[544] Kafka Streaming

Tyler Caraza-Harter

Learning Objectives

- describe the benefits of using streaming for ETL (extract transform load) work
- write code for Kafka consumers and producers in order to interact with topic data that stored by brokers
- scale out brokers and consumers by configuring topic partitions and consumer groups, respectively

Outline: Kafka Streaming

Sending/Receiving Messages
- RPC (Remote Procedure Calls)
- Streaming

ETL (Extract Transform Load)

Kafka Design

Procedure Calls

```
counts = {
   "A": 123, ...
}

def increase(key, amt):
    counts[key] += amt
    return counts[key]

curr = increase("A", 5)
print(curr) # 128
```

what if we want many programs running on different computers to have access to this dict and the increase function?

Remote Procedure Calls (RPCs)

client

```
curr = increase("A", 5)
print(curr) # 128
```

server

```
counts = {
   "A": 123, ...
}

def increase(key, amt):
    counts[key] += amt
    return counts[key]
```

client

...

move counts and increase to a server accessible to many client programs on different computers

Remote Procedure Calls (RPCs)

client

```
def increase(key, amt):
    ...code to send




curr = increase("A", 5)
print(curr) # 128
```

computer 1

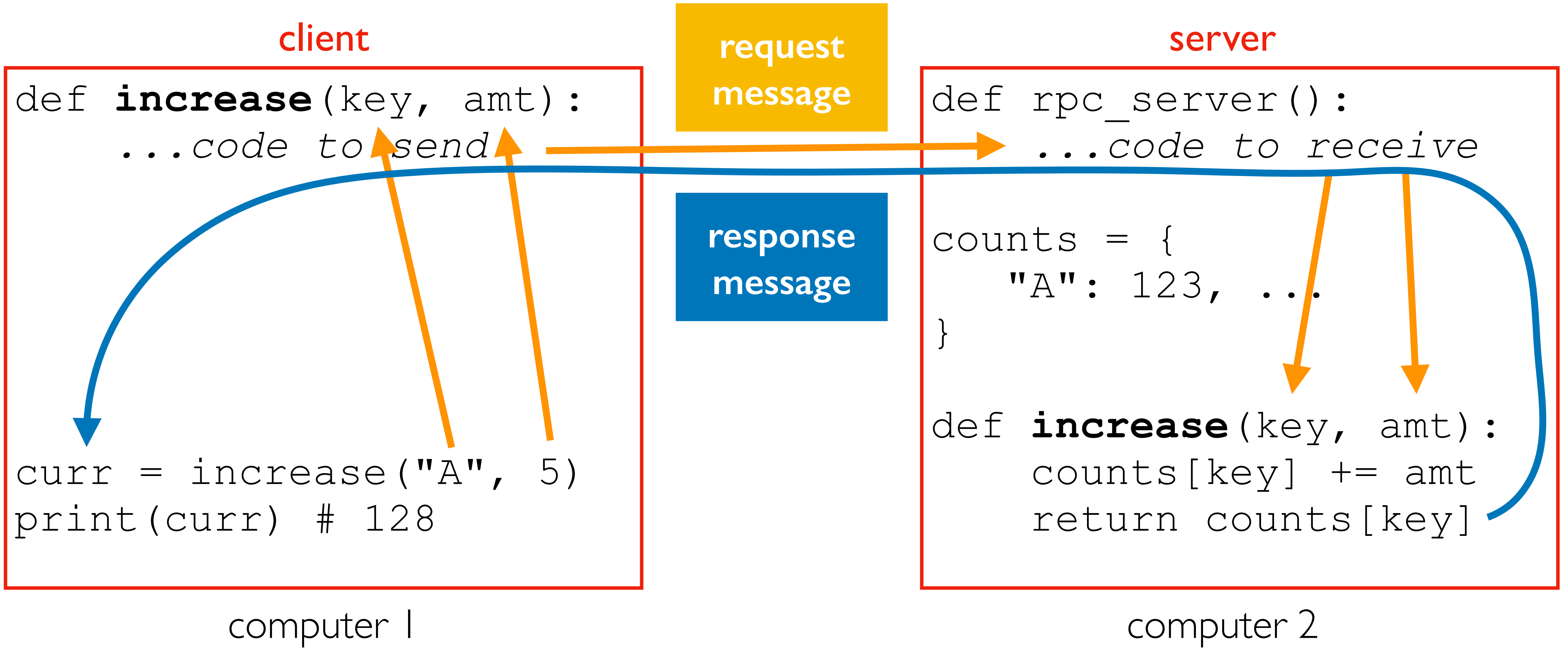
server

```
def rpc_server():
    ...code to receive

counts = {
   "A": 123, ...
}

def increase(key, amt):
    counts[key] += amt
    return counts[key]
```

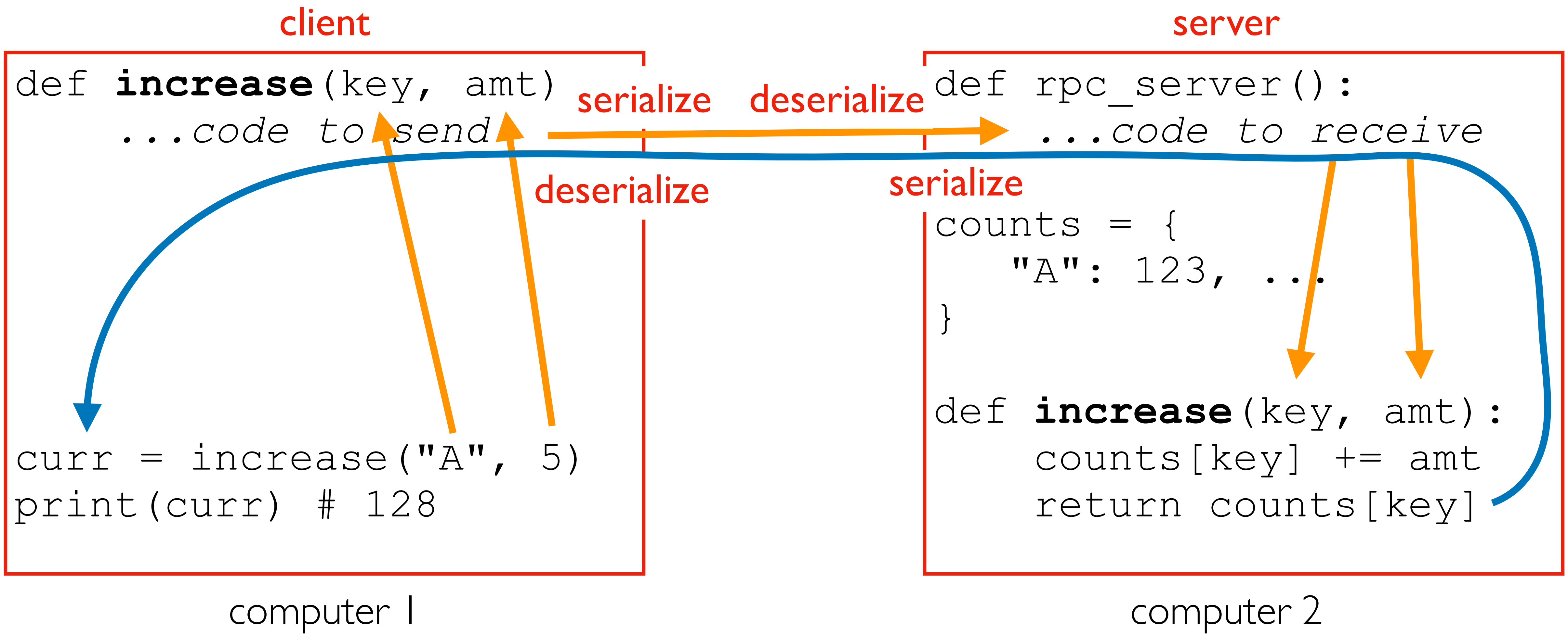
computer 2

need some extra functions to make calling a remote function *feel* the same as calling a regular one

Remote Procedure Calls (RPCs)



Serialization/Deserialization



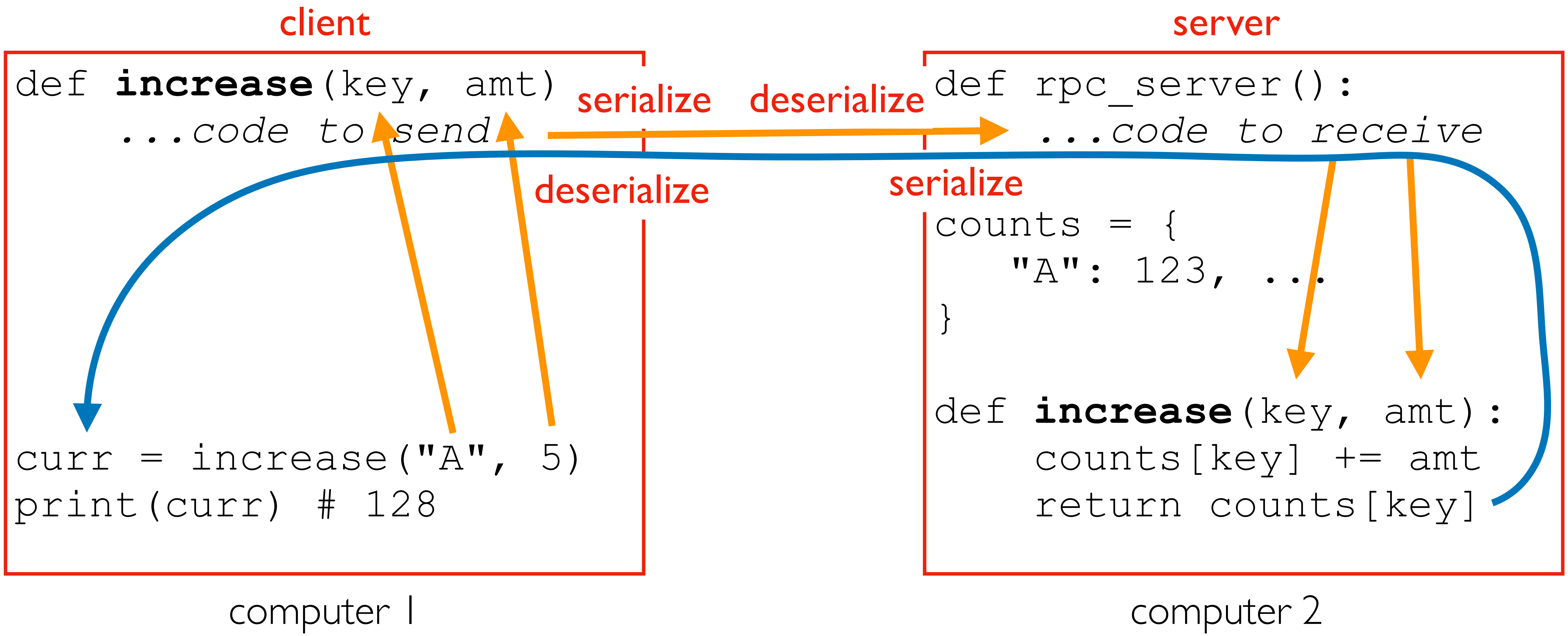
request message

```
args somehow encoded as bytes:
b'{"key": "A"
   "amt": 5}'
```

