Router-based stream processing implemented in P4

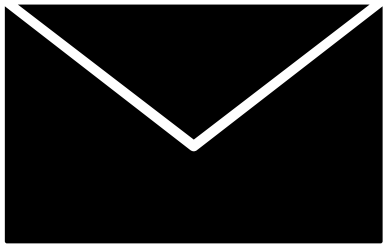
Sammy Moseley

Outline

1. Background on stream processing
2. Implementation using P4
3. Next steps

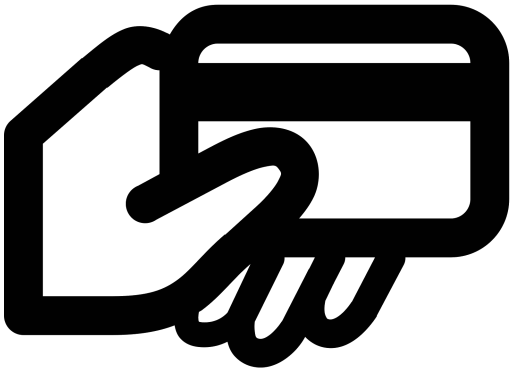
Stream Processing Applications

Friend/Follow Requests



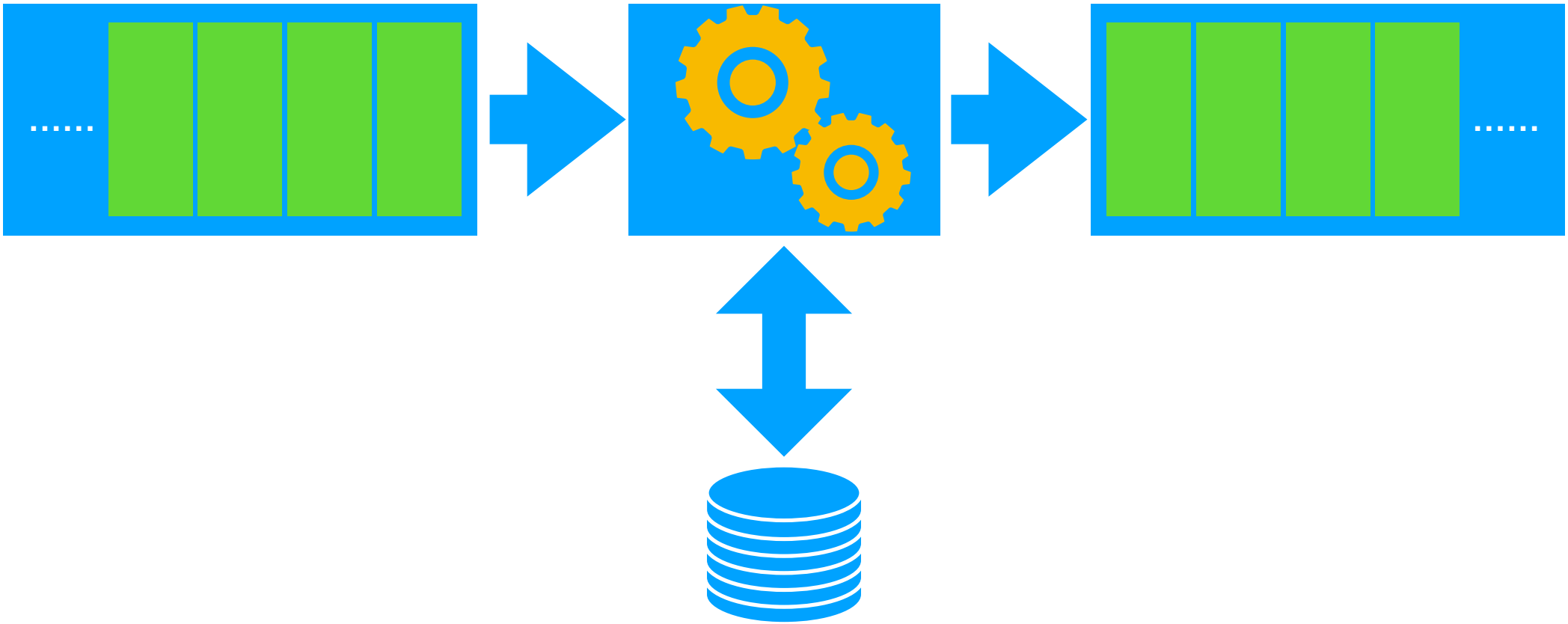
Messaging

Webpage view/post clicks

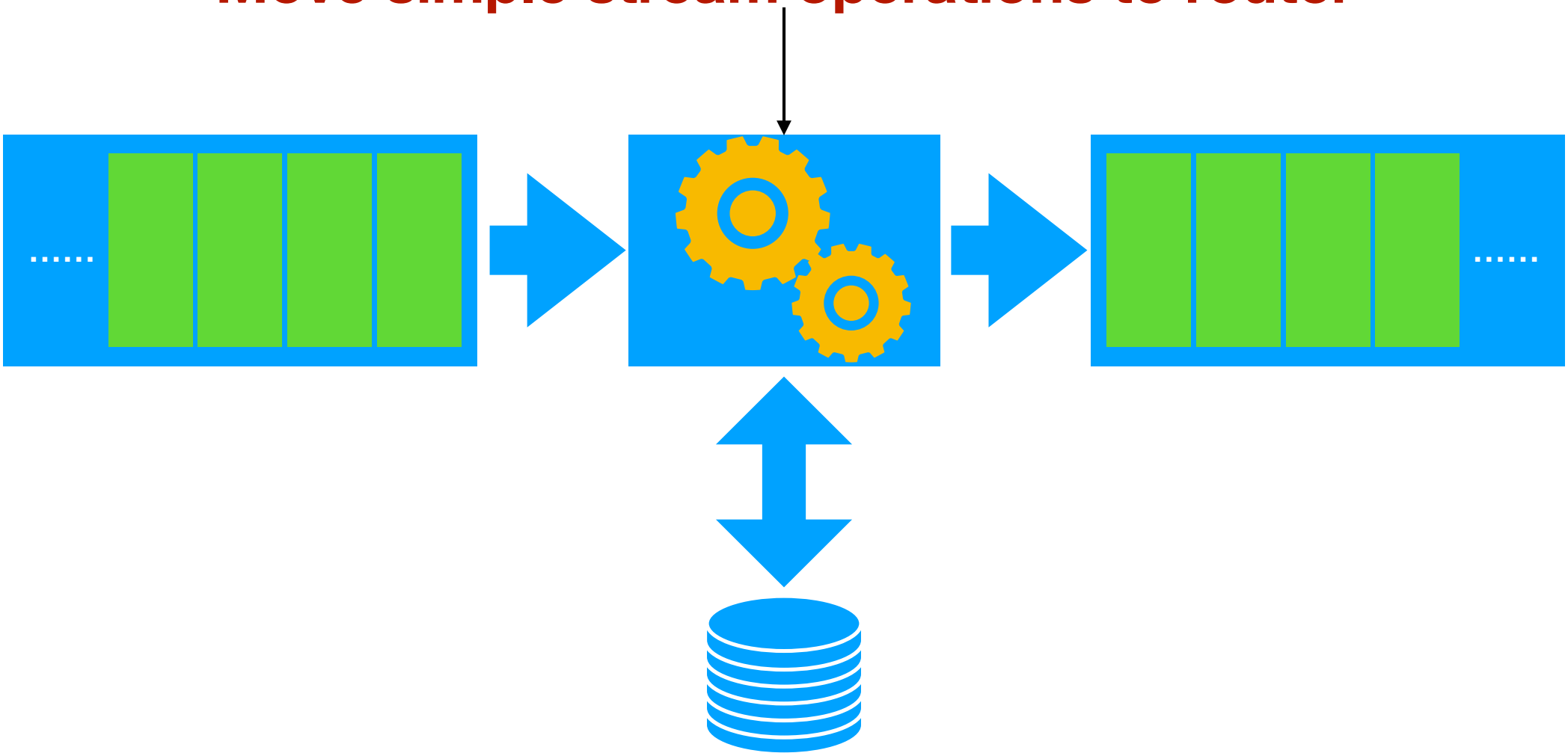


Payment Transactions

A Quick Background on Stream Processing



