Kafka pairwise domain/range cardinality combinations constraint discovery results

Generation of instances by combining every value that the cardinality of the domain set and range set can take, for every relation pair.

- isOneOne defines a 1 to 1 relationship where #domain = #range = 1
- isOneMany defines a 1 to Many relationship where #domain = 1, #range = 2
- isManyOne defines a Many to 1 relationship where #domain = 2, #range = 1
- ***NOTE***: isManyMany is not strictly equivalent to a many-many relation. It just means that #domain = 2 and #range=2.

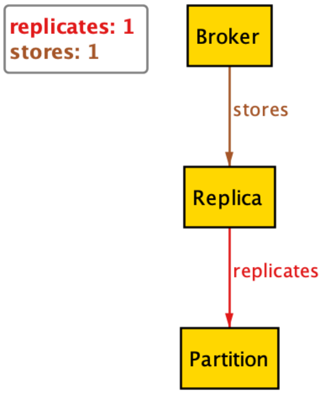
Approach

- The main idea is to constrain any given pair of relations by applying any of the four predicates to each relation: [isOneOne, isOneMany, isManyOne, isManyMany]
- For a pair of relations, there will be total 4 x 4 = 16 constraints
- For `n` relations: total nC2 * 16 constraints = 8n * (n - 1) constraints

Constraint 1

```
run constraint1 {
        isOneOne[replicates]
        isOneOne[stores]
}
```

Legal



Constraint 2

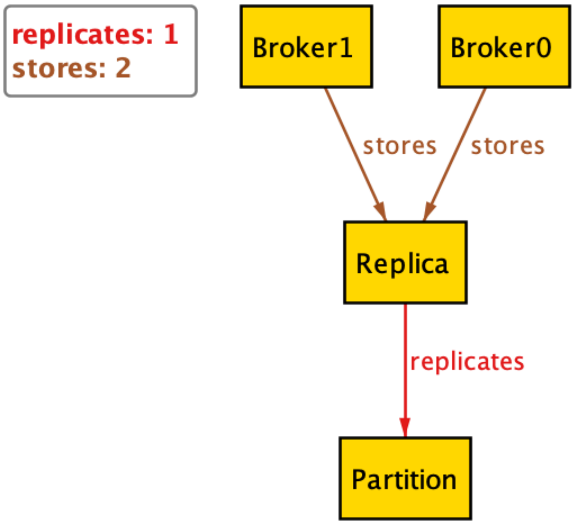
```
run constraint2 {
	isOneOne[replicates]
	isOneMany[stores]
}
```

```
Executing "Run constraint2"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 35ms.
   No instance found. Predicate may be inconsistent. 6ms.
```

Constraint 3

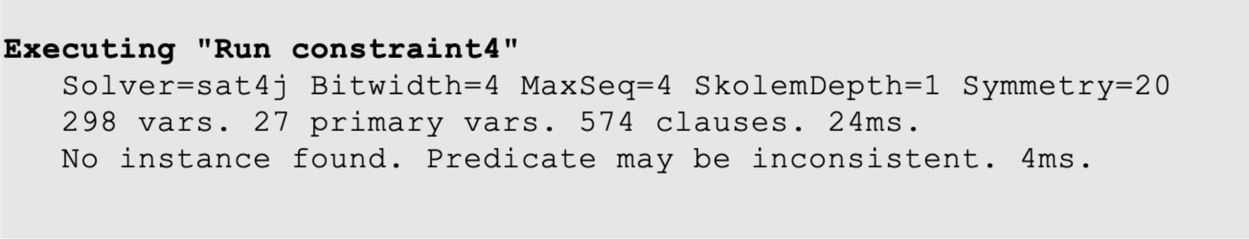
```
run constraint3 {
	isOneOne[replicates]
	isManyOne[stores]
}
```

Illegal: Same replica cannot be stored on multiple brokers



Constraint 4

```
run constraint4 {
	isOneOne[replicates]
	isManyMany[stores]
}
```



```
Executing "Run constraint4"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 24ms.
   No instance found. Predicate may be inconsistent. 4ms.
```

Constraint 5-7

```
run constraint5 {
	isOneMany[replicates]
	isOneOne[stores]
}

run constraint6 {
	isOneMany[replicates]
	isOneMany[stores]
}

run constraint7 {
	isOneMany[replicates]
	isManyOne[stores]
}

run constraint8 {
	isOneMany[replicates]
	isManyMany[stores]
}
```

```
Executing "Run constraint5"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 32ms.
   No instance found. Predicate may be inconsistent. 5ms.
```

```
Executing "Run constraint6"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 25ms.
   No instance found. Predicate may be inconsistent. 10ms.
```