response message

```
return val as bytes:
b'128'
```

gRPC uses protocol buffers for wire format



request message

protobuf (args to bytes)
1001000101011111
(contains "A" and 5)

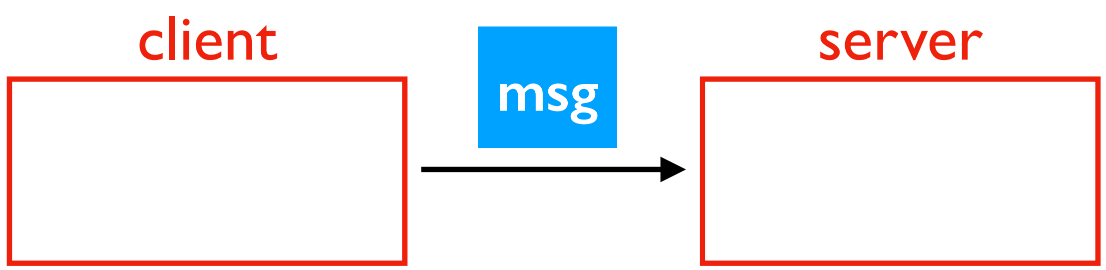
response message

protobuf (ret val to bytes)
01000000
(contains 128)

Synchronous vs. Asynchronous Communication

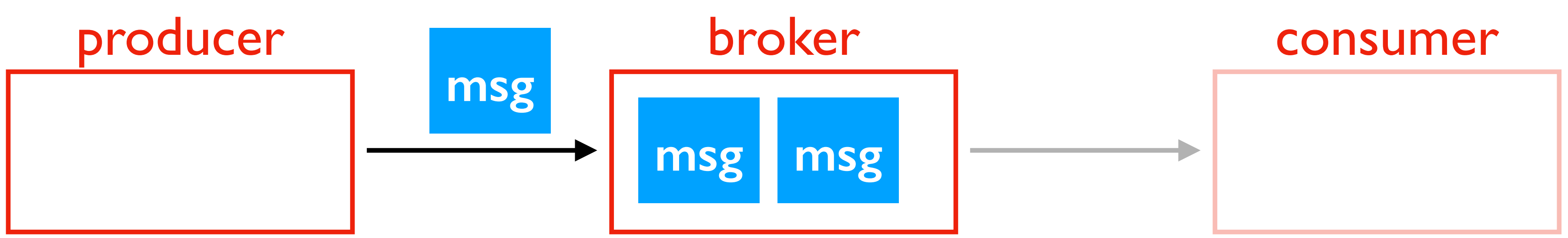
Synchronous

- both parties have to participate at the same time
- examples: phone call, RPC call



Asynchronous

- one party can send any time, the other can receive later
- examples: email, texting, streaming



Outline: Kafka Streaming

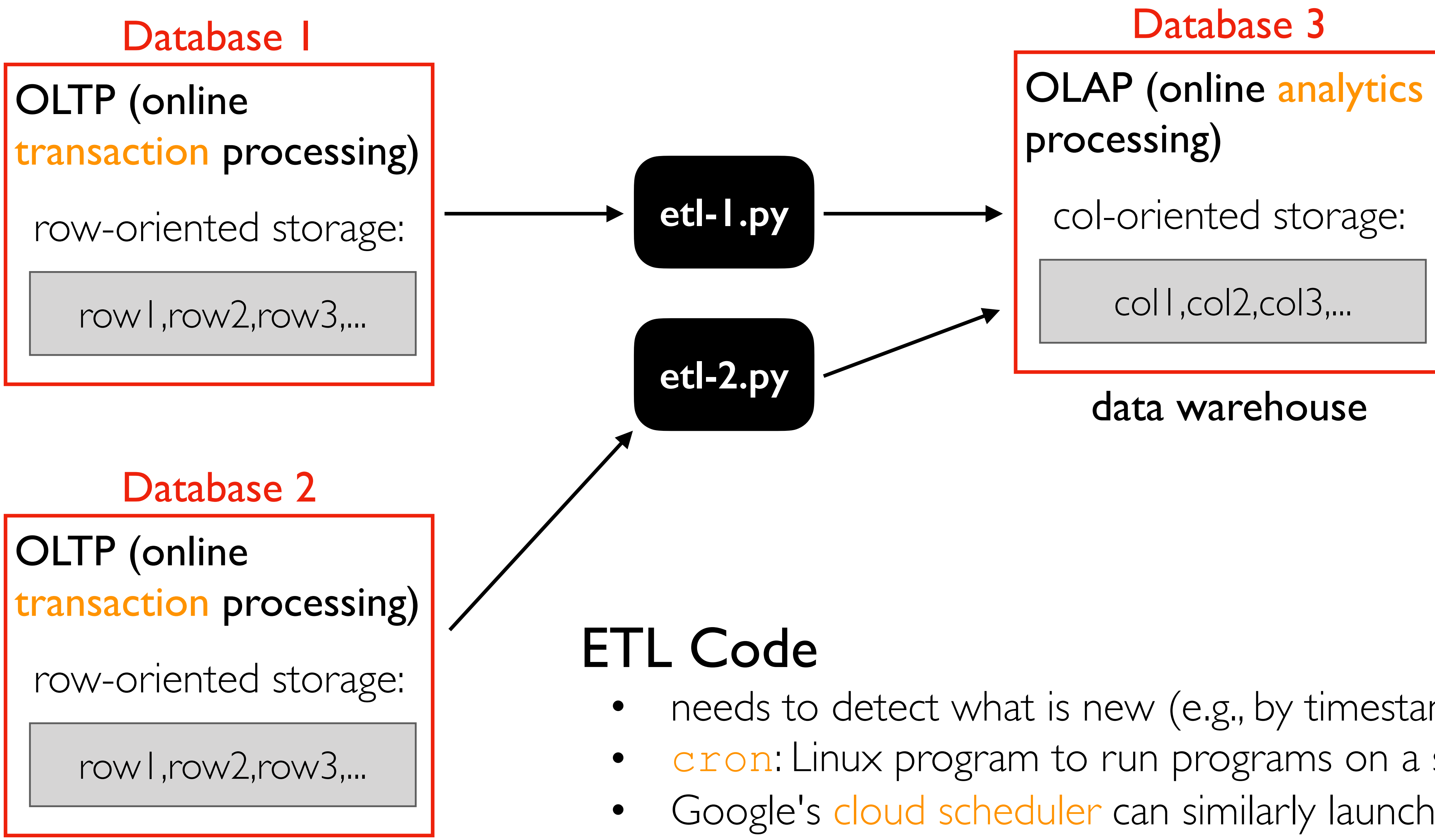
Sending/Receiving Messages

ETL (Extract Transform Load)

- Batch
- Streaming

Kafka Design

Extract Transform Load (ETL)