Move simple stream operations to router



Fundamental stream query operators

1. Filter
2. Map
3. Join
4. Aggregate
5. Zip

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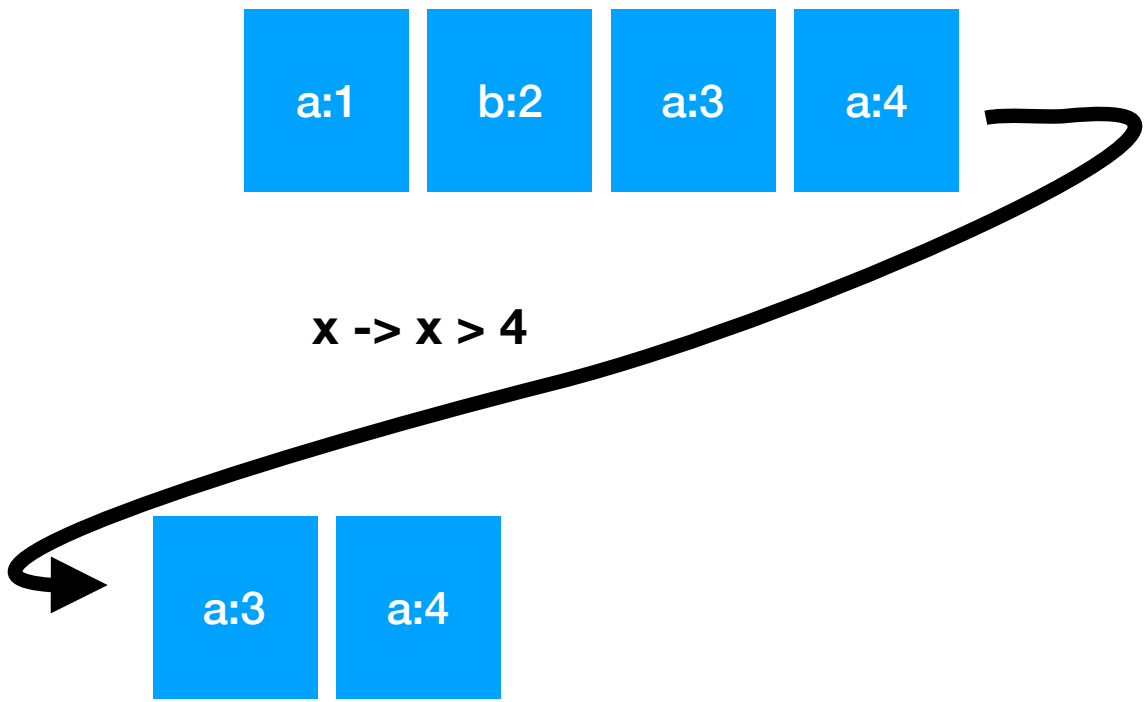

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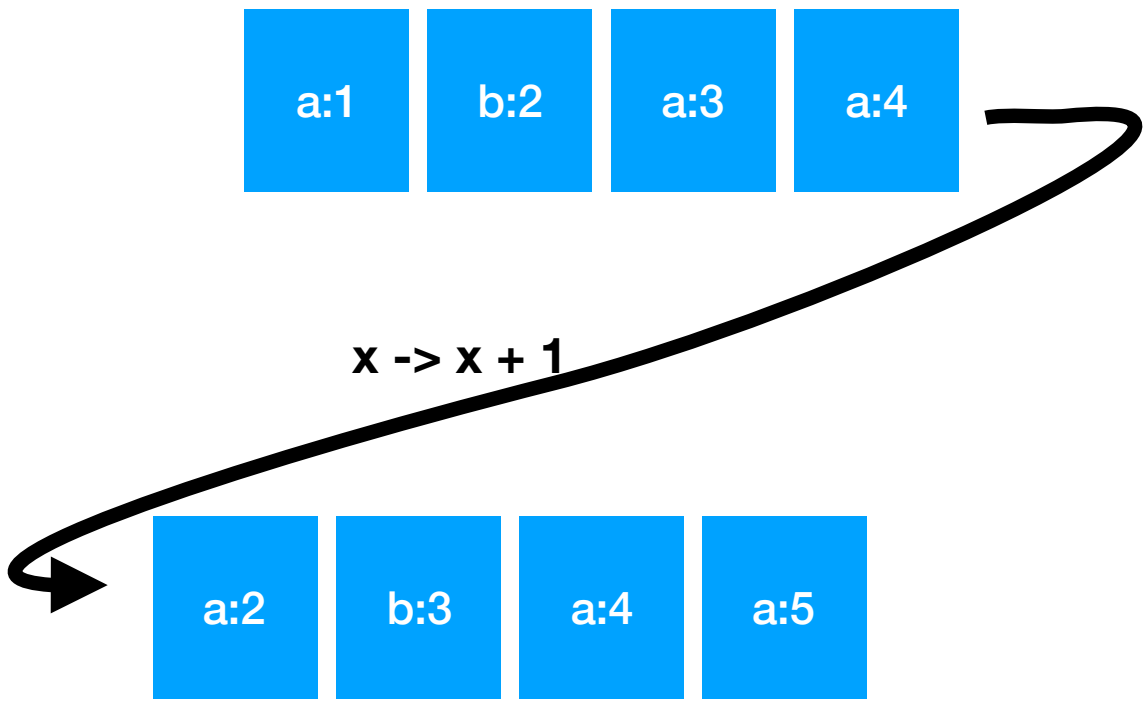

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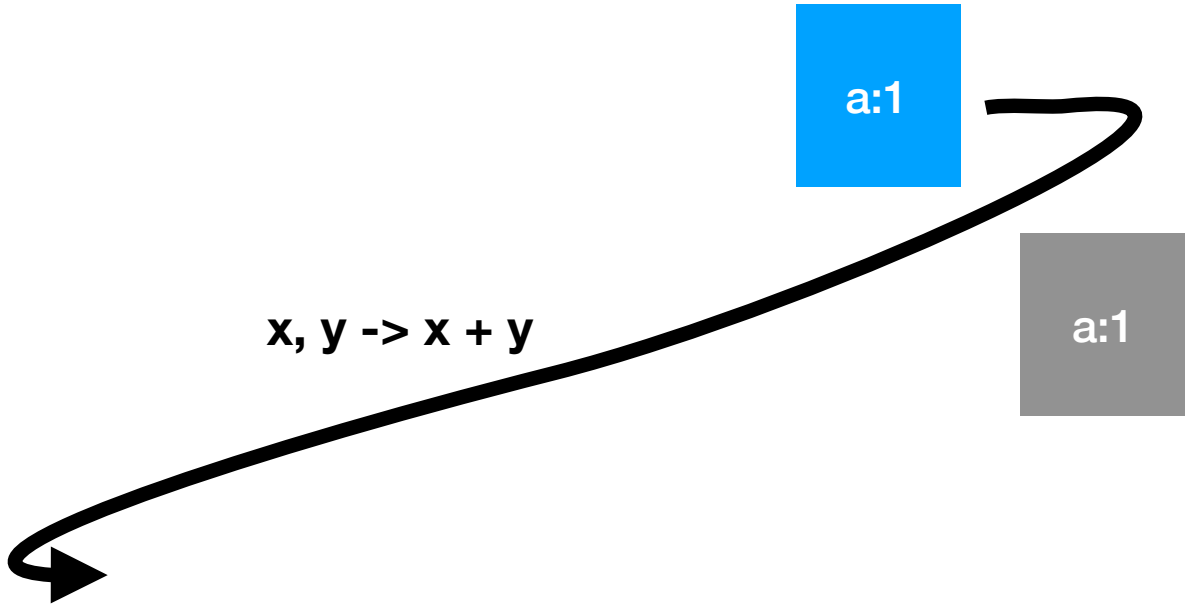

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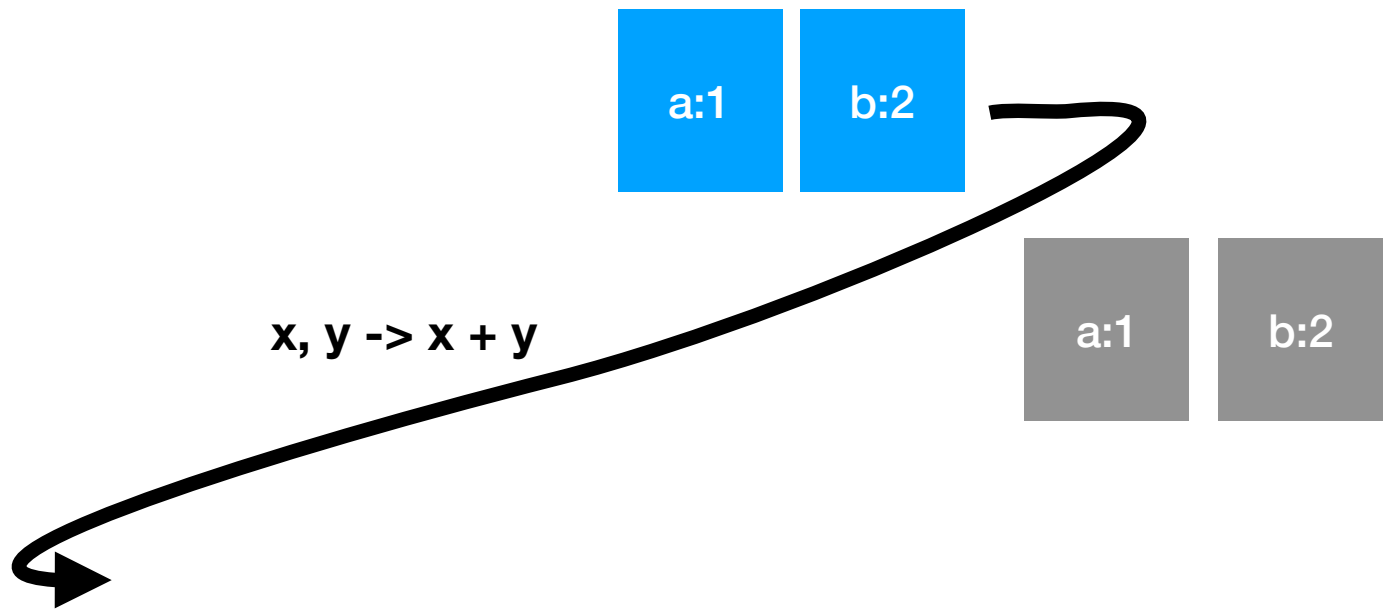