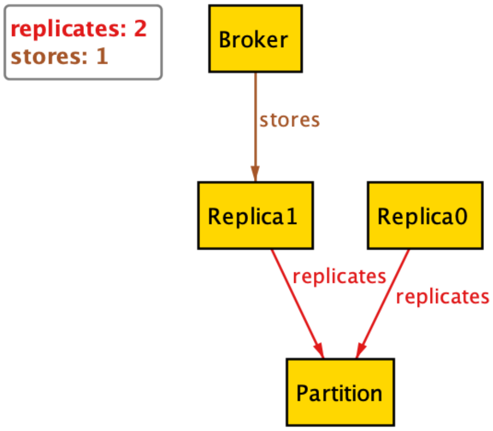
```
Executing "Run constraint7"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 37ms.
   No instance found. Predicate may be inconsistent. 4ms.
```

```
Executing "Run constraint8"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 25ms.
   No instance found. Predicate may be inconsistent. 3ms.
```

Constraint 9

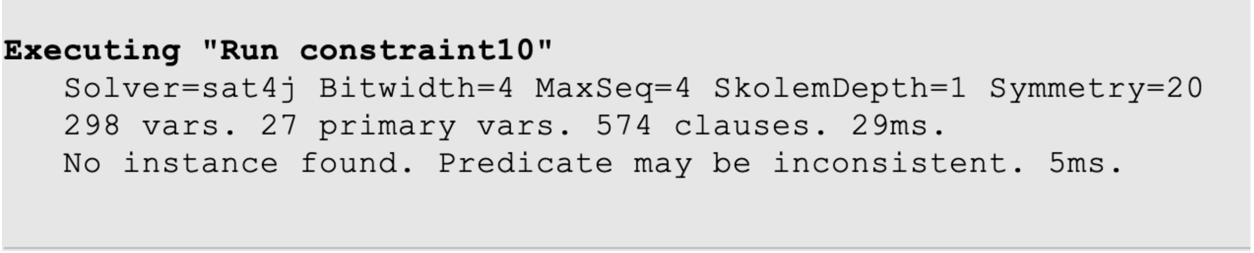
```
run constraint9 {
        isManyOne[replicates]
        isOneOne[stores]
}
```

Legal



Constraint 10

```
run constraint10 {
	isManyOne[replicates]
	isOneMany[stores]
}
```

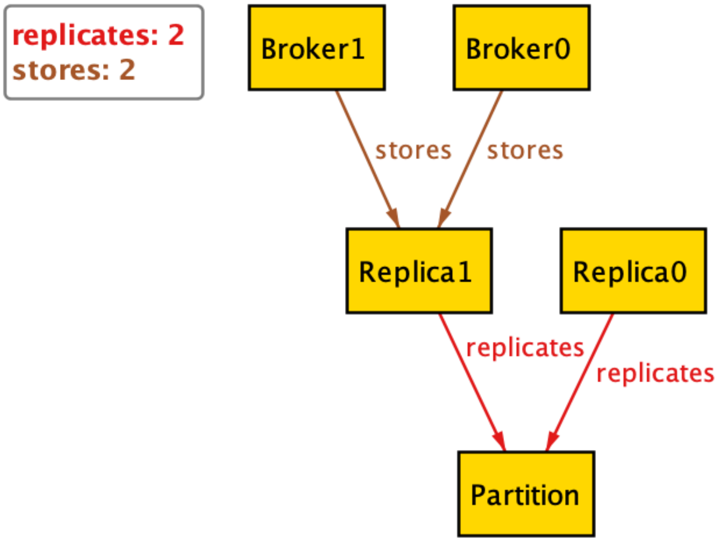


```
Executing "Run constraint10"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 29ms.
   No instance found. Predicate may be inconsistent. 5ms.
```

Constraint 11

```
run constraint11 {
	isManyOne[replicates]
	isManyOne[stores]
}
```

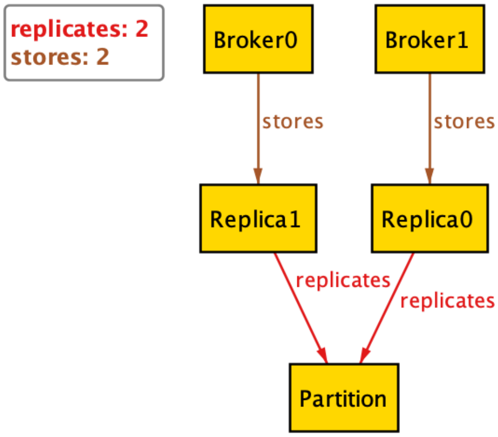
Illegal: One replica stored in multiple brokers



Constraint 12

```
run constraint12 {
        isManyOne[replicates]
        isManyMany[stores]
}
```