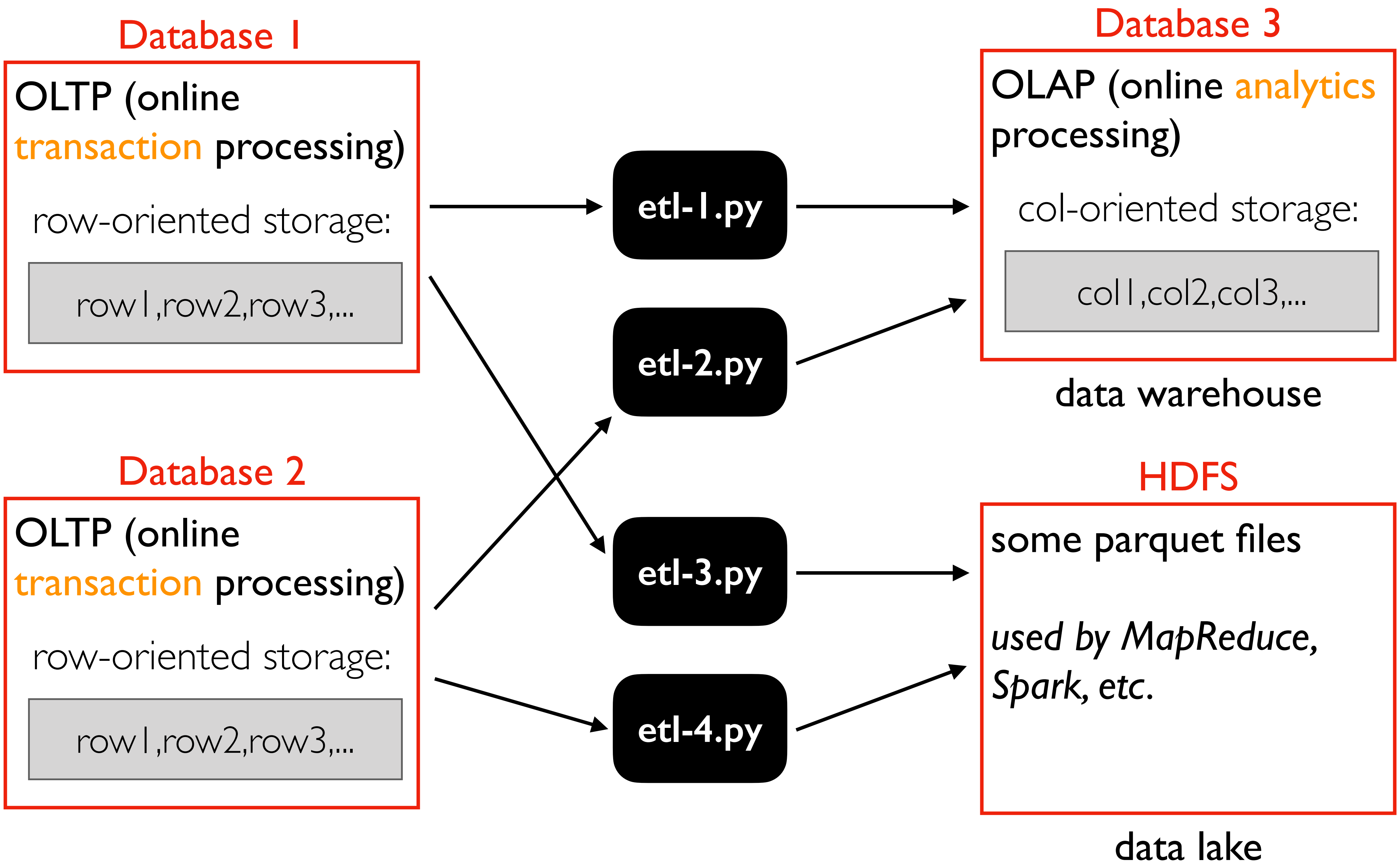


ETL Code

- needs to detect what is new (e.g., by timestamp)
- `cron`: Linux program to run programs on a schedule
- Google's cloud scheduler can similarly launch tasks (other clouds have similar options)

issue 1: data freshness

Extract Transform Load (ETL)



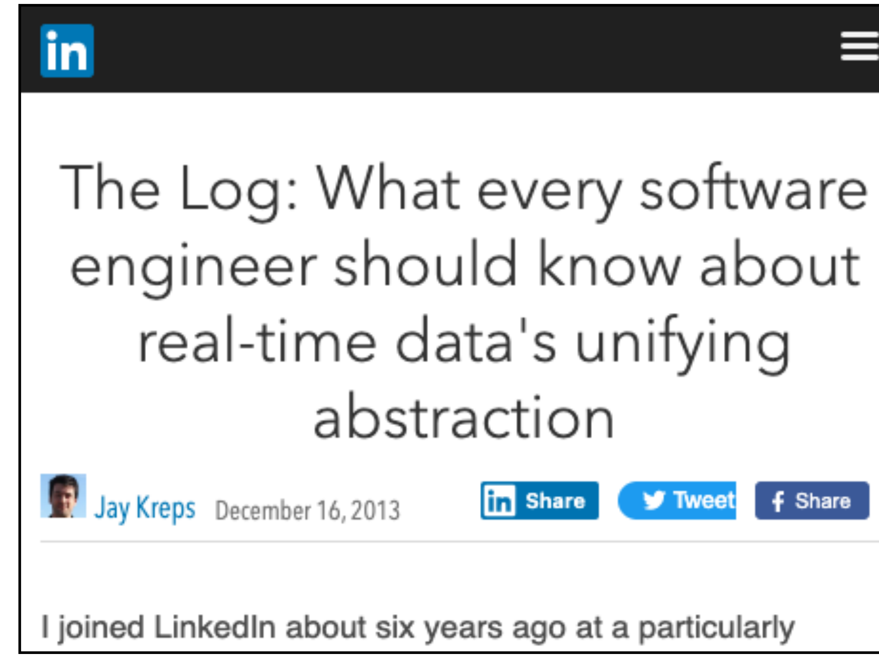
if we have **X** OLTP databases and **Y** derivative stores, how many ETL programs must we write?

issue 2: scaling engineering effort

Too much ETL...

Don't want data transfer between every pair of DB/services

- Jay Krepps helped build Kafka at LinkedIn
- Later co-founded Confluent (Kafka-based company)
- Partners with cloud providers to provide Kafka as a service


The Log: What every software engineer should know about real-time data's unifying abstraction

Jay Kreps December 16, 2013

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I joined LinkedIn about six years ago at a particularly

https://engineering.linkedin.com/distributed-systems/log-what-every-software-engineer-should-know-about-real-time-datas-unifying

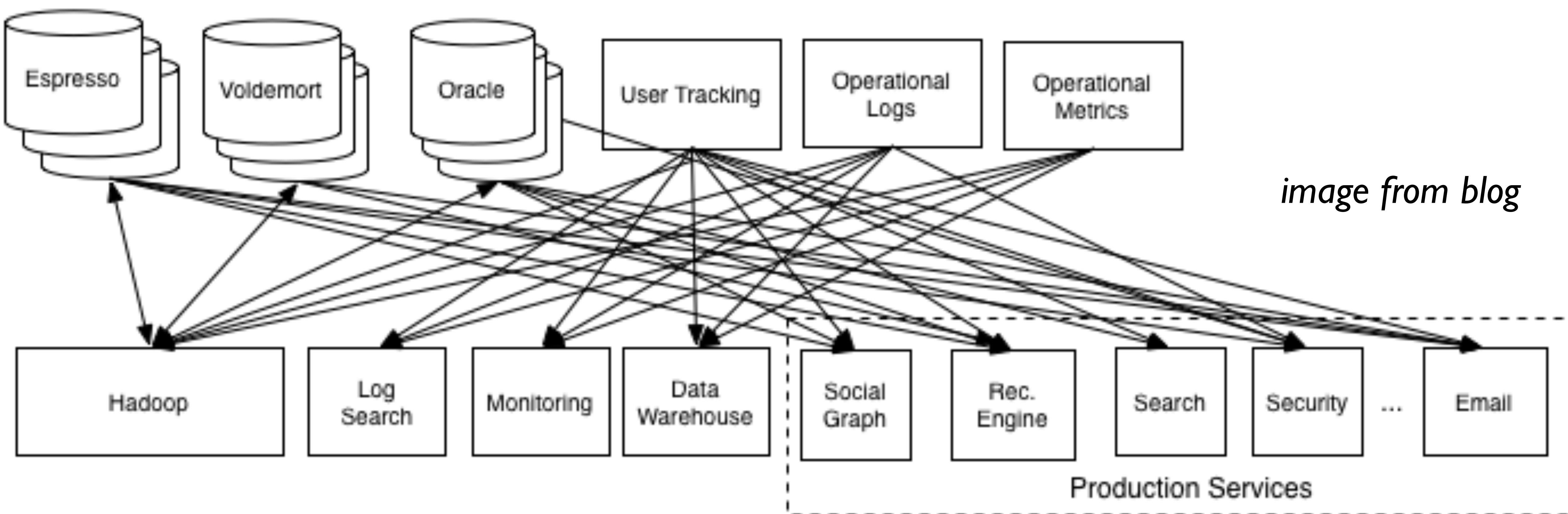


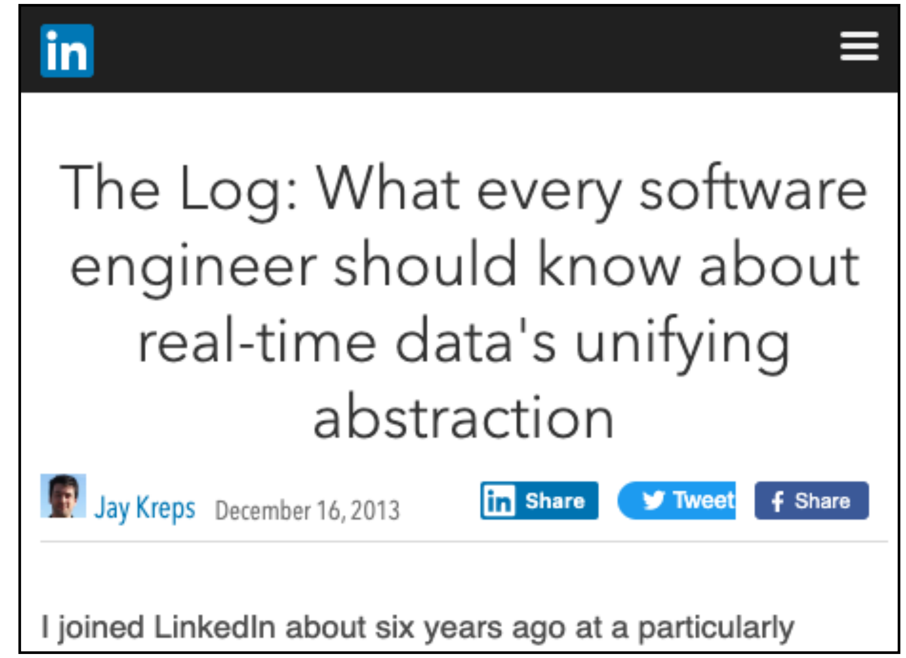
image from blog

Unified Log

Centralize changes in a distributed logging service

- Many writers (called producers)
- Many readers (called consumers)

Data is constantly flowing, so ETL can be done in realtime (instead of batch jobs with cron)



https://engineering.linkedin.com/distributed-systems/log-what-every-software-engineer-should-know-about-real-time-datas-unifying