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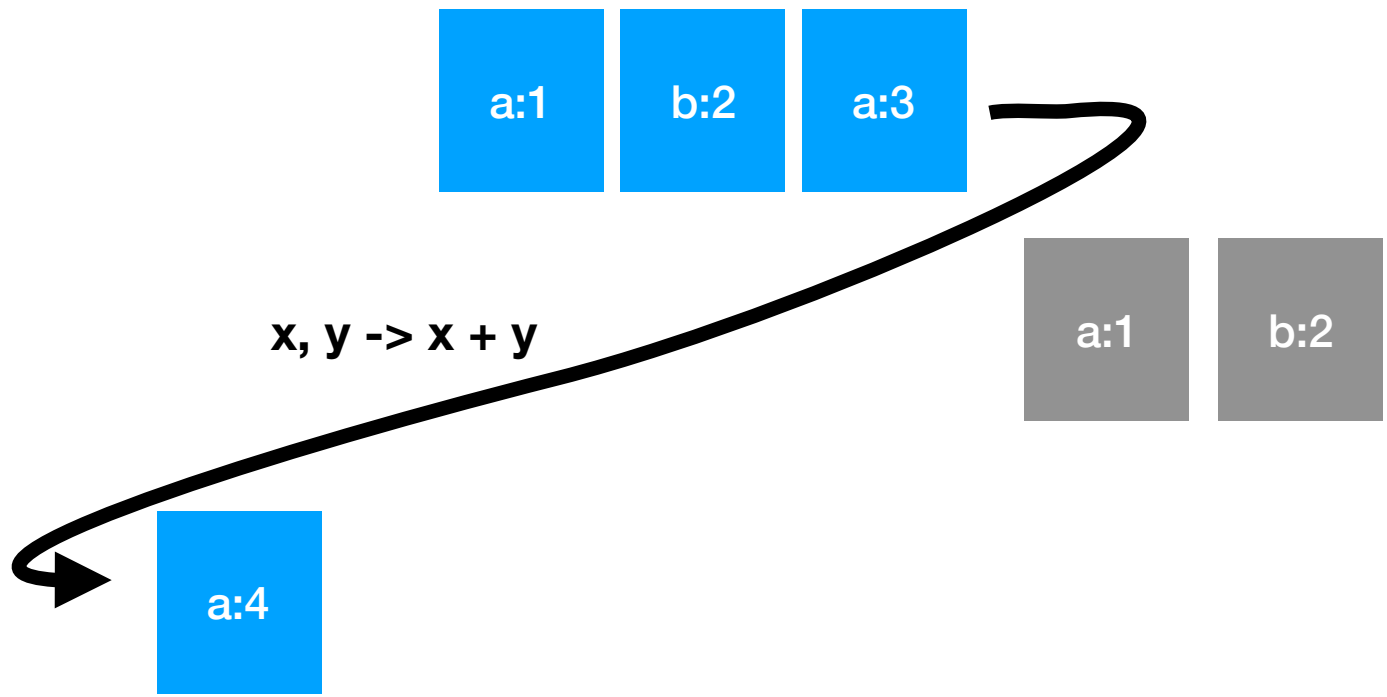

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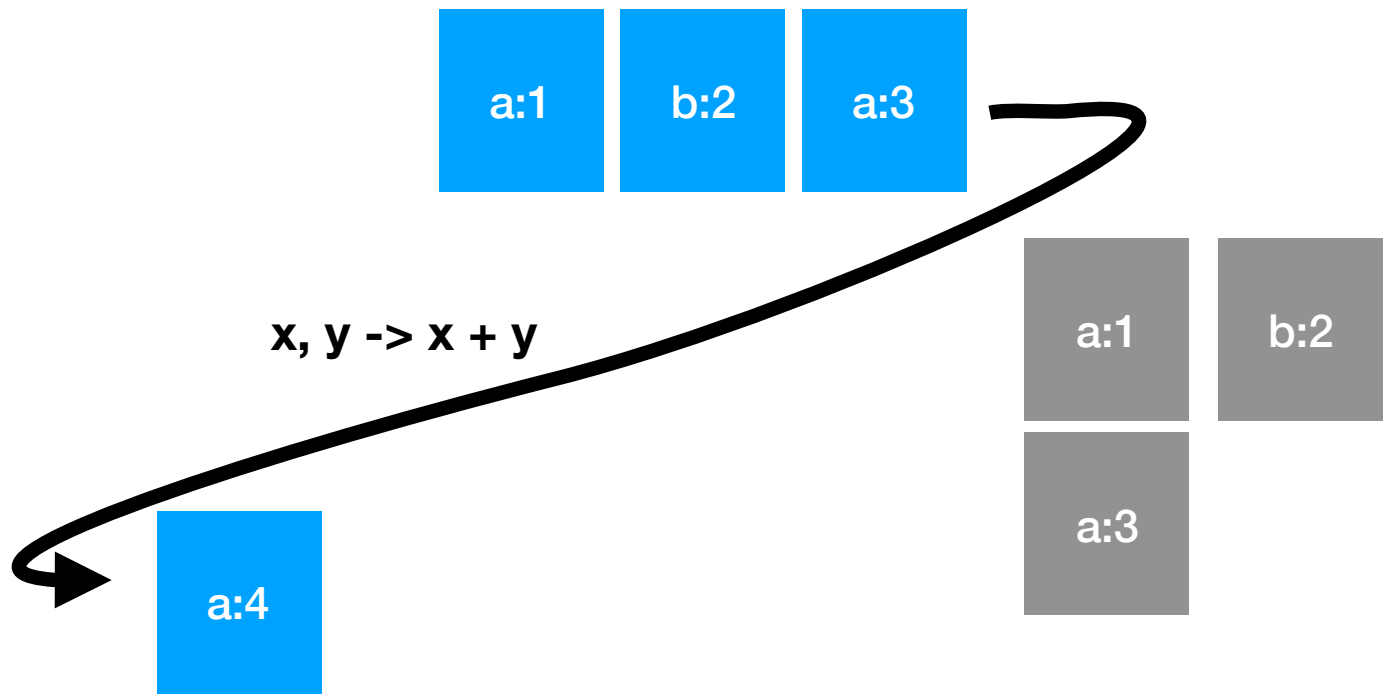

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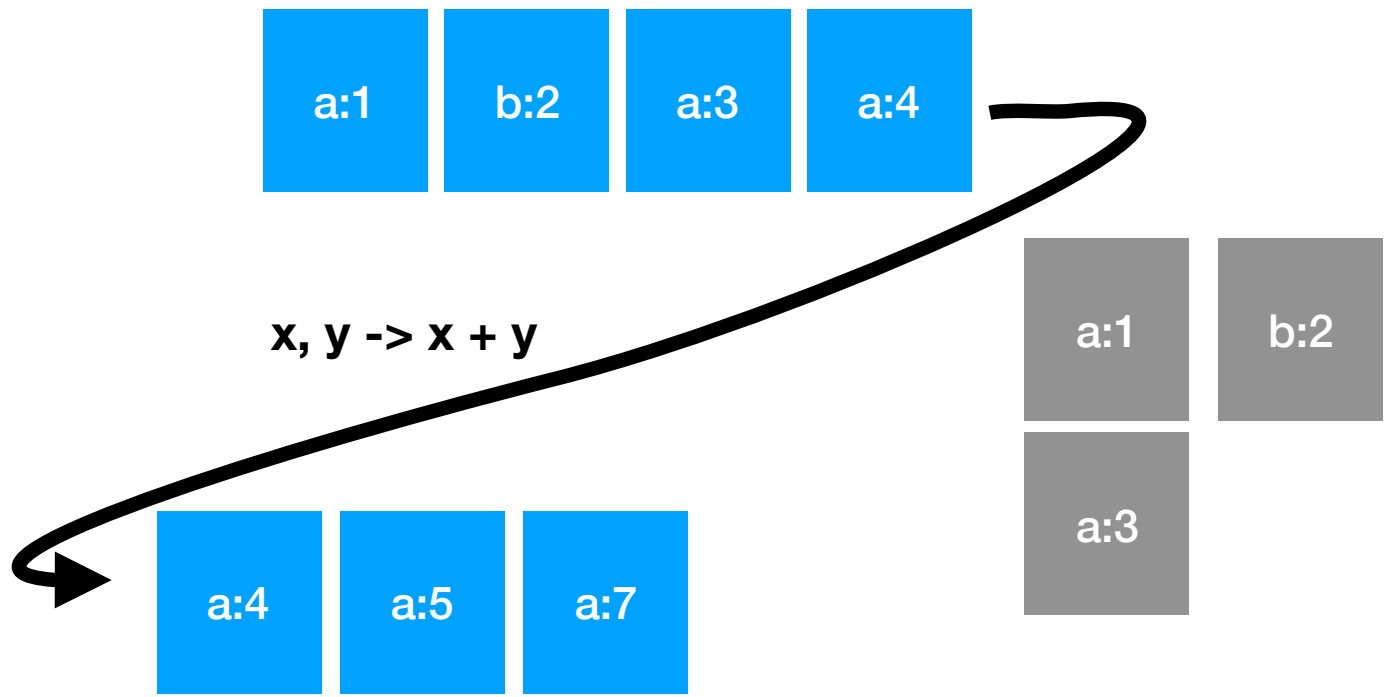

