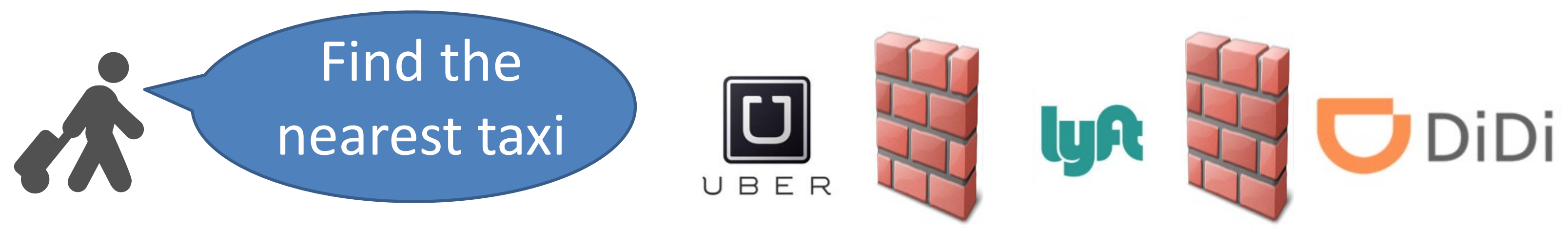
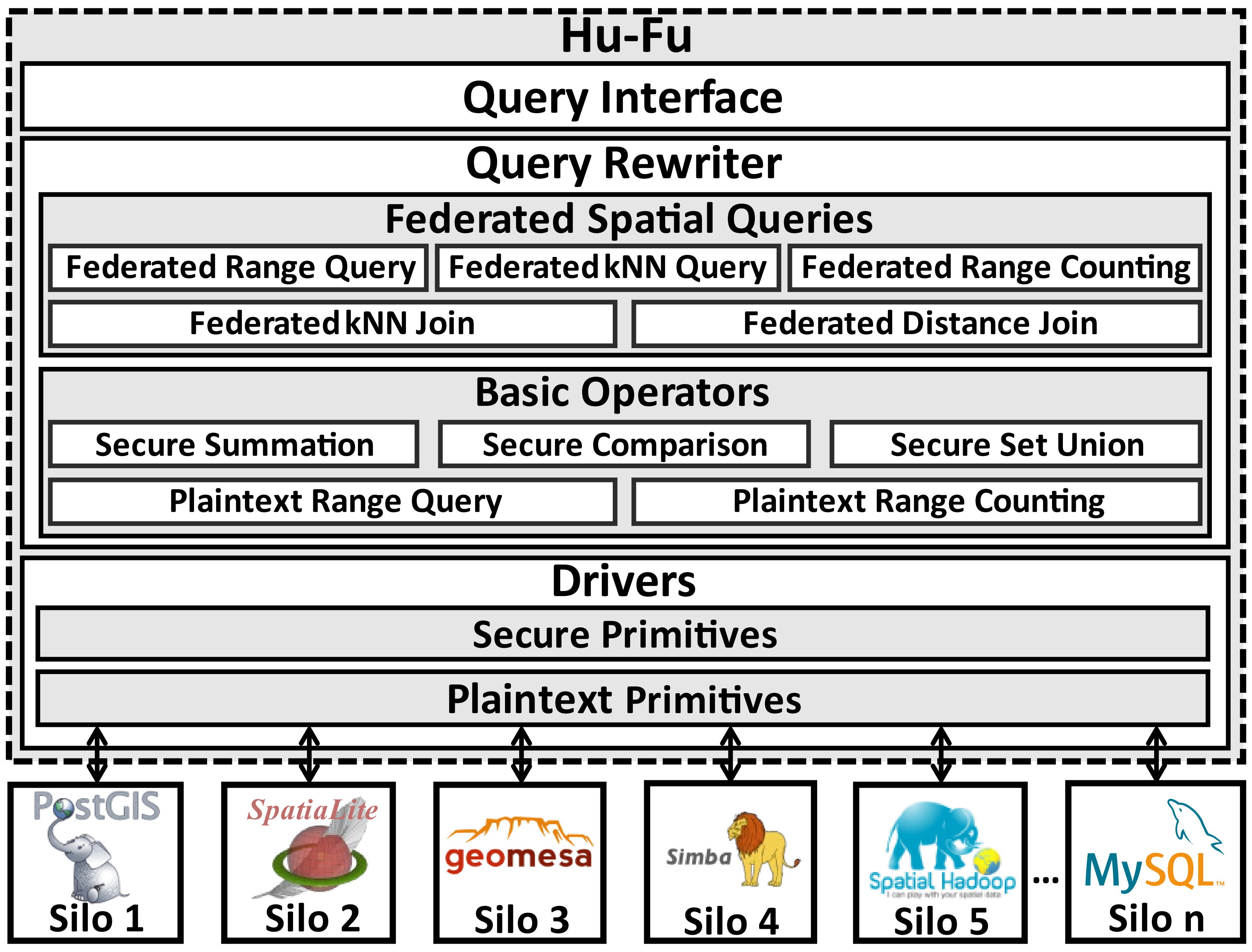
Introduction