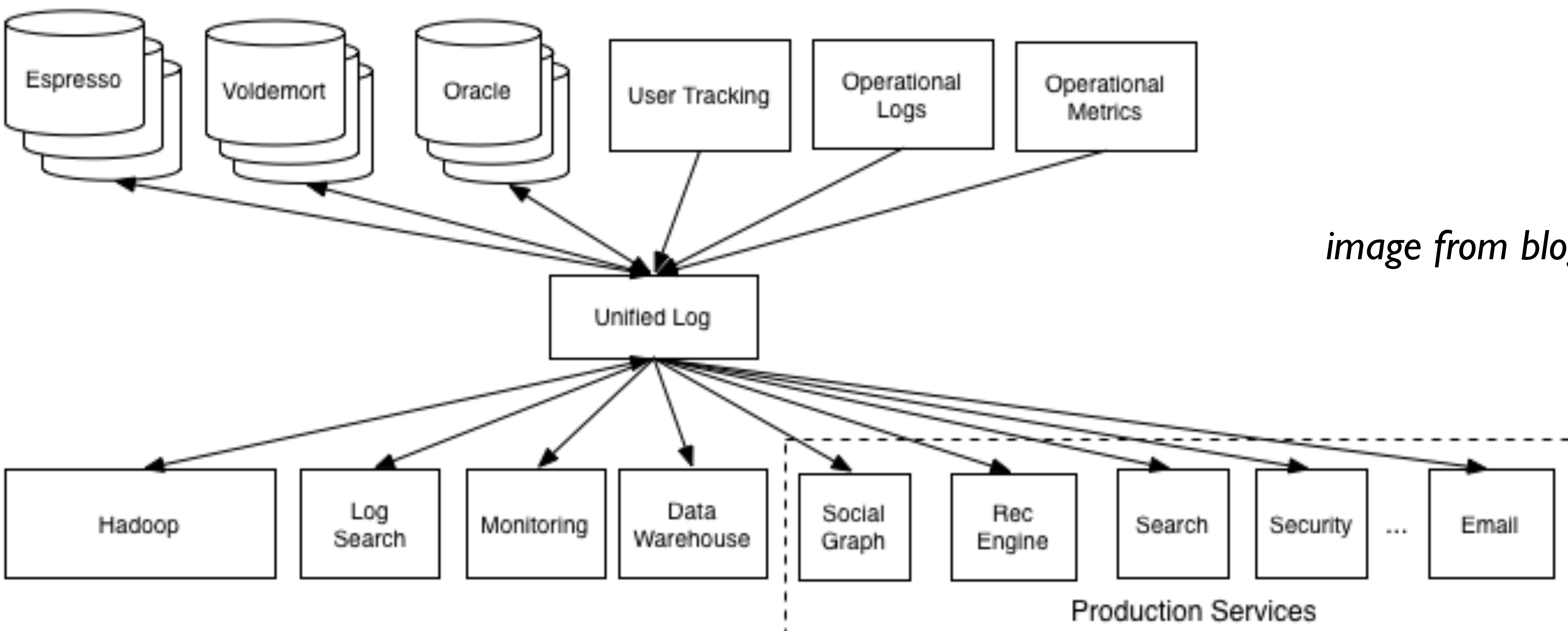


image from blog

Outline: Kafka Streaming

Sending/Receiving Messages

ETL (Extract Transform Load)

Kafka Design

- Topics
- Producers, Consumers, Brokers
- Scalability with Partitioning

Topics

Kafka topics (managed by servers called brokers)

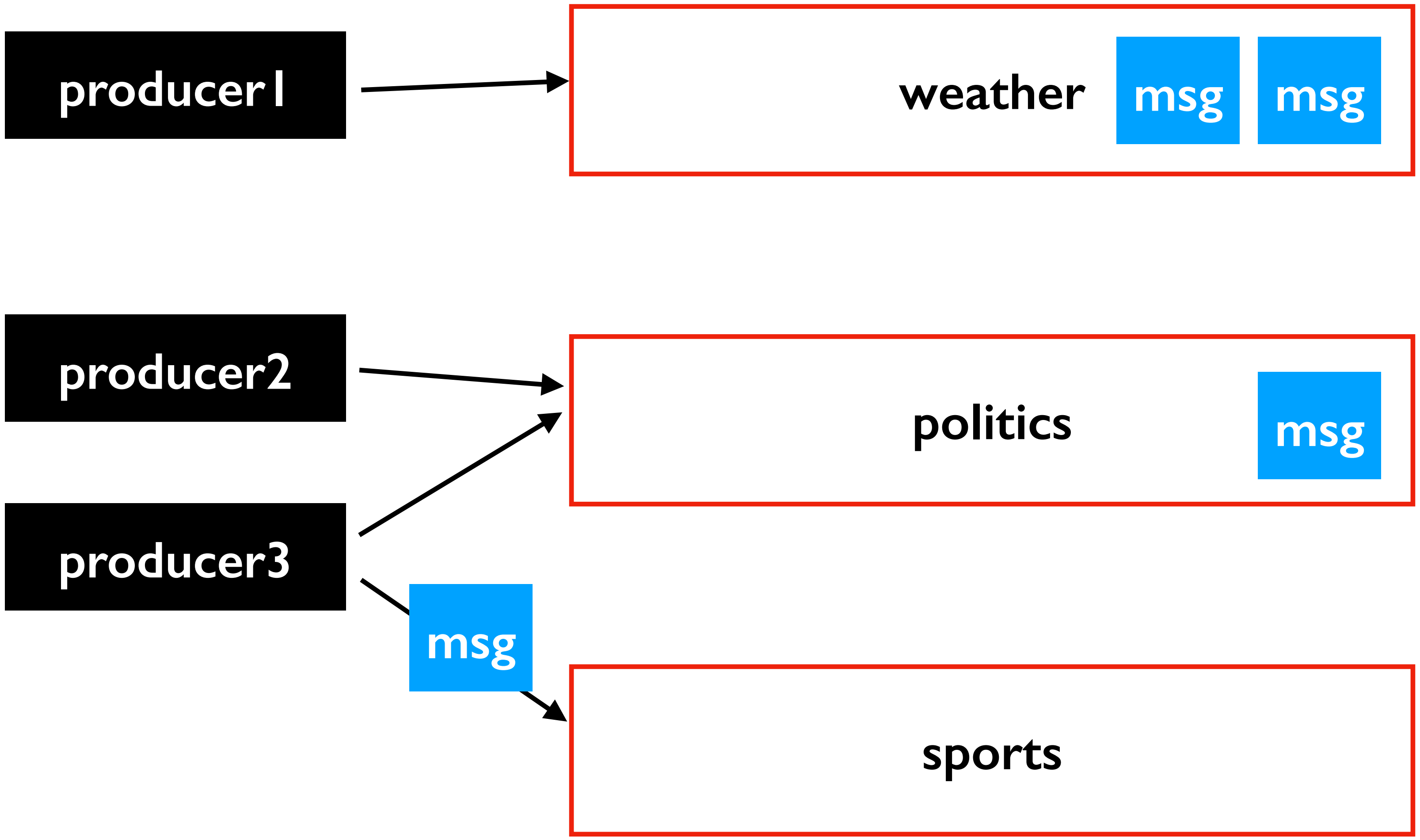

```
admin = KafkaAdminClient(...)
admin.create_topics([NewTopic("sports", ...)])
```

```
pip install kafka-python
```

Producers **Publish** (pub/sub)

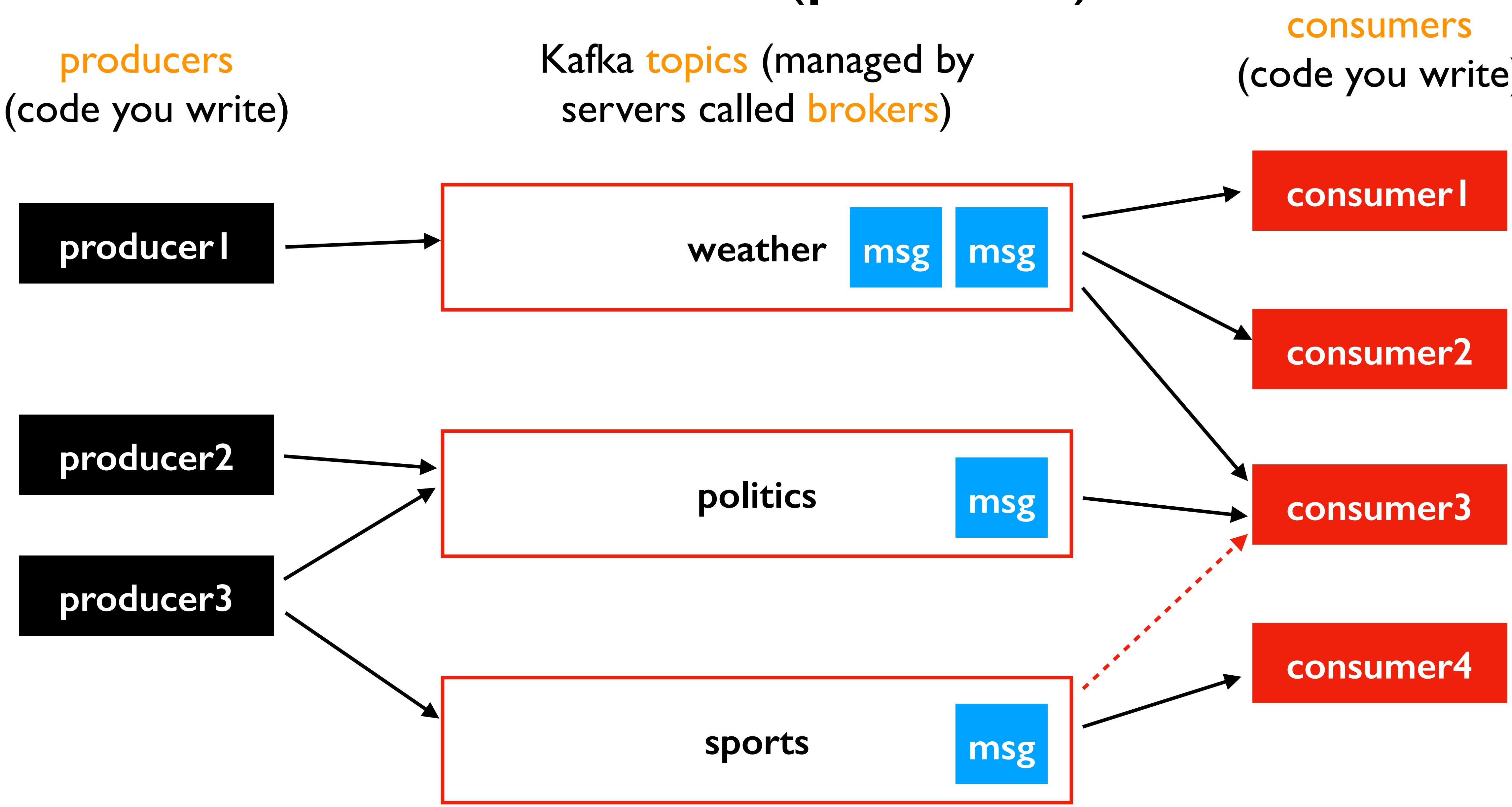
producers
(code you write)

