International Technology Alliance
in
Network & Information Sciences

Safe Query Processing for Pairwise Authorizations in Coalition Networks

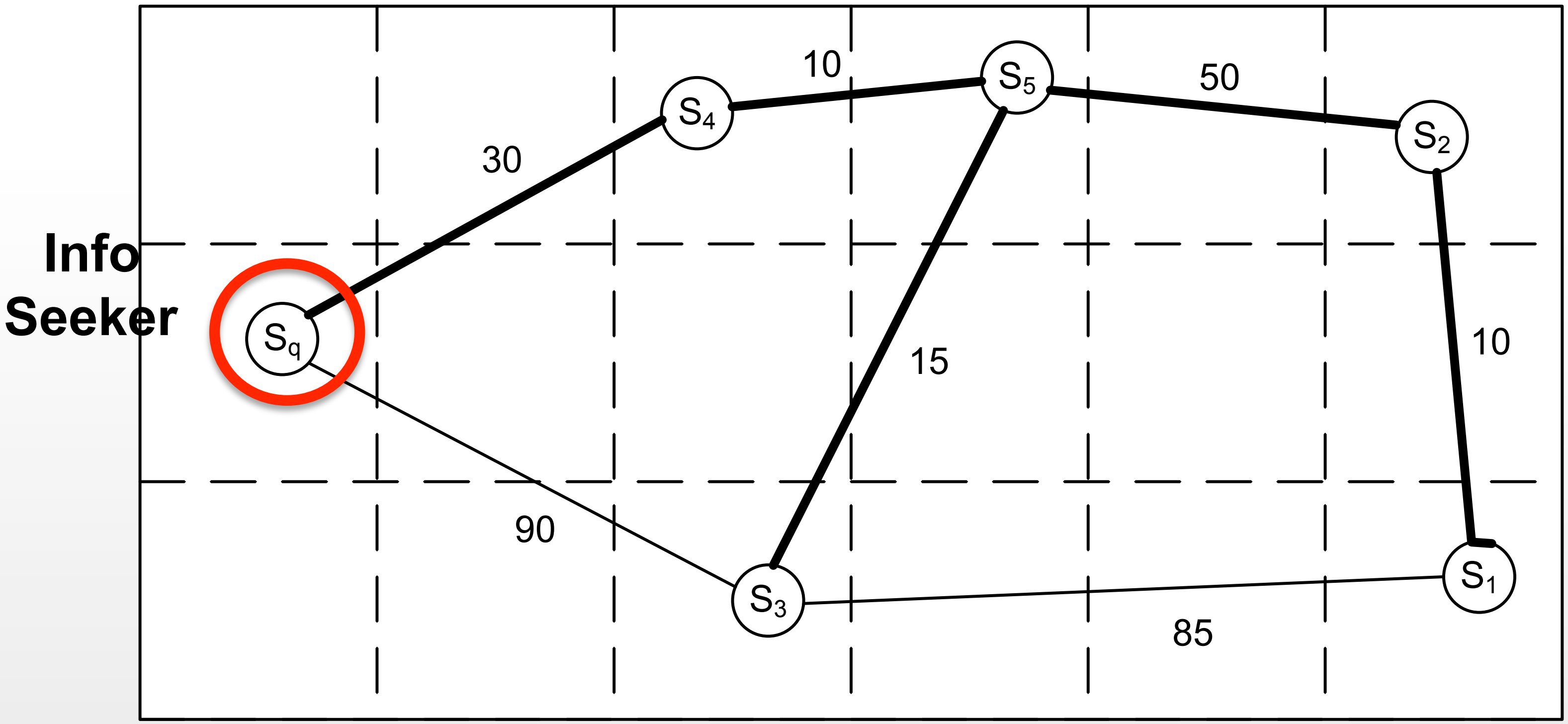
Qiang Zeng, Jorge Lobo, **Peng Liu**, Seraphin Calo, Poonam Yadav

Penn State Univ., IBM Watson

ACITA
September 2012

MINISTRY OF DEFENCE

Example scenario (1/2)



- Information is shared among servers of multi-parties
- A distributed DB system is established by the servers
- Top concerns: Safety, flexibility and efficiency.