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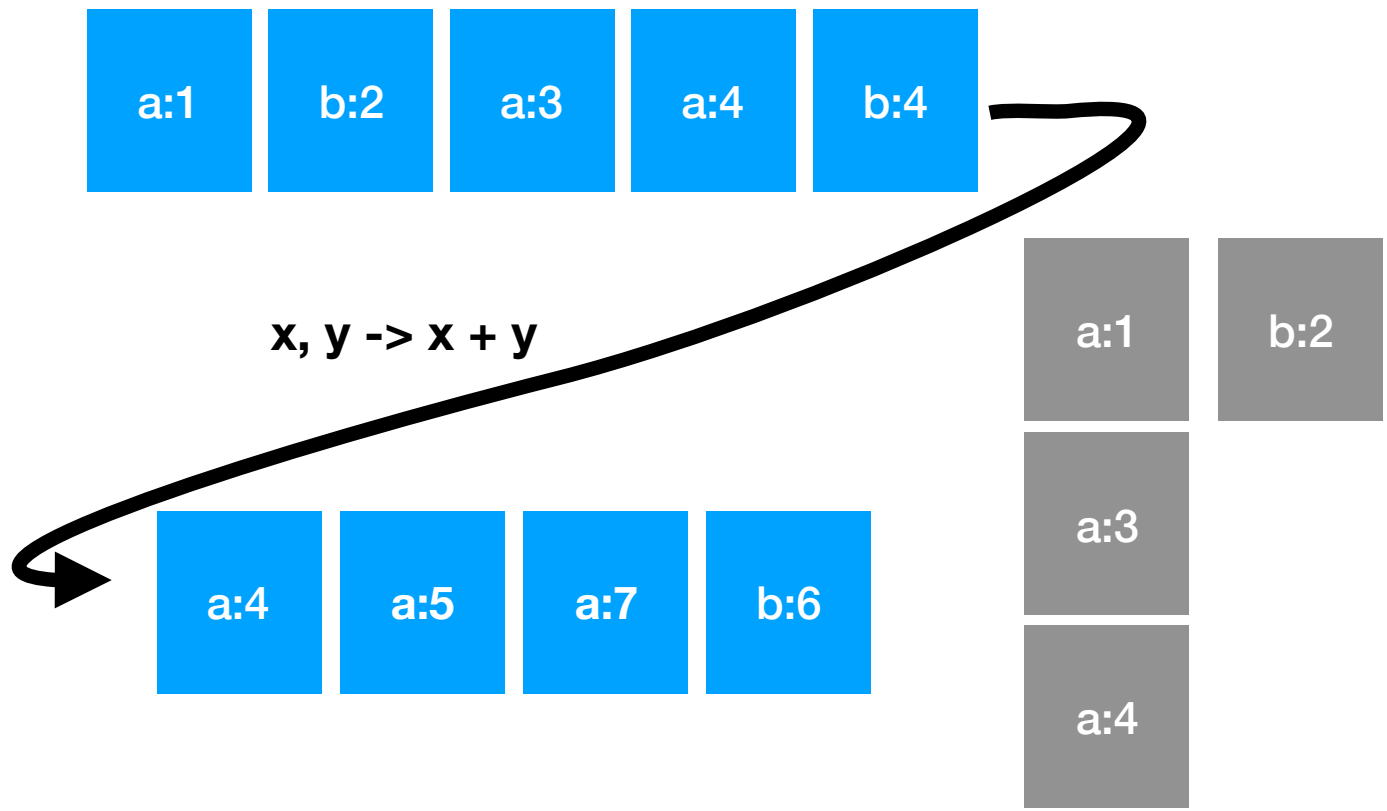

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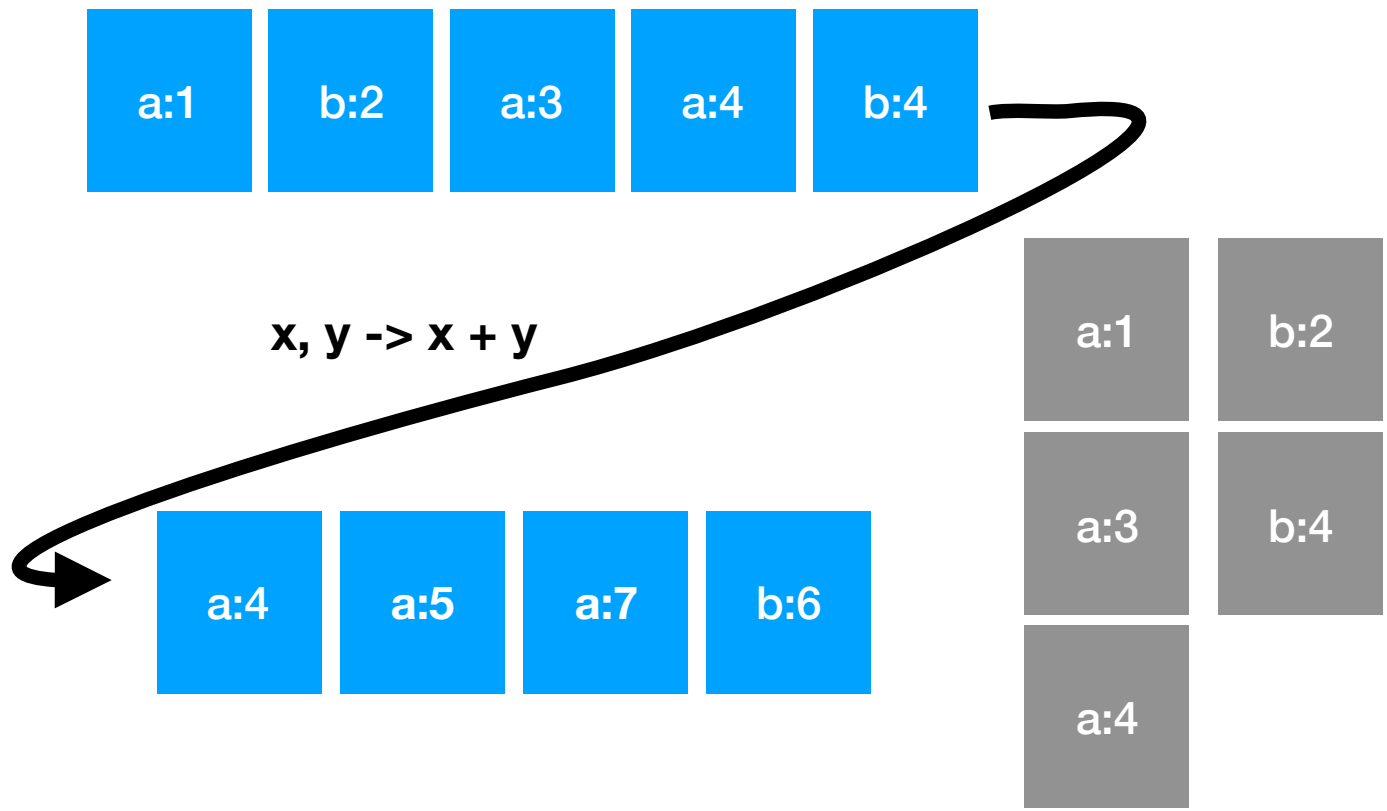