Kafka topics (managed by
servers called brokers)



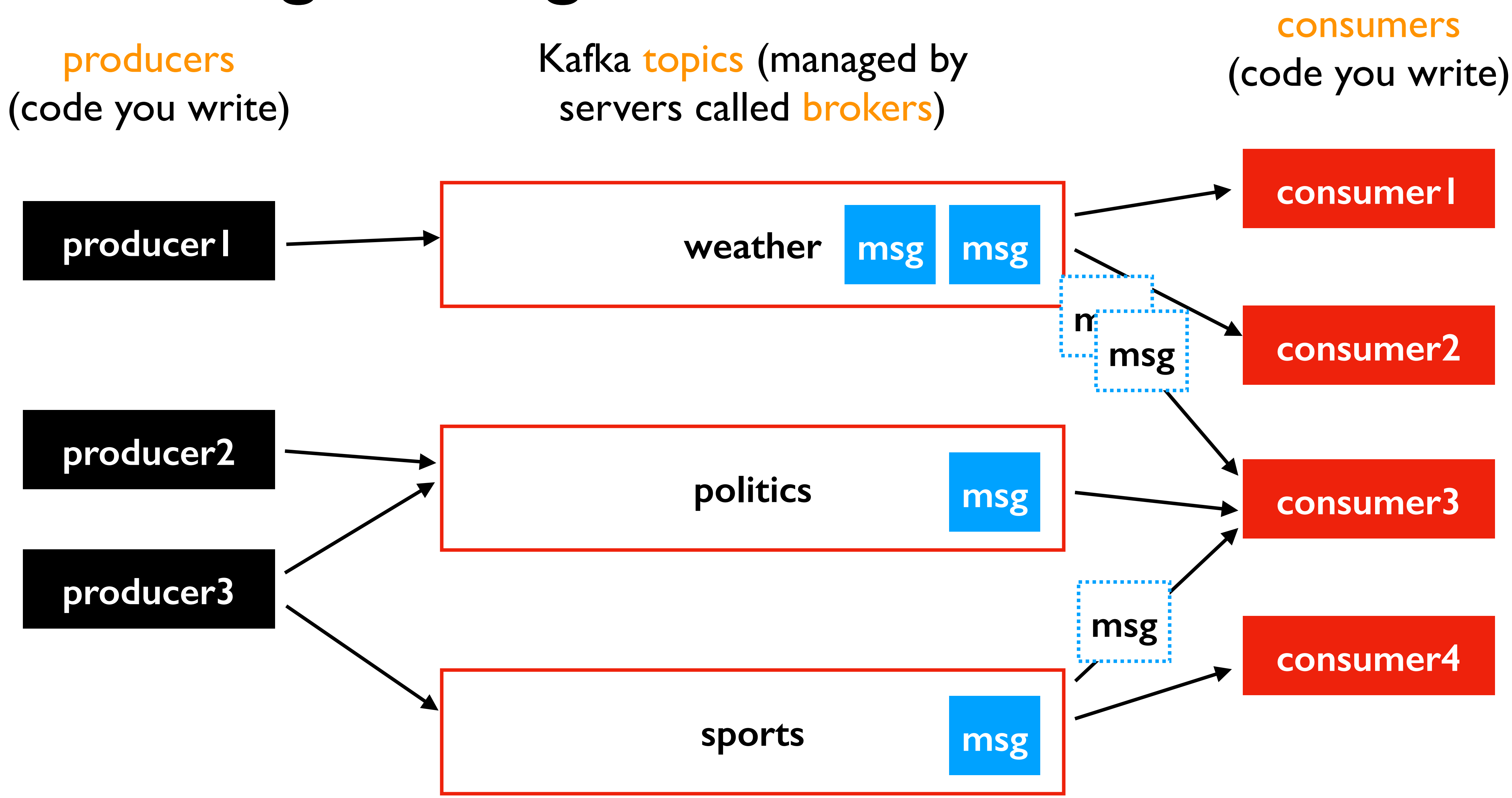

```
producer3 = KafkaProducer(...)
producer3.send("sports", ...)
```

Consumers Subscribe (pub/sub)




```
consumer3 = KafkaConsumer(...)
consumer3.subscribe(["sports"])
```

Receiving Messages



`poll()` loop

- generally runs forever
- poll (ideally) returns some messages the consumer hasn't seen before, from any subscribed topic
- leaves messages intact on brokers (for other consumers), unlike many prior streaming systems

```
consumer3 = KafkaConsumer(...)
while True:
    batch = consumer3.poll(????)
    for topic, messages in batch.items():
        for msg in messages:
            ...
```

What's in a Message?

Message parts

- key (optional): *some bytes*
- value (required): *some bytes*
- other stuff...

```
producer.send("topic", value=????)
OR
producer.send("topic", value=????, key=????)
```

Common usage: the value is usually some kind of structure with many values. The key is used for partitioning and is usually one of the entries in the value structure.

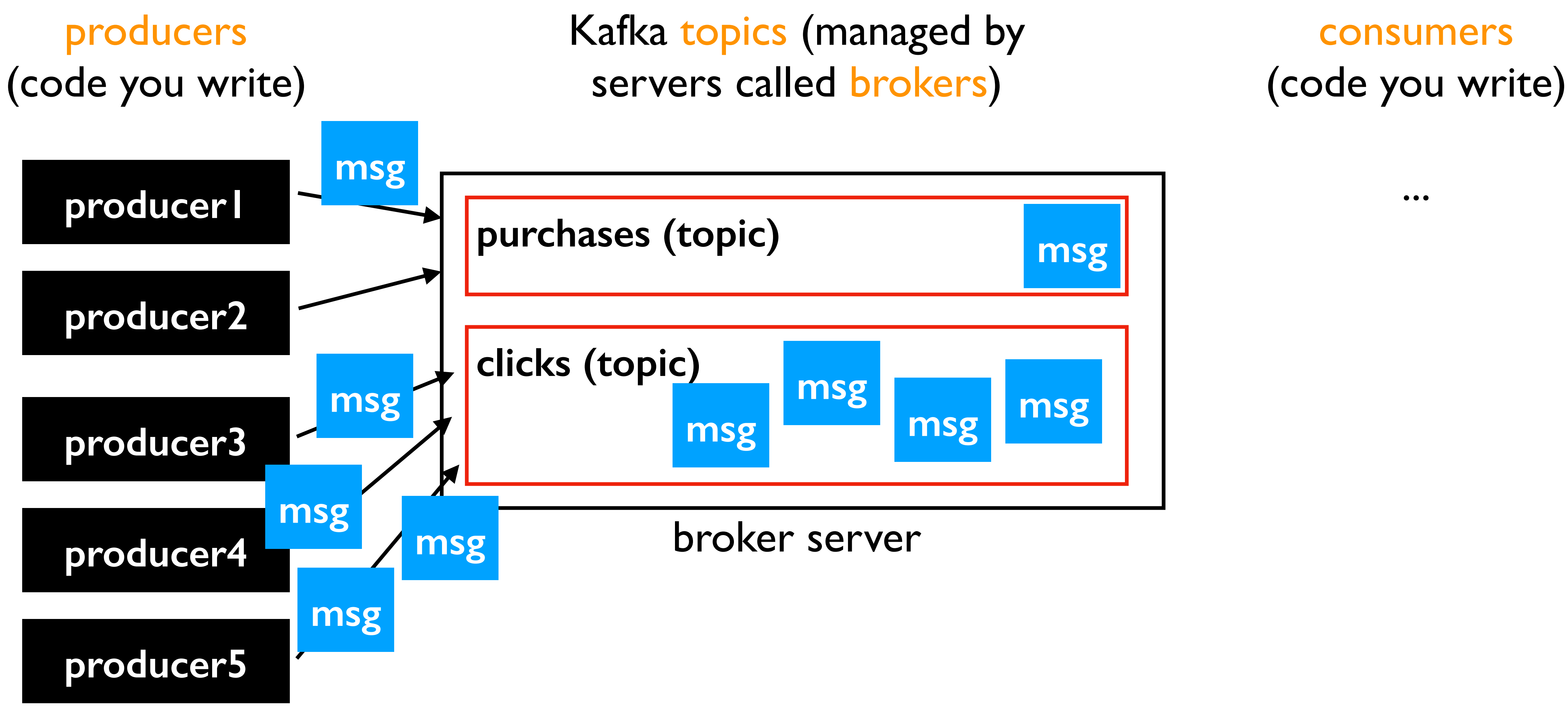
Python dict => bytes:

```
d = {...}
value = bytes(json.dumps(d), "utf-8")
```