Example Scenario (2/2)

- Say, for some specific data, its owner Party *V1* only wants to share with *V2* and *V3*
- For some other data, *V1* only wants to expose it to *V2* and *V4*
- How to achieve such information sharing autonomy?
- *Goal: A safe and efficient solution to autonomous information sharing in a multi-party distributed system.*

Requirements for access control

- R1: each party has its own view over the database.
- R2: each party can independently determine which portion of its data is shared and with whom.
- R3: tuple-granularity access control.
- Last but not least, low communication cost

Existing work

- None has addressed *R1-R3* simultaneously.
- Federated database systems: all parties share a uniform view over the database [Bocca et al., VLDB'94], [Vimercati, JCS'97], which violates *R1*.
- [Vimercati JCS'11] requires different parties to define policies collaboratively and cannot provide tuple-granularity access control, which violates *R2* and *R3*.

Start from *policy*…

- A policy is defined as a triple <*Vi, Vj, tuple_set*>, where *tuple_set* defines a set of tuples owned by *Vi* and accessible by *Vj*, that is, *Vi* is the data owner party, while *Vj* is the consumer.
- Key uniqueness: (1) the data consumer is a specific party (instead of the whole federation) (*R1*); (2) the policy definer is the data owner (instead of some supervisor) (R2).
- So, a safe query processing has to consider the view disparity between parties, when data is transmitted among servers.

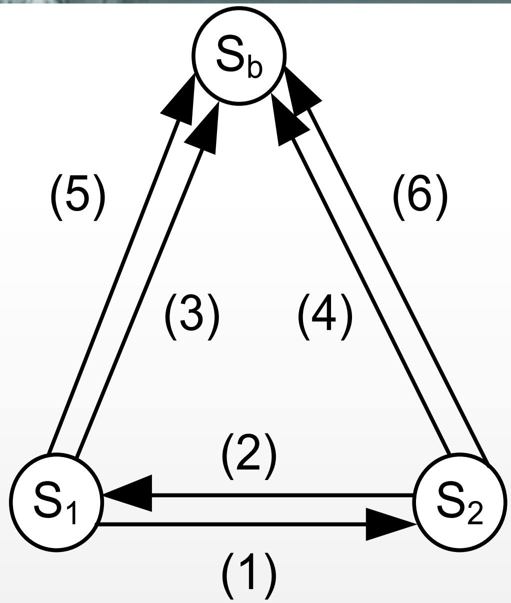
Split-join (1/2)

- Semi-join [Bernstein et al., 1981] breaks down a join query into two sub-joins to save communication cost.
- However, it assumes the view equality between parties.
- We propose *split-join*, which splits a join to three sub-joins to save communication cost and is compliant with the view disparity between parties:

A join B = A join (B1 U B2)

= (A join B1) U (A1 join B2) U (A2 join B2)

Split-join (2/2)



A join B = (A join B1) // step 2, 5
U (A1 join B2) // step 1, 6
U (A2 join B2) // step 3, 4

- Given a medium join selectivity factor, we can expect

|A1 join B2|< |A1| and

|A join B1| < |B1|

So, the total communication cost may be much lower than that of a straightforward and safe strategy by sending *A* and *B* to the destination directly.

The *consolidator* is S_b

The *master* is S_1

Steps: (1) $<S_1, S_2, A_1>$,

(2) $<S_2, S_1, B_1>$,

(3) $<S_1, S_b, A_2>$,

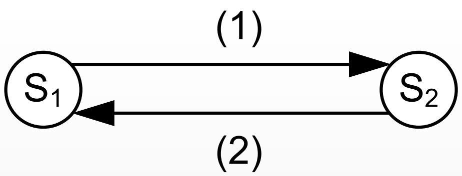
(4) $<S_2, S_b, B_2>$,

(5) $<S_1, S_b, A \bowtie B_1>$,

(6) $<S_2, S_b, A_1 \bowtie B_2>$

Other join methods

In each join, a buddy can act as a broker.