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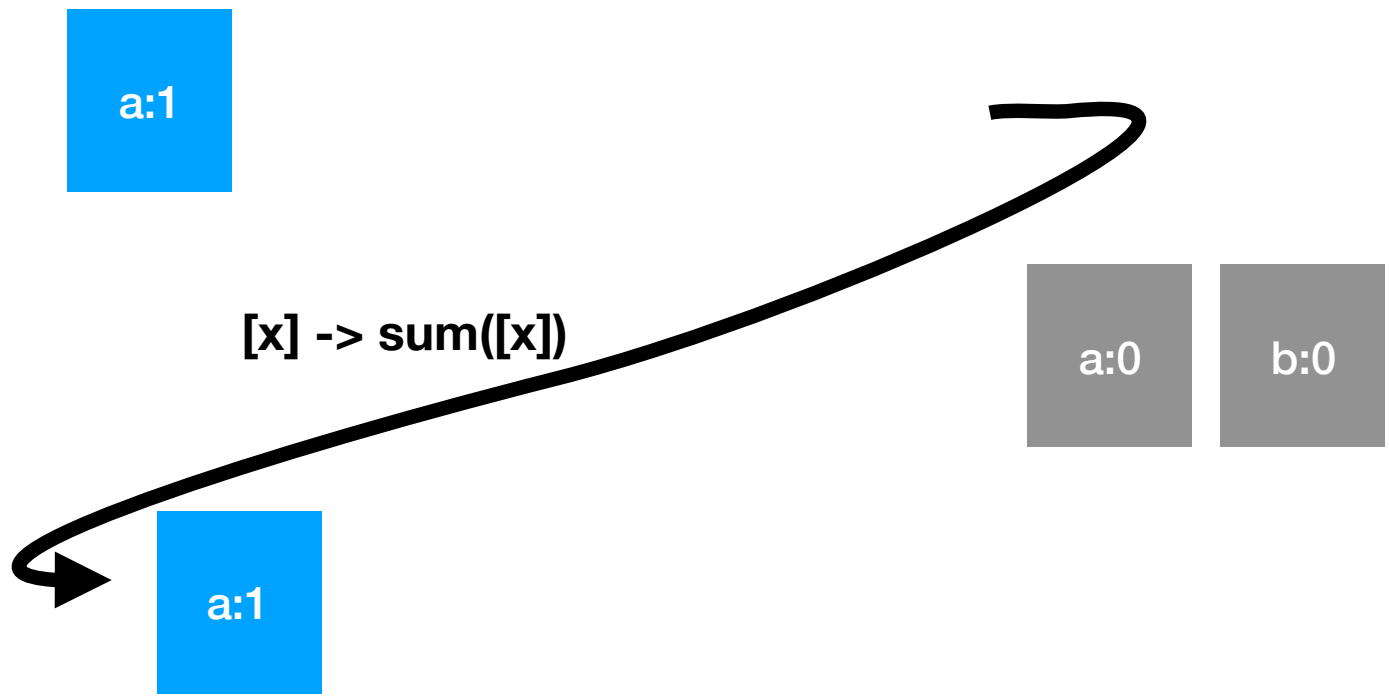

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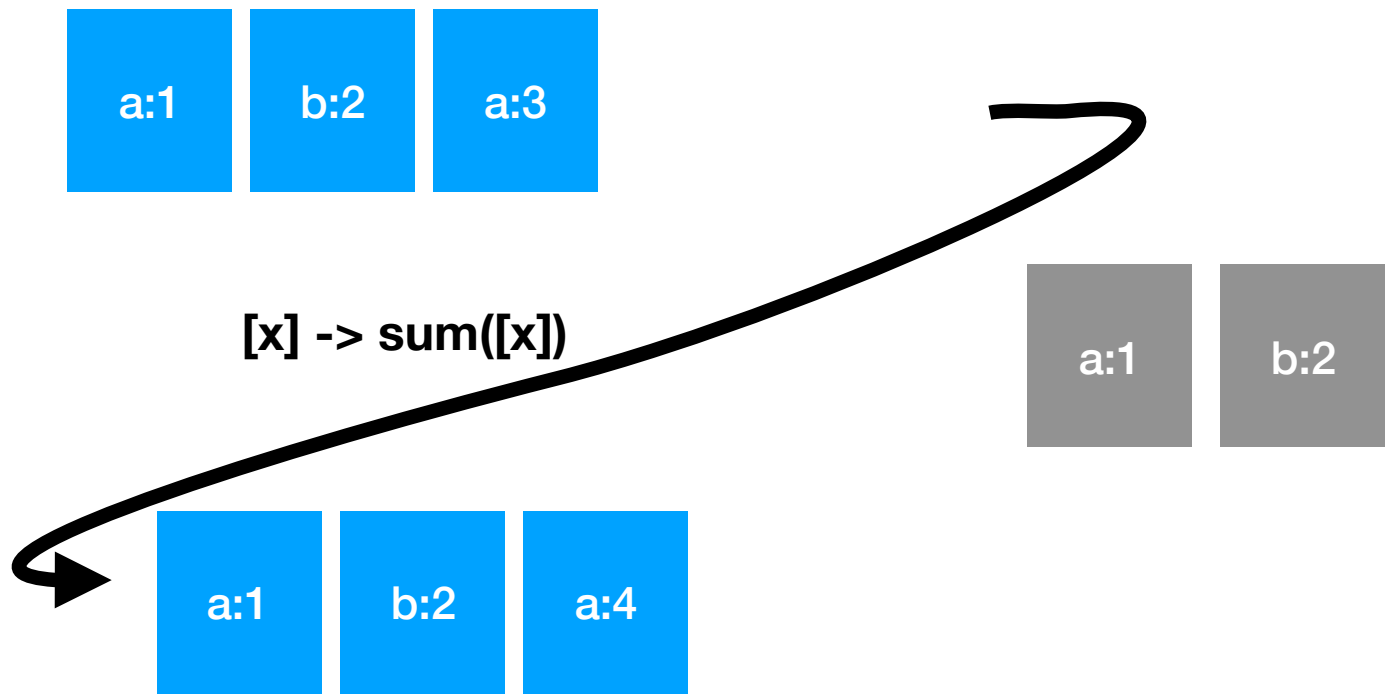

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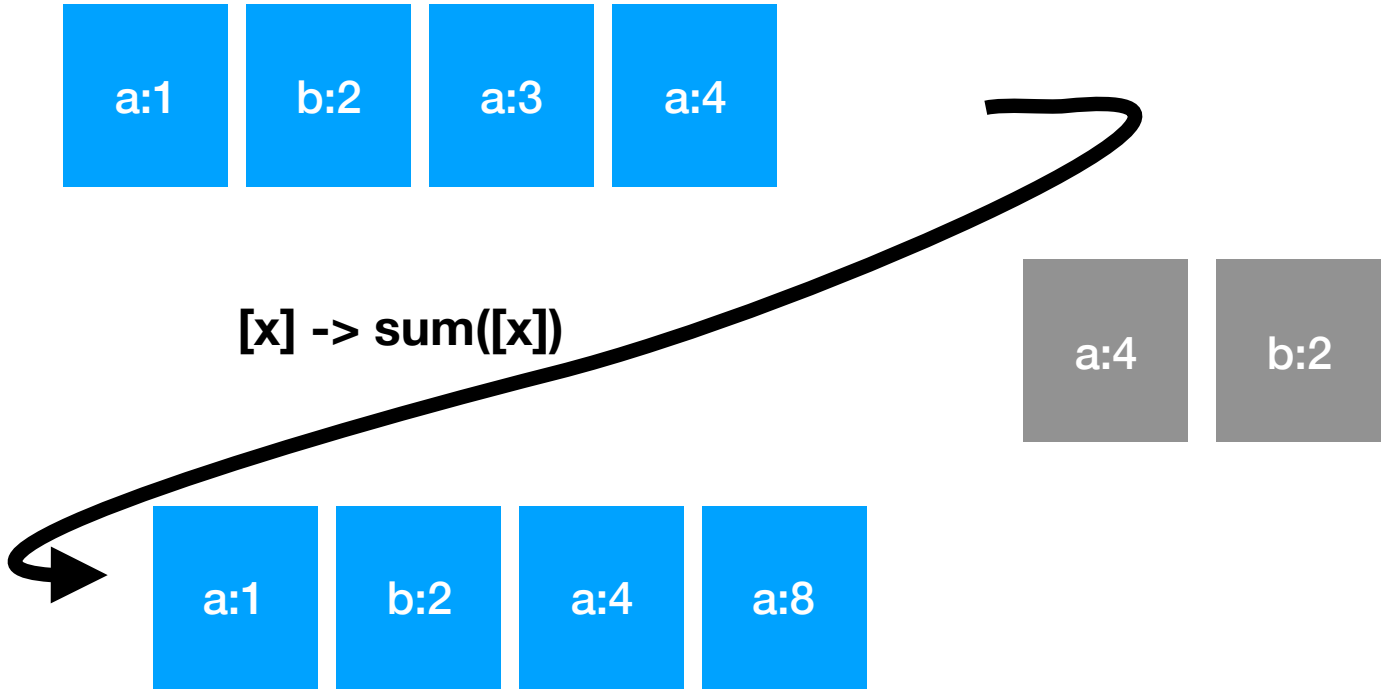