Protobuf => bytes:

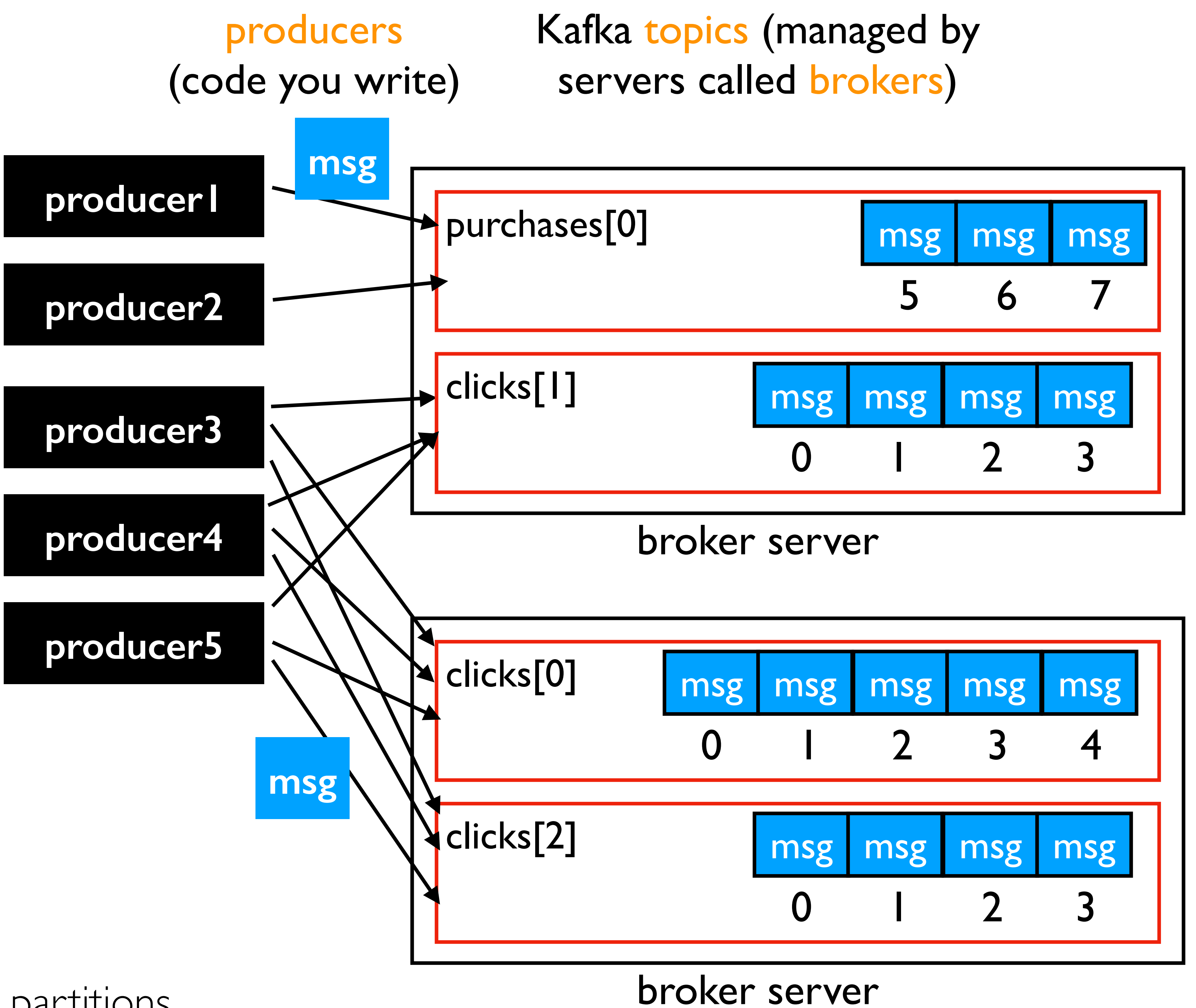
```
msg = mymod_pb2.MyMessage(...)
value = msg.SerializeToString() # actually bytes, not str
```

Scaling the Brokers



problem: some topics might have too many messages for one machine (or set of machines with replicas) to keep up

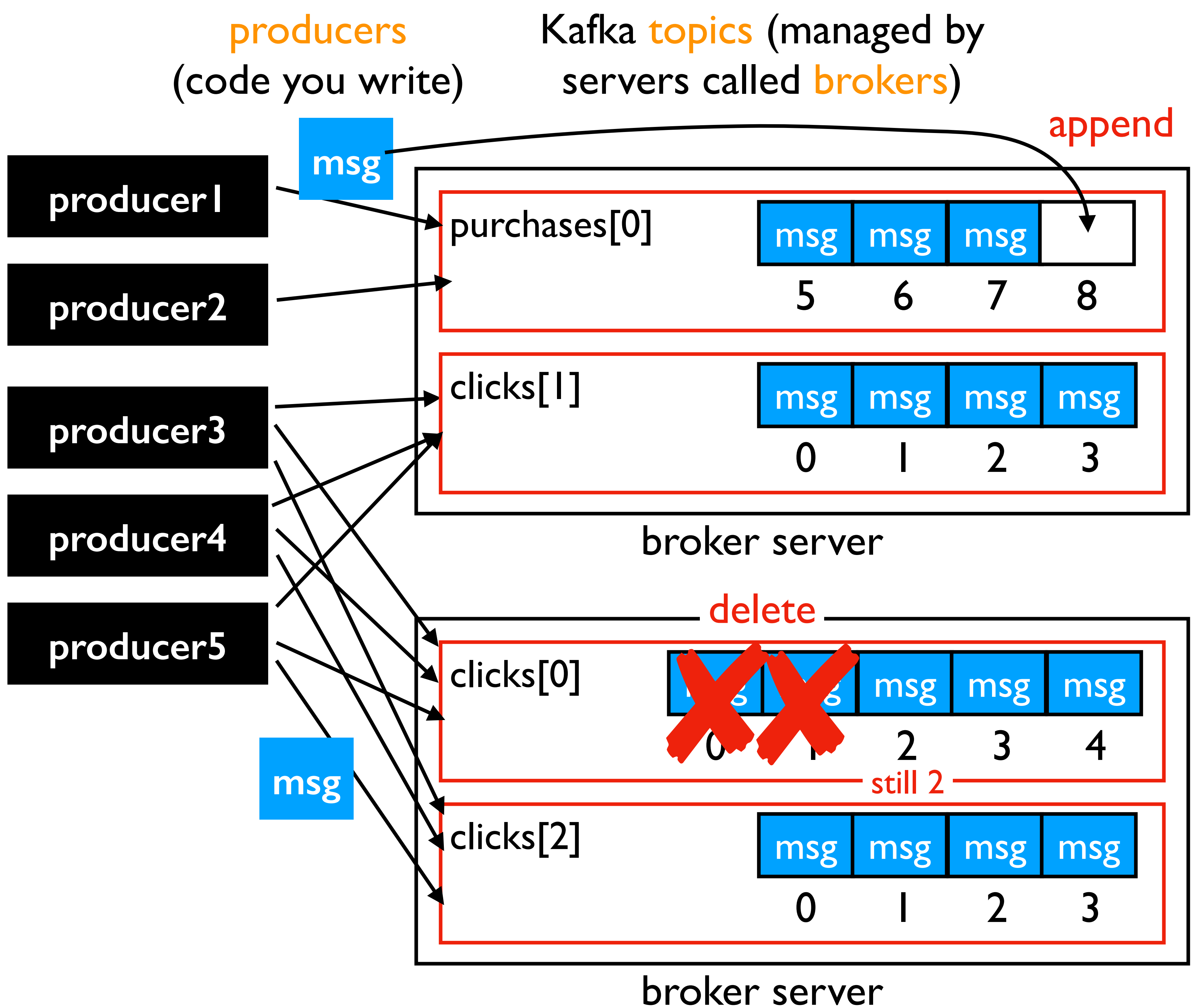
Partitions



Topics can be created with N partitions

- each partition is like an array of messages
- partitions are assigned to brokers
- each producer using a stream works with all partitions