- Spatial queries are essential for a wide spectrum of applications, but data isolation has become an obstacle to scale up query processing due to security concerns



- A promising paradigm to tackle the data isolation problem is to perform secure queries over a data federation
- Existing data federation systems are inefficient on spatial queries due to
  - excessive secure distance operations for query processing
  - usage of general-purpose SMC libraries for secure operation implementation

Hu-Fu Overview



Hu-Fu

Query Interface

Query Rewriter

Federated Spatial Queries

Federated Range Query | Federated kNN Query | Federated Range Counting

Federated kNN Join | Federated Distance Join

Basic Operators

Secure Summation | Secure Comparison | Secure Set Union

Plaintext Range Query | Plaintext Range Counting

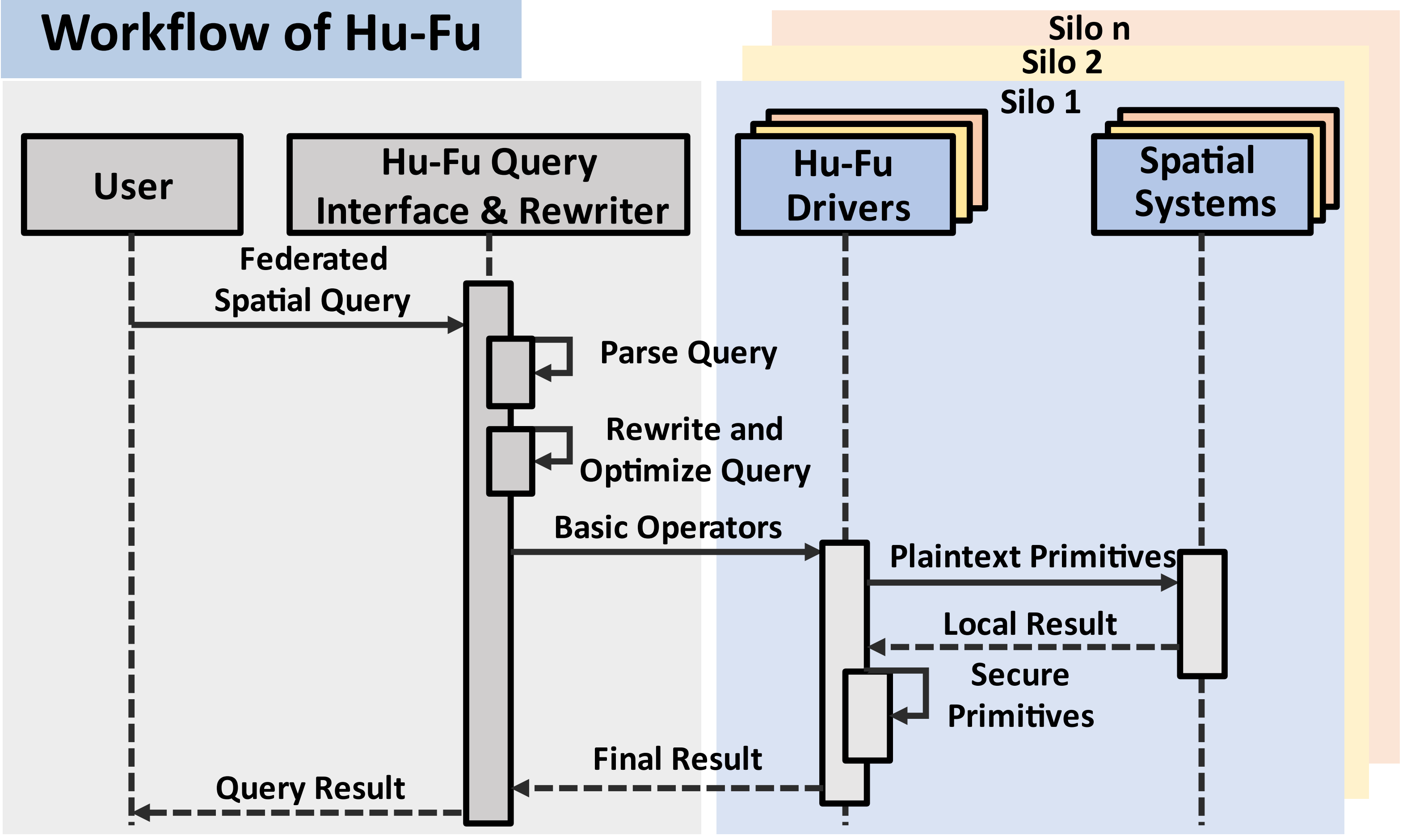
Drivers

Secure Primitives

Plaintext Primitives

- **Query Rewriter:** Decompose federated spatial queries into basic operators (plaintext operators and secure operators)
- **Drivers:** Implement secure operators as secure primitives with SMC protocol, and plaintext operators as plaintext primitives on top of silo's underlying spatial databases
- **Query Interface:** Provide federation view to users and support federated spatial queries written in SQL