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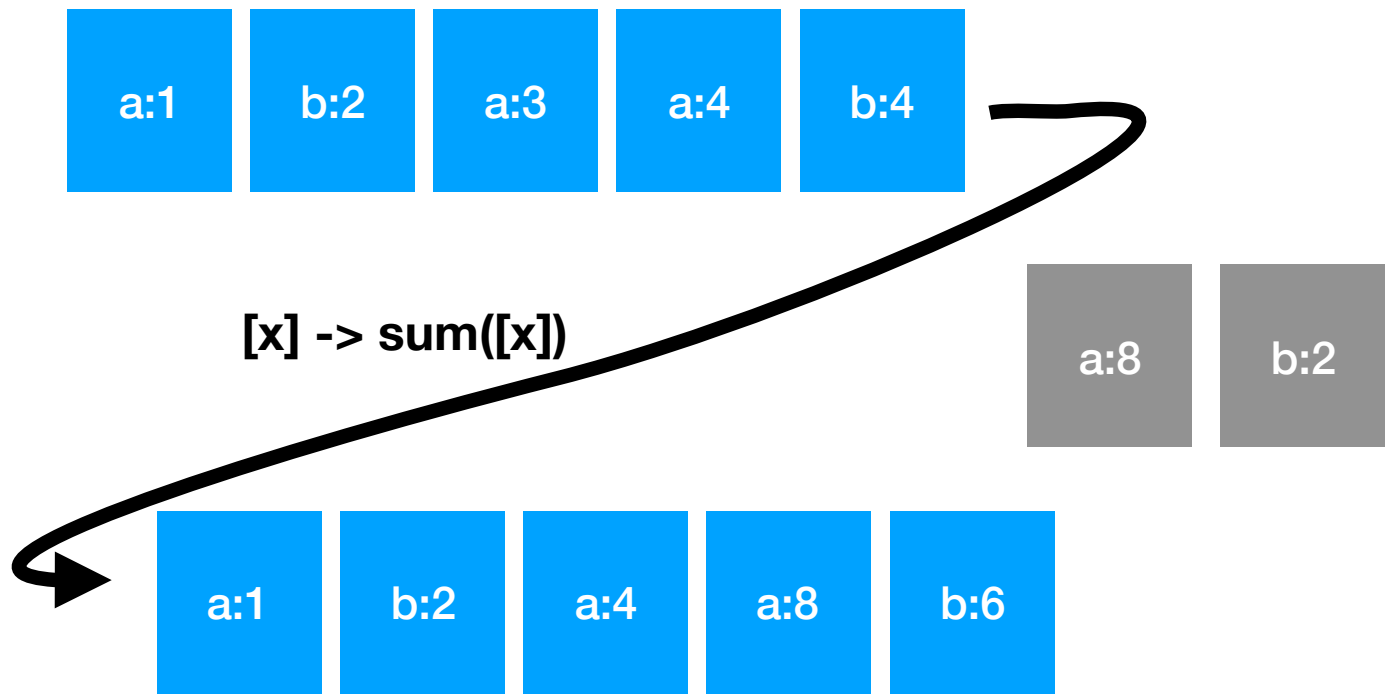

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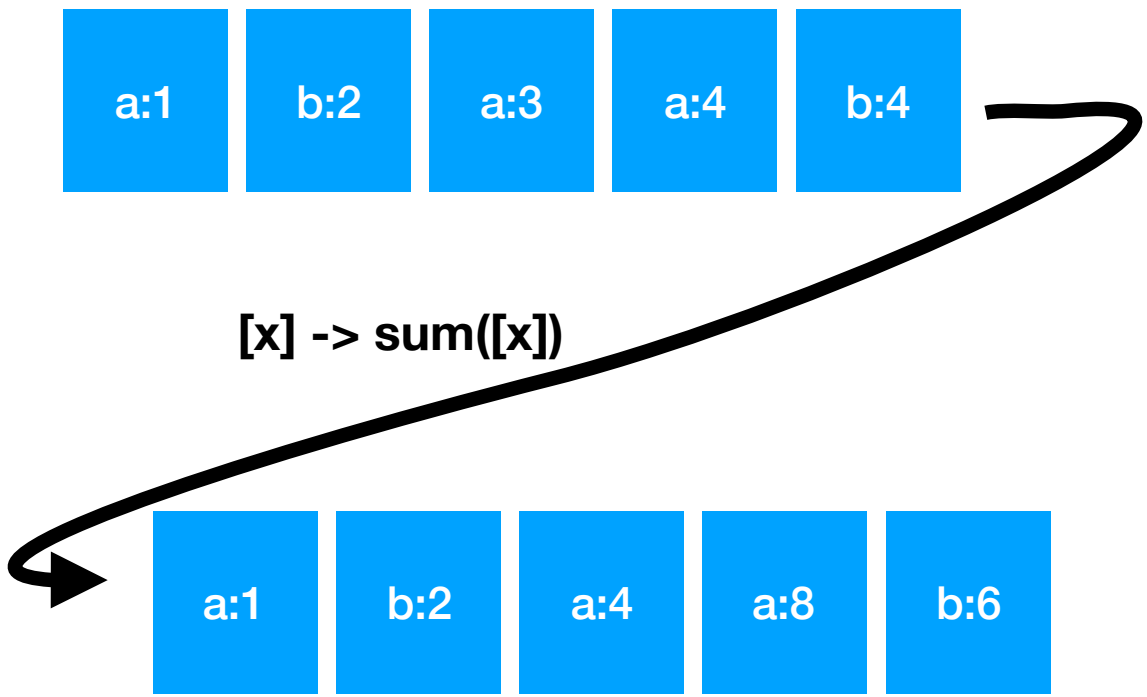

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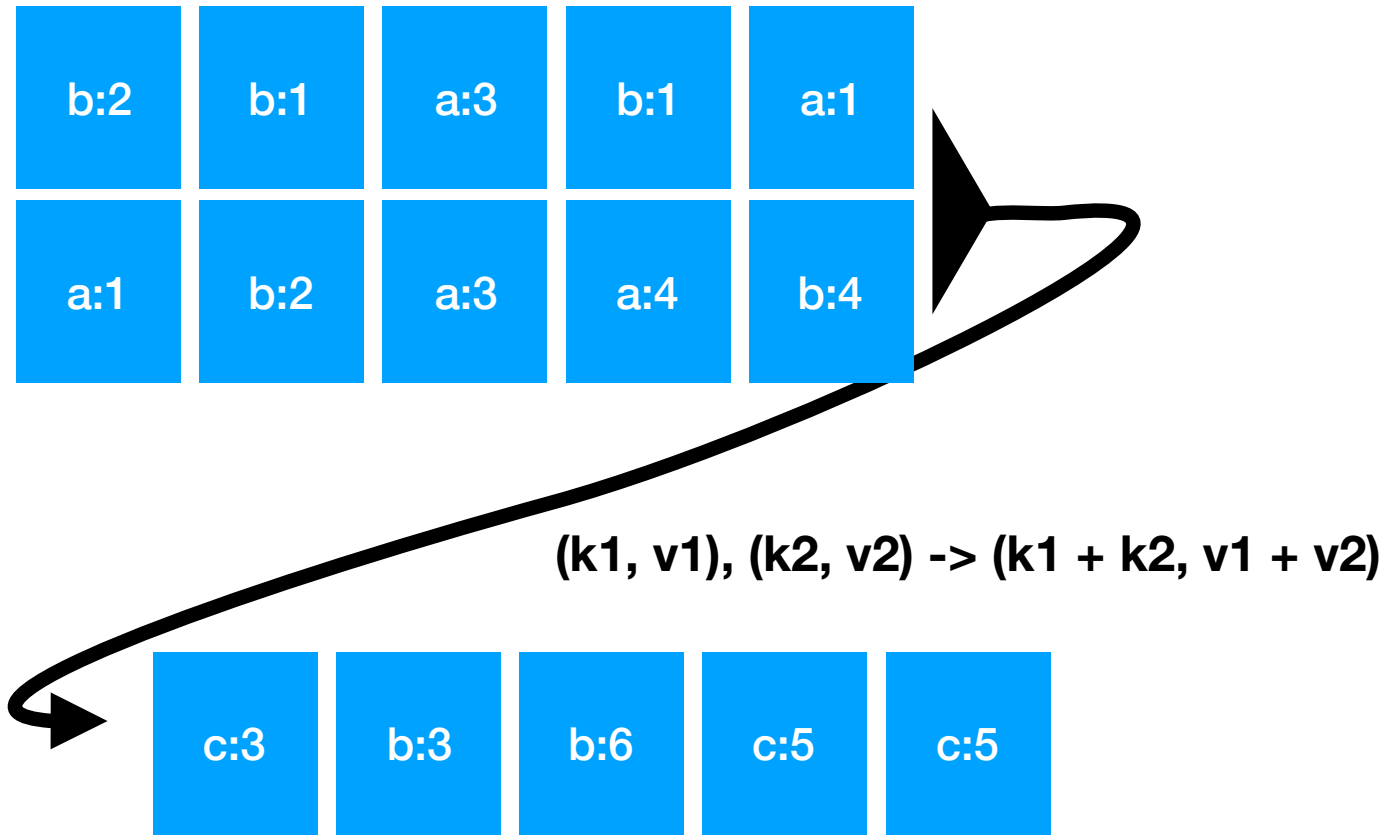