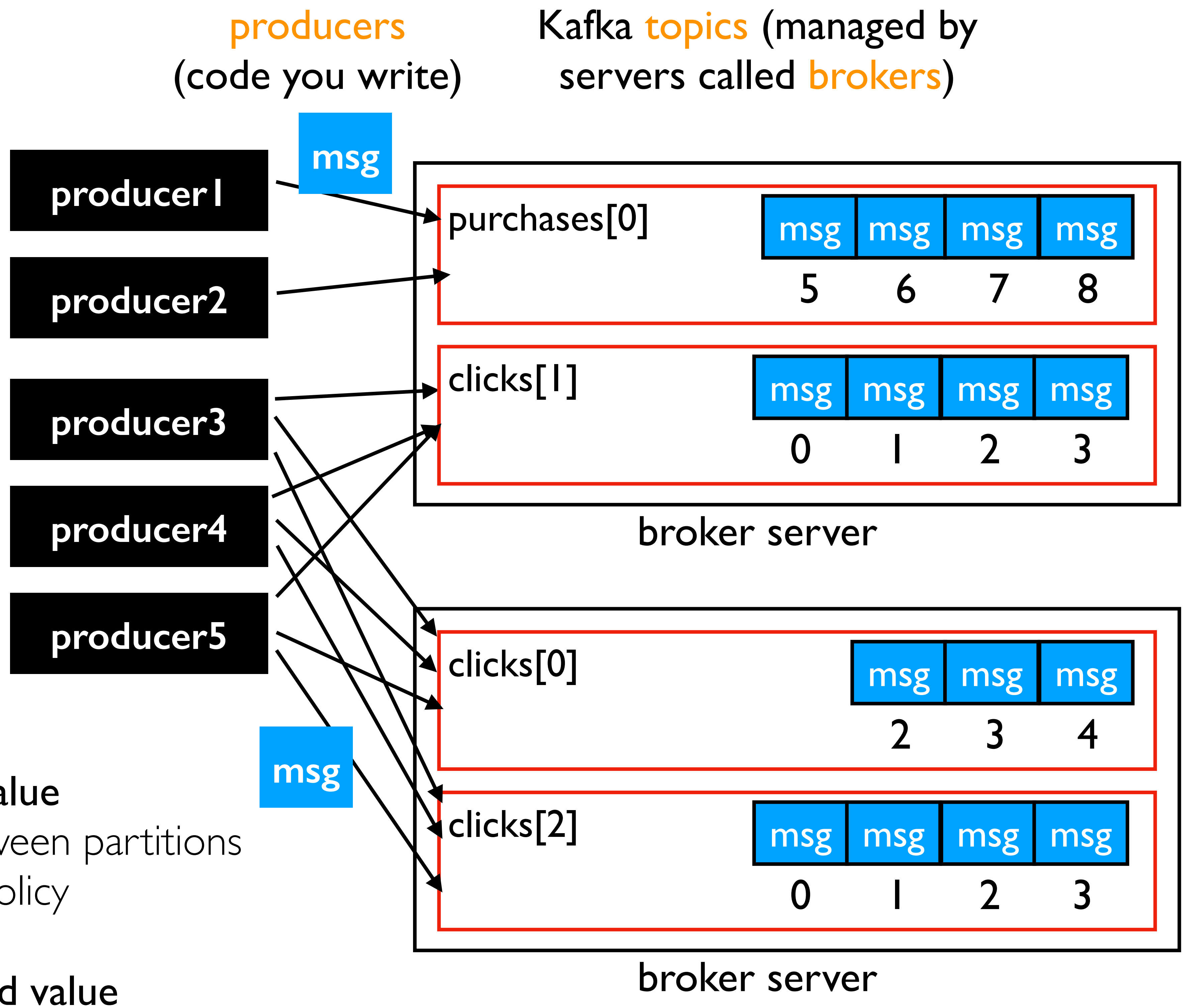
Changing Partitions



Changes

- append right
- delete left (depends on "retention" policy)
- delete does NOT change indexes

Selecting Partitions



case 1: message only has value

- producer rotates between partitions
- called "round robin" policy

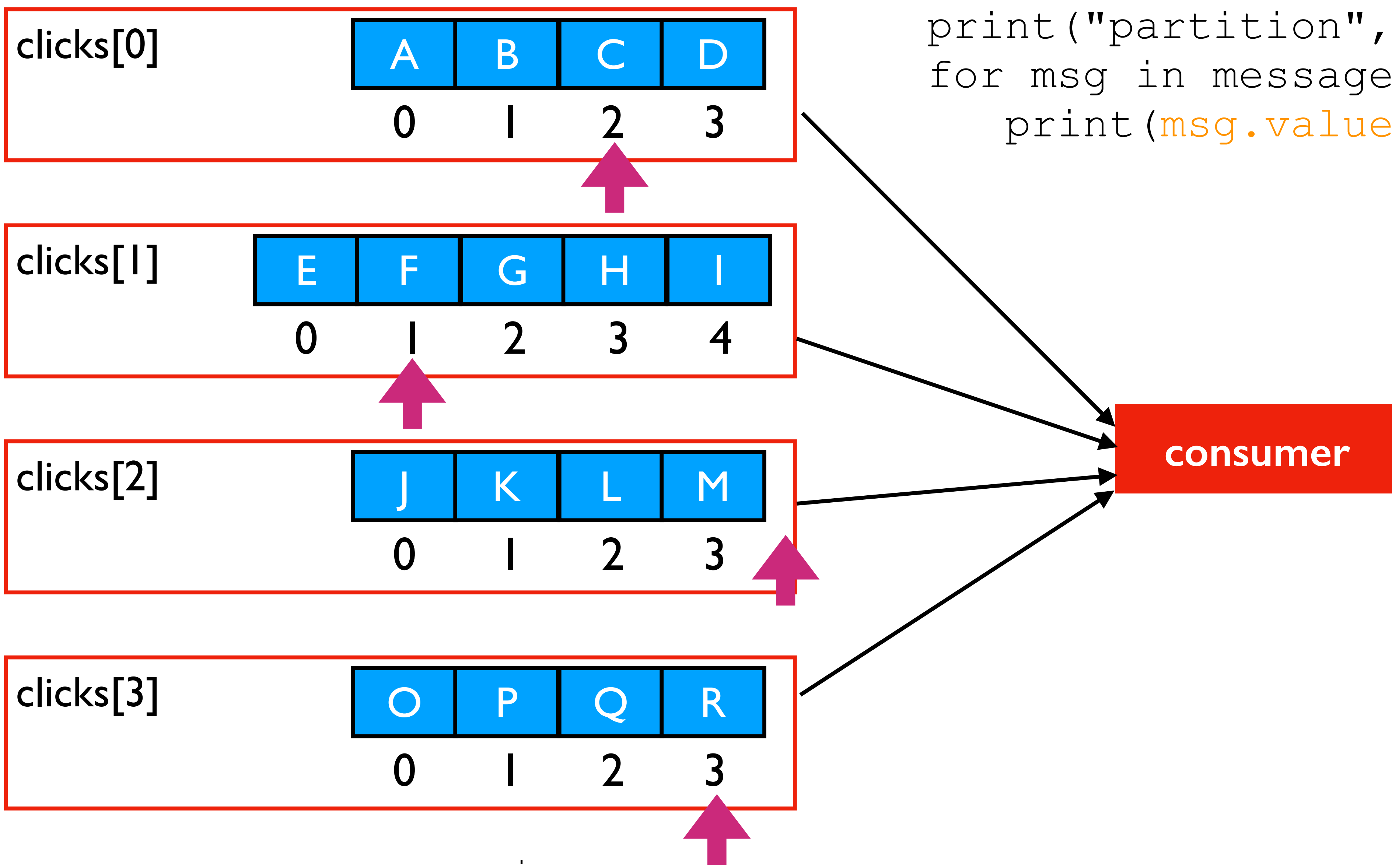
case 2: message has key and value

- calculate partition, for example:
  `hash(key) % partition_count`
- same keys will go to the same partition
- *can plug in alternative partitioning schemes*

Consumers: Read Offsets

```
batch = consumer.poll(1000)
for topic, messages in batch.items():
    print("partition", topic.partition)
    for msg in messages:
        print(msg.value)
```

Topic Partitions



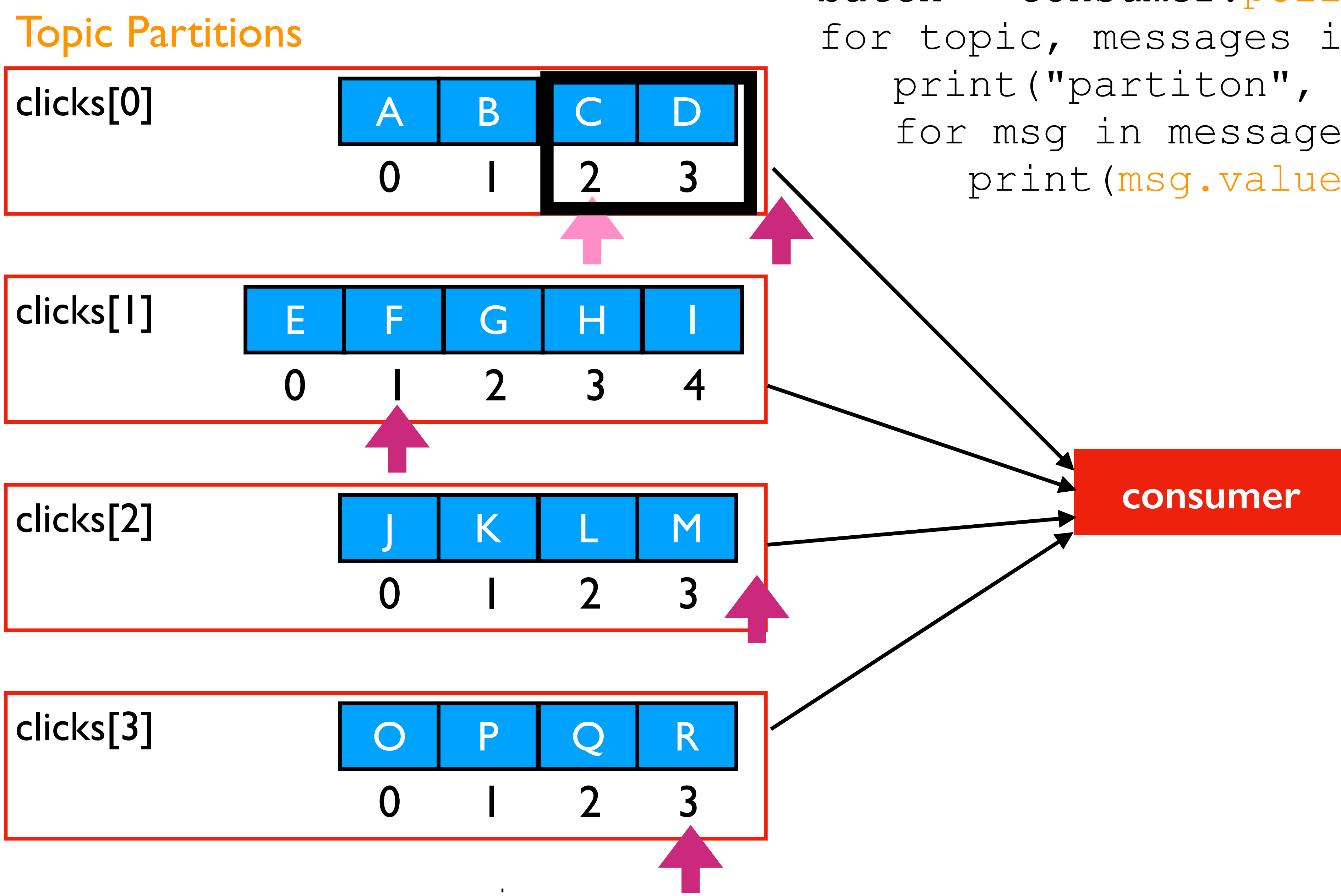
	offset
clicks[0]	2
clicks[1]	1
clicks[2]	4
clicks[3]	3