Workflow of Hu-Fu



User

Hu-Fu Query Interface & Rewriter

Hu-Fu Drivers

Spatial Systems

Silo n

Silo 2

Silo 1

Federated Spatial Query

Parse Query

Rewrite and Optimize Query

Basic Operators

Plaintext Primitives

Local Result

Secure Primitives

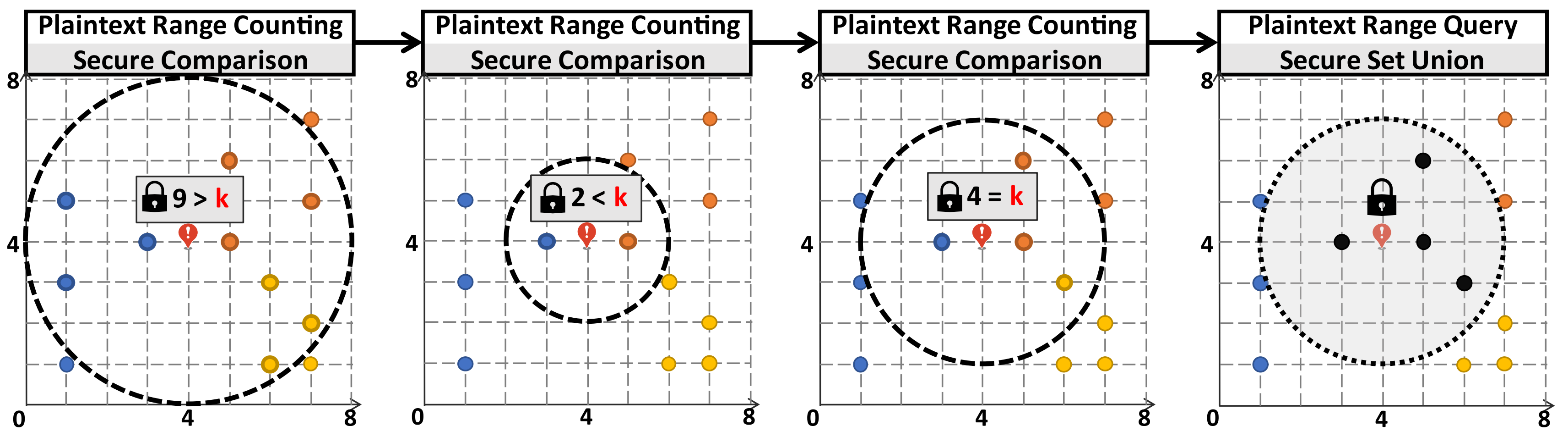
Final Result

Query Result

Query Decomposition

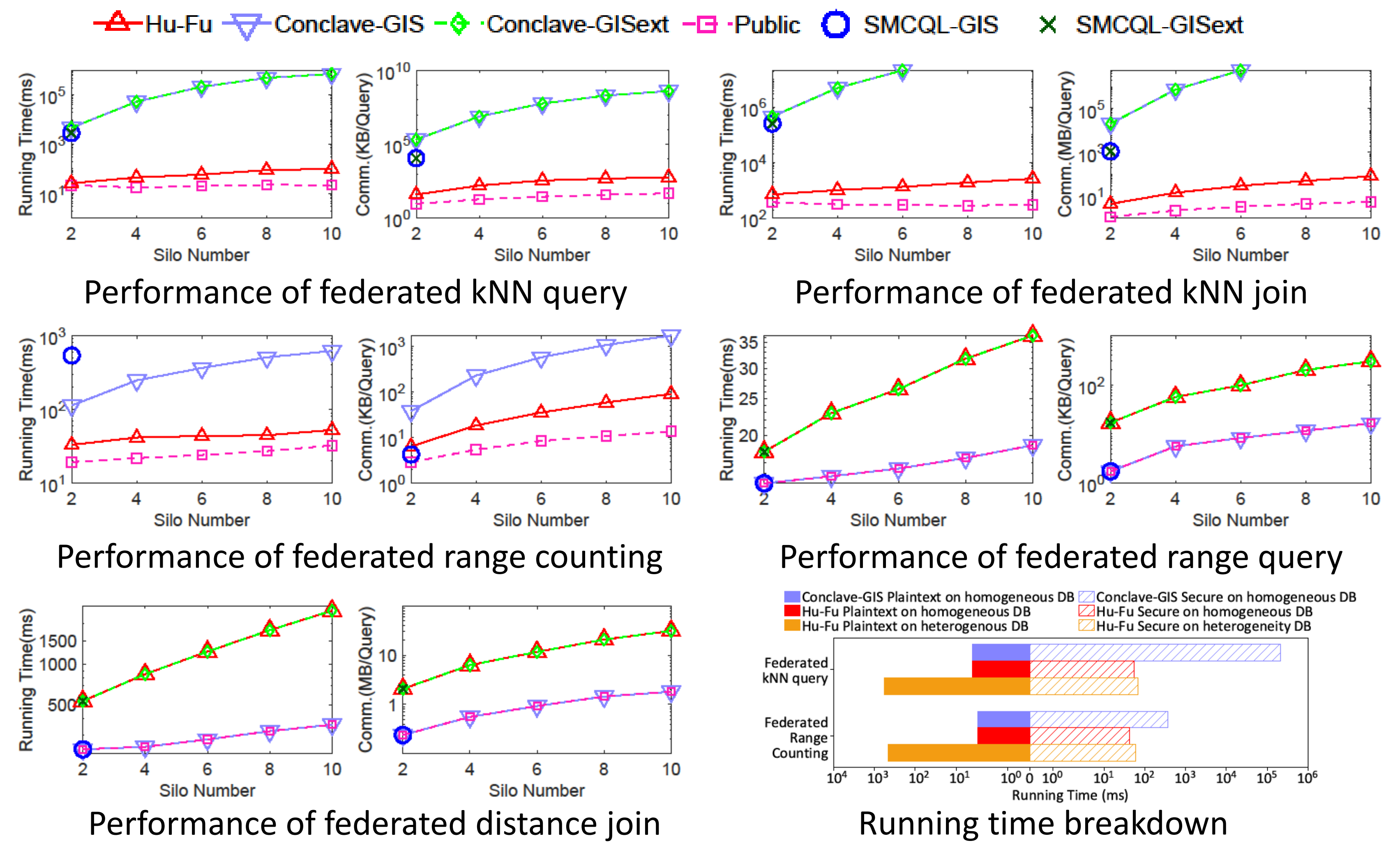
Category	Federated Spatial Query	Number of Plaintext Operator		Number of Secure Operator	
		Range Query	Range Counting	Comparison	Set Union / Summation
Radius-Known	Federated Range Query	n	0	0	$1/0$
	Federated Range Counting	0	n	0	$0/1$
	Federated Distance Join	$N\|R\|$	0	0	$1/0$
Radius-Unknown	Federated kNN Query	n	$O(n\, log\frac{v_0}{\epsilon_0})$	$O(log\frac{v_0}{\epsilon_0})$	$1/0$
	Federated kNN Join	$N\|R\|$	$O(\|R\|log\frac{v_0}{\epsilon_0})$	$O(\|R\|log\frac{v_0}{\epsilon_0})$	$1/0$

Decomposition principle: Decompose federated spatial queries into as many plaintext operators and as few secure operators as possible such that a large portion of the query can be executed in plaintext without compromising security



Example(Federated kNN query): We first derive a radius which contains k spatial objects via binary search, and then retrieve the spatial objects within this radius. In each binary search literation, we perform a plaintext range counting and a secure comparison to adjust the searching radius boundary. In the last round, a plaintext range query and a secure set union is performed to get the final result.

Experimental Evaluation



Performance of federated kNN query

Performance of federated kNN join

Performance of federated range counting

Performance of federated range query

Performance of federated distance join

Running time breakdown

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