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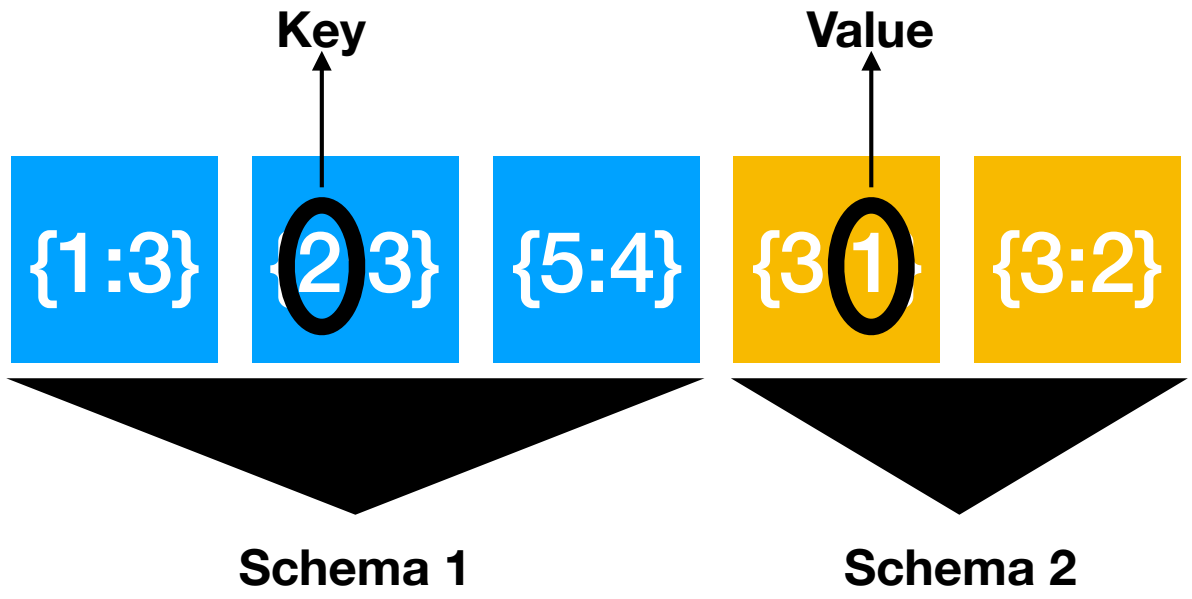
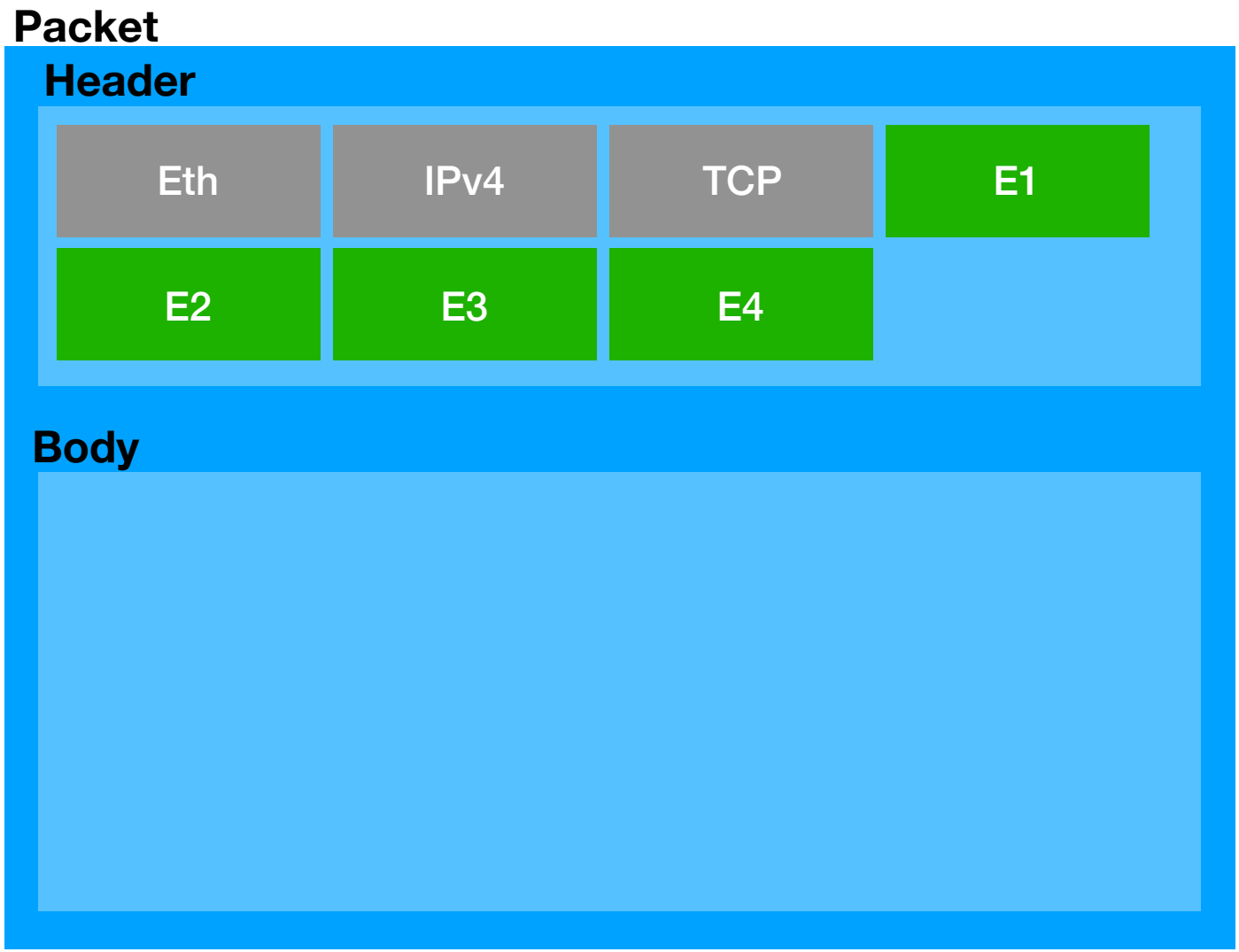
P4 Implementation: Stream Objects



P4 Implementation: Header Format

```
header entry_t {
    bit<32> schema;
    bit<32> key;
    bit<32> val;
    bit<8> unprocessed;
}
```

Always process first stream object on stack



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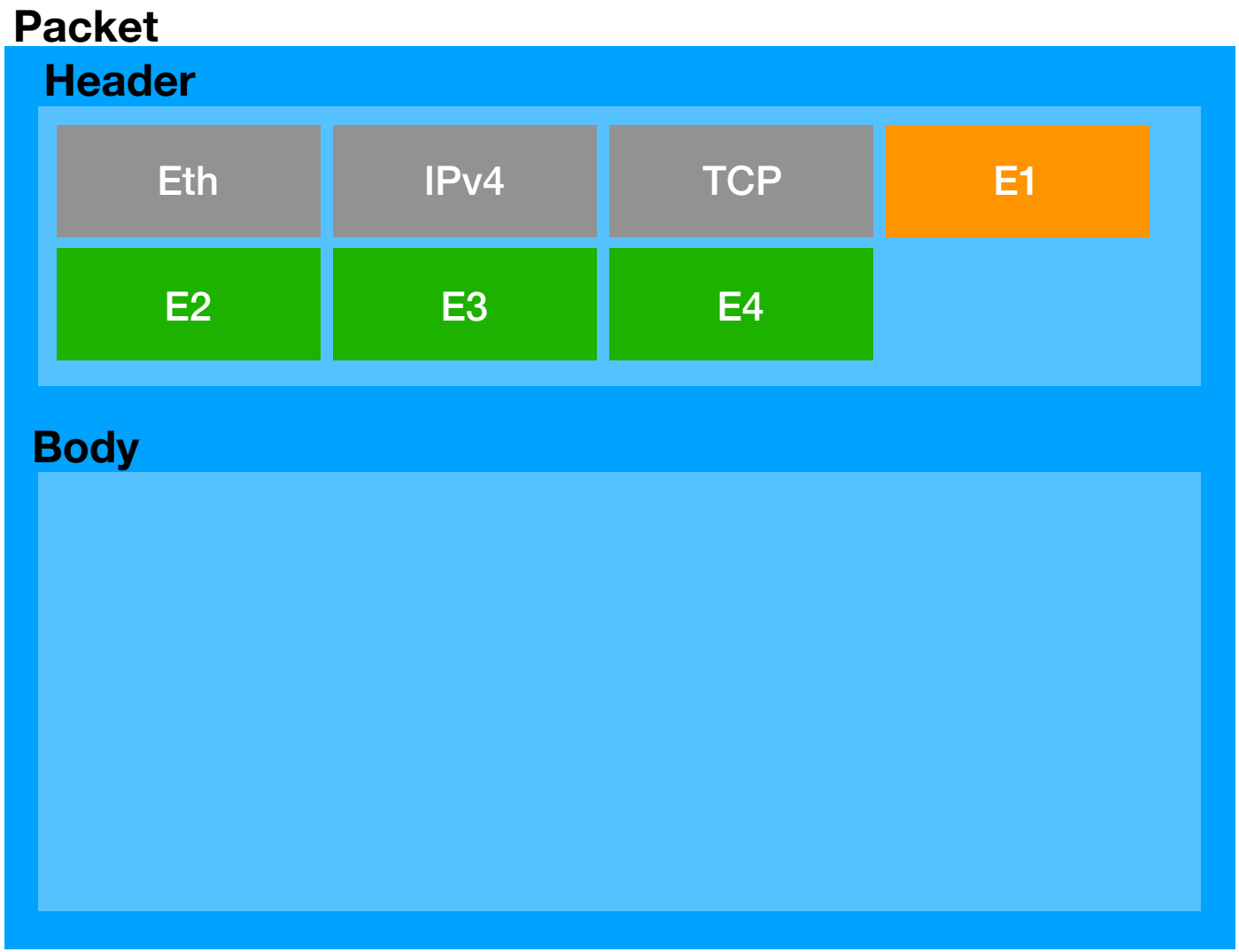
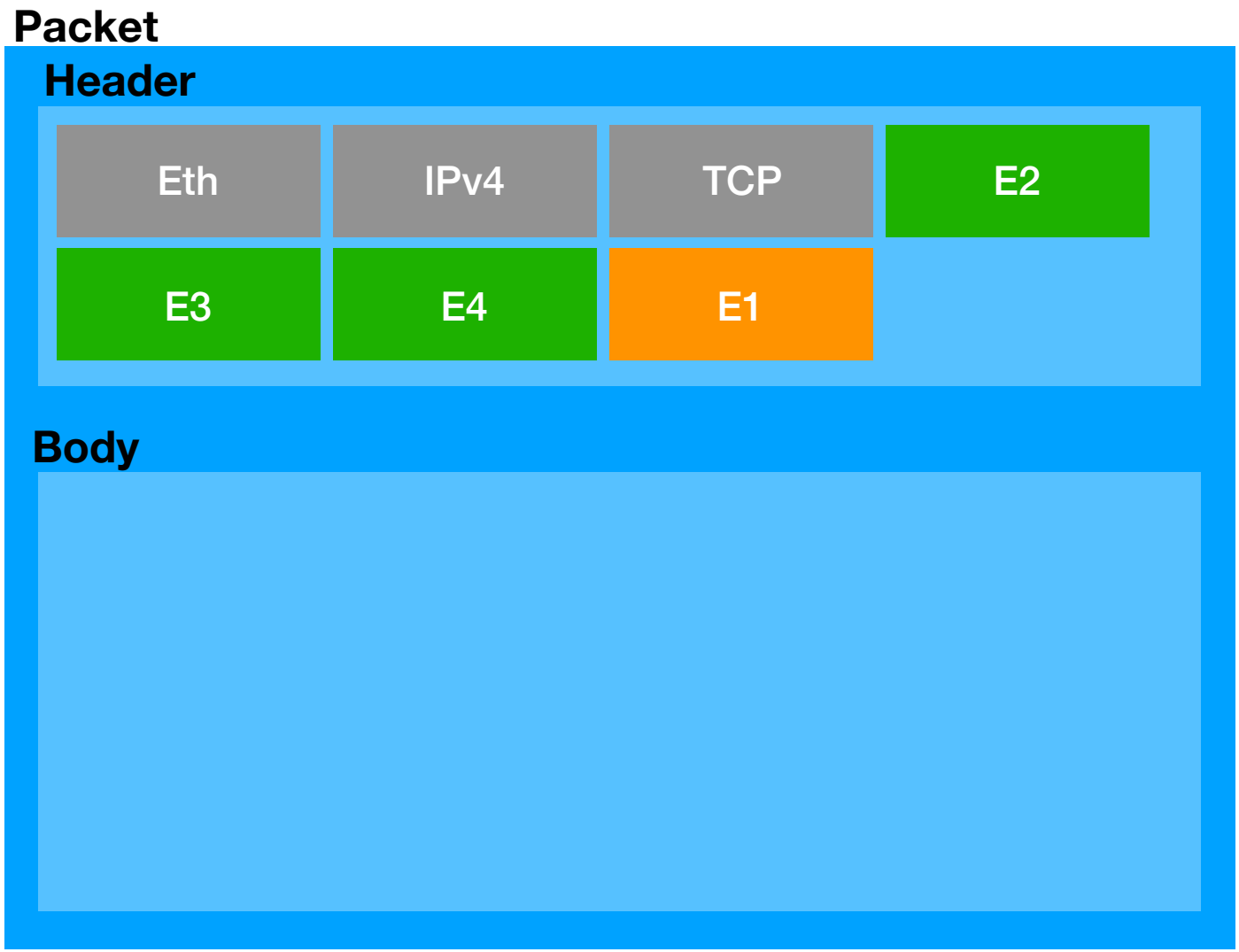