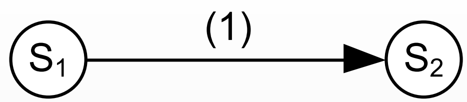


The *consolidator* is S_1

Steps: (1) $<S_1, S_2, \pi_{district}(A)>$

(2) $<S_2, S_1, \pi_{district}(A) \bowtie B>$

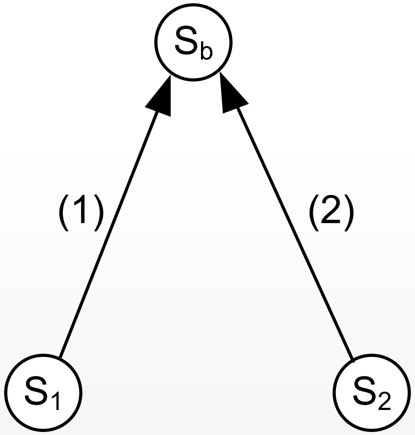
(a) Semi-join



The *consolidator* is S_2

Steps: (1) $<S_1, S_2, A>$

(b) Peer-join



The *consolidator* is S_b

Steps: (1) $<S_1, S_b, A>$,

(2) $<S_2, S_b, B>$

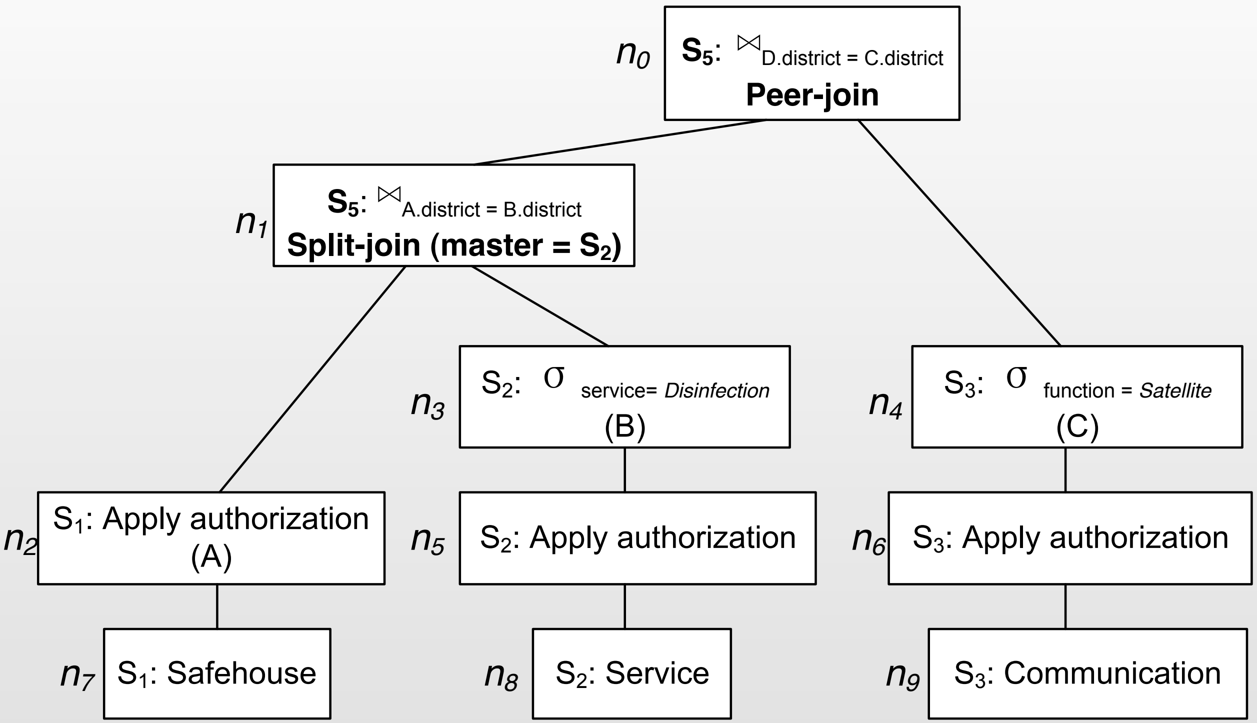
(c) Broker-join

Algorithm (1/2)

- The most efficient join method for “*A join B*” is not necessarily the best in “*A join B join C*”, considering, e.g., the server that obtains “*A join B*” may vary for different join methods.
- An algorithm that achieves the best overall efficiency for any given query is proposed.

Algorithm (2/2)

- It takes a poster-order walk over the query tree to accumulate candidate query strategies and finally annotates the tree with the best strategy.



Proofs

- We have proved the algorithm
  - Correct: always generate correct query results
  - Safe: compliant with all policies
- We also proved a desirable property of the algorithm: *Authorization Confidentiality*, i.e., the policy definition doesn't need to be leaked for executing the query.

Experiments

- The experiments compare the costs of following cases:
- Case 1: all related tables are sent to *Sq*

  --- baseline

  Case 2: buddy servers are explored

  --- save 42% communication cost

  Case 3: split-join is applied

  --- save 39%

  Case 4: both buddies and split-joins are used

  --- save 60%

Conclusion

- Identified essential information sharing needs:
  - R1: per-party view
  - R2: data owner has the information sharing autonomy
  - R3: fine-granularity access control
- Formalized the authorization policies defined in terms of parties and tuple set.
- Proposed a novel join method (split-join) and an algorithm that generates efficient query strategies.