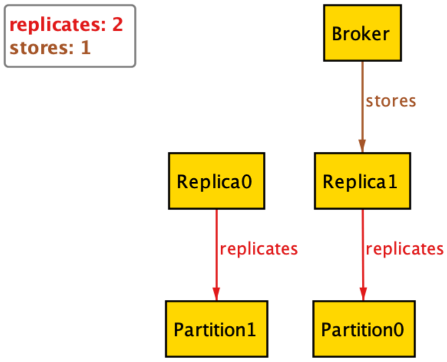
Legal



Constraint 13

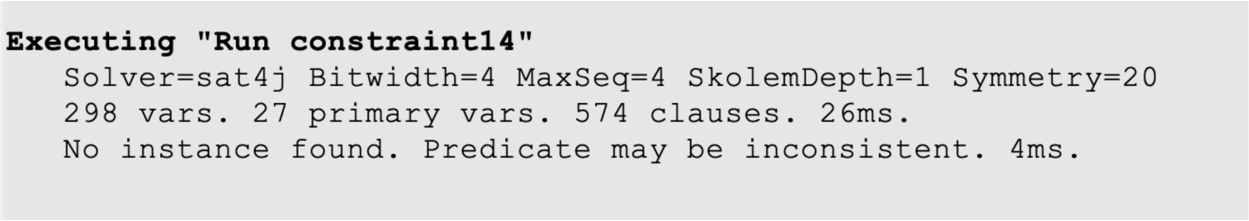
```
run constraint13 {
        isManyMany[replicates]
        isOneOne[stores]
}
```

Legal



Constraint 14

```
run constraint14 {
        isManyMany[replicates]
        isOneMany[stores]
}
```

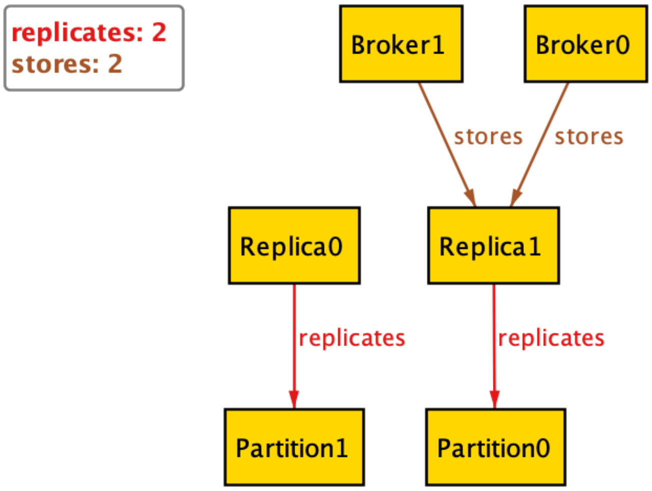


```
Executing "Run constraint14"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   298 vars. 27 primary vars. 574 clauses. 26ms.
   No instance found. Predicate may be inconsistent. 4ms.
```

Constraint 15

```
run constraint15 {
        isManyMany[replicates]
        isManyOne[stores]
}
```

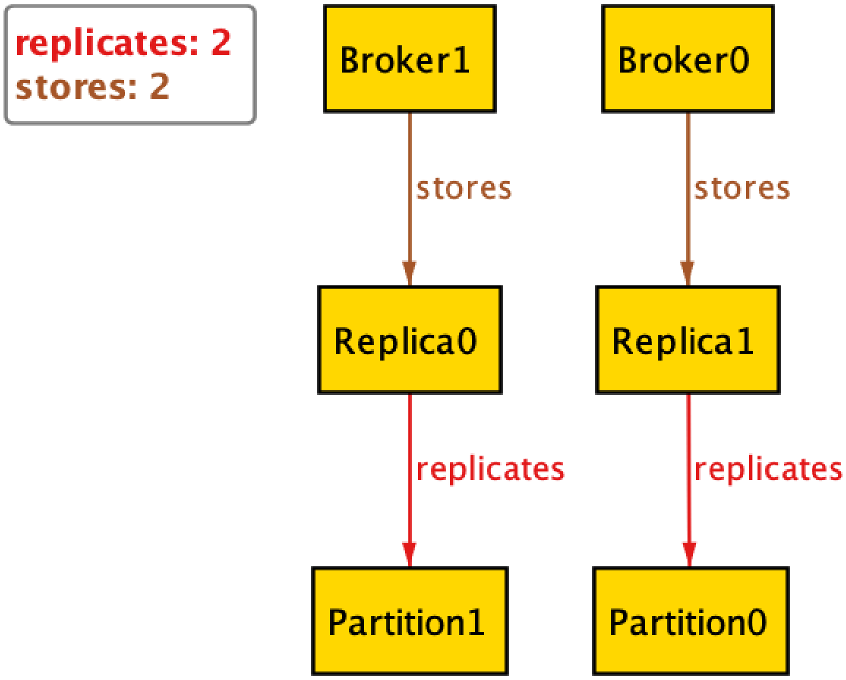
Illegal: Same replica in multiple brokers



Constraint 16

```
run constraint16 {
        isManyMany[replicates]
        isManyMany[stores]
}
```

Legal


replicates: 2
stores: 2
Broker1
Broker0
stores
stores
Replica0
Replica1
replicates
replicates
Partition1
Partition0