Circulate stack to get next element



`recirculate` packets and use temporary header field to rotate stack

```
struct headers {
    ethernet_t   ethernet;
    ipv4_t       ipv4;
    tcp_t        tcp;
    entry_count_t entry_count;
    entry_t[10] entry;
    entry_t entry_swap;
}
```

P4 Implementation: Representing Stream Operations

```
{
  "table": "MyIngress.stream_ops",
  "match": {
    "hdr.entry[0].schema": 0,
    "meta.lineNo": 0
  },
  "action_name": "MyIngress.add",
  "action_params": {
    "i": 1
  }
}
```

P4 Implementation: Representing Stream Operations

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}
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  "action_name": "MyIngress.add",
  "action_params": {
    "i": 1
  }
},
{
  "table": "MyIngress.stream_ops",
  "match": {
    "hdr.entry[0].schema": 0,
    "meta.lineNo": 1
  },
  "action_name": "MyIngress.add",
  "action_params": {
    "i": 1
  }
}
```

Map operator in action

```
###[ TCP ]###
        sport     = 56169
        dport     = 4660
        seq       = 0
        ack       = 0
        dataofs   = 5L
        reserved  = 0L
        flags     = S
        window    = 8192
        chksum    = 0x8a26
        urgptr    = 0
        options   = []
###[ KeyValCount ]###
           count     = 1
###[ KeyValPair ]###
              schema    = 0
              key       = 3
              val       = 7
              unprocessed= 1L
```

{3:7}

```
###[ TCP ]###
        sport     = 56169
        dport     = 4660
        seq       = 0
        ack       = 0
        dataofs   = 5L
        reserved  = 0L
        flags     = S
        window    = 8192
        chksum    = 0x8a26
        urgptr    = 0
        options   = []
###[ KeyValCount ]###
           count     = 1
###[ KeyValPair ]###
              schema    = 0
              key       = 3
              val       = 9
              unprocessed= 0L
```

{3:9}

P4 Implementation: Representing Stream Operations

```
{
  "table": "MyIngress.stream_ops",
  "match": {
    "hdr.entry[0].schema": 1,
    "meta.lineNo": 0
  },
  "action_name":
"MyIngress.key_window_aggregate",
  "action_params": { }
}
```

Aggregate operator in action

```
###[ TCP ]###
        sport     = 56169
        dport     = 4660
        seq       = 0
        ack       = 0
        dataofs   = 5L
        reserved  = 0L
        flags     = S
        window    = 8192
        chksum    = 0x8a26
        urgptr    = 0
        options   = []
###[ KeyValCount ]###
           count     = 1
###[ KeyValPair ]###
             schema    = 0
             key       = 3
             val       = 7
             unprocessed= 1L
```

{4:7}

```
###[ TCP ]###
        sport     = 52165
        dport     = 4660
        seq       = 0
        ack       = 0
        dataofs   = 5L
        reserved  = 0L
        flags     = S
        window    = 8192
        chksum    = 0x99c7
        urgptr    = 0
        options   = []
###[ KeyValCount ]###
           count     = 1
###[ KeyValPair ]###
             schema    = 1
             key       = 4
             val       = 8
             unprocessed= 1L
```

{4:8}

```
###[ TCP ]###
        sport     = 62853
        dport     = 4660
        seq       = 0
        ack       = 0
        dataofs   = 5L
        reserved  = 0L
        flags     = S
        window    = 8192
        chksum    = 0x7006
        urgptr    = 0
        options   = []
###[ KeyValCount ]###
           count     = 1
###[ KeyValPair ]###
             schema    = 1
             key       = 4
             val       = 9
             unprocessed= 1L
```

{4:9}

→

```
###[ TCP ]###
        sport     = 62853
        dport     = 4660
        seq       = 0
        ack       = 0
        dataofs   = 5L
        reserved  = 0L
        flags     = S
        window    = 8192
        chksum    = 0x7006
        urgptr    = 0
        options   = []
###[ KeyValCount ]###
           count     = 1
###[ KeyValPair ]###
             schema    = 1
             key       = 4
             val       = 24
             unprocessed= 0L
```

{4:24}

P4 Implementation: Representing Stream Operations

```
{
  "table": "MyIngress.stream_ops",
  "match": {
    "hdr.entry[0].schema": 2,
    "meta.lineNo": 0
  },
  "action_name":
"MyIngress.join_sum",
  "action_params": { }
}
```

Join operator in action

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 1
             val       = 1
             unprocessed= 1L
```

{1:1}

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 2
             val       = 2
             unprocessed= 1L
```

{2:2}

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 1
             val       = 3
             unprocessed= 1L
```

{1:3}

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 1
             val       = 4
             unprocessed= 1L
```

{1:4}

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 2
             val       = 4
             unprocessed= 1L
```

{2:4}

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 1
             val       = 4
             unprocessed= 0L
```

{1:4}

```
###[ KeyValCount ]###
          count     = 2
###[ KeyValPair ]###
             schema    = 2
             key       = 1
             val       = 5
             unprocessed= 0L
###[ KeyValPair ]###
             schema    = 2
             key       = 1
             val       = 7
             unprocessed= 0L
```

{1:5},{1:7}

```
###[ KeyValCount ]###
          count     = 1
###[ KeyValPair ]###
             schema    = 2
             key       = 2
             val       = 6
             unprocessed= 0L
```

{2:6}

Next steps

- Implement Stream QL compiler
- Compare to python stream processing implementation