Batches

- poll returns batches (when enough data or timeout)
- batches contain some subset of partitions
- some number of messages in partition, starting at offset

Example 1

```
batch = consumer.poll(1000)
for topic, messages in batch.items():
    print("partiton", topic.partition)
    for msg in messages:
        print(msg.value)
```



output:
partition 0
b'C'
b'D'

	offset
clicks[0]	4
clicks[1]	1
clicks[2]	4
clicks[3]	3

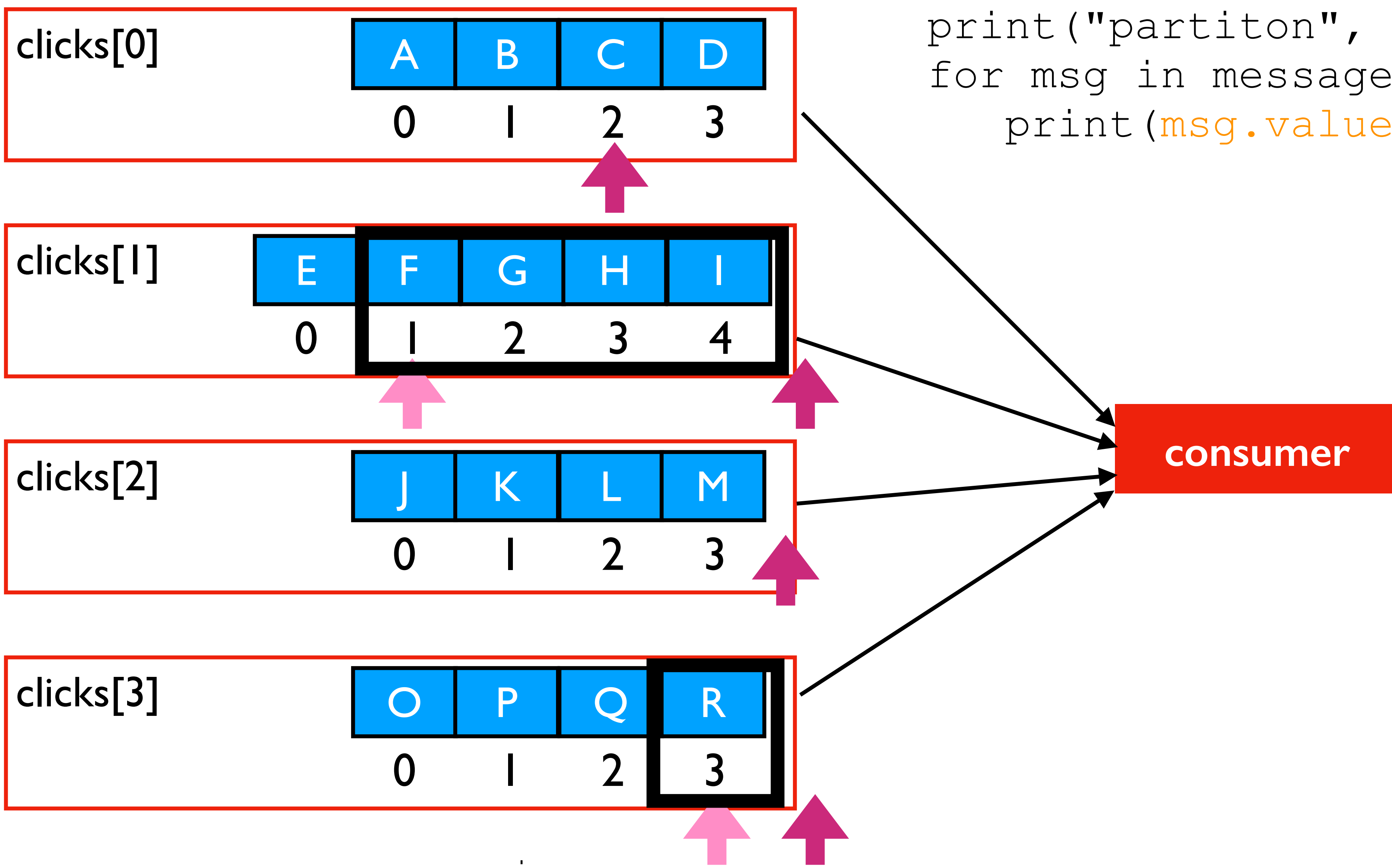
Batches

- poll returns batches (when enough data or timeout)
- batches contain some subset of partitions
- some number of messages in partition, starting at offset

Example 2

```
batch = consumer.poll(1000)
for topic, messages in batch.items():
    print("partiton", topic.partition)
    for msg in messages:
        print(msg.value)
```

Topic Partitions



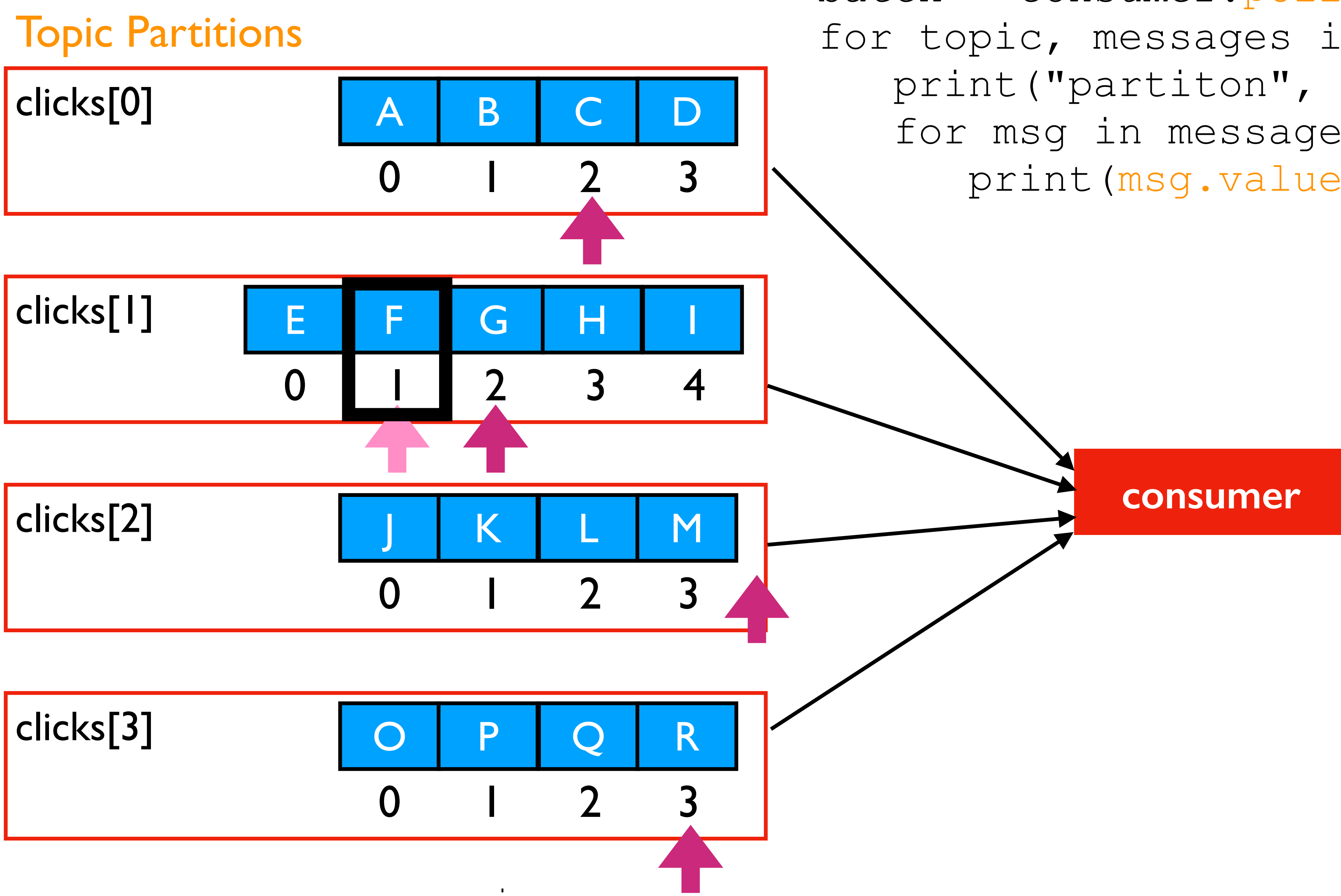
output:
partition 1
b'F'
b'G'
b'H'
b'I'
partition 3
b'R'

	offset
clicks[0]	2
clicks[1]	5
clicks[2]	4
clicks[3]	4

Batches

- poll returns batches (when enough data or timeout)
- batches contain some subset of partitions
- some number of messages in partition, starting at offset

Example 3




```
batch = consumer.poll(1000)
for topic, messages in batch.items():
    print("partiton", topic.partition)
    for msg in messages:
        print(msg.value)
```

output:
partition 1
b'F'

	offset
clicks[0]	2
clicks[1]	2
clicks[2]	4
clicks[3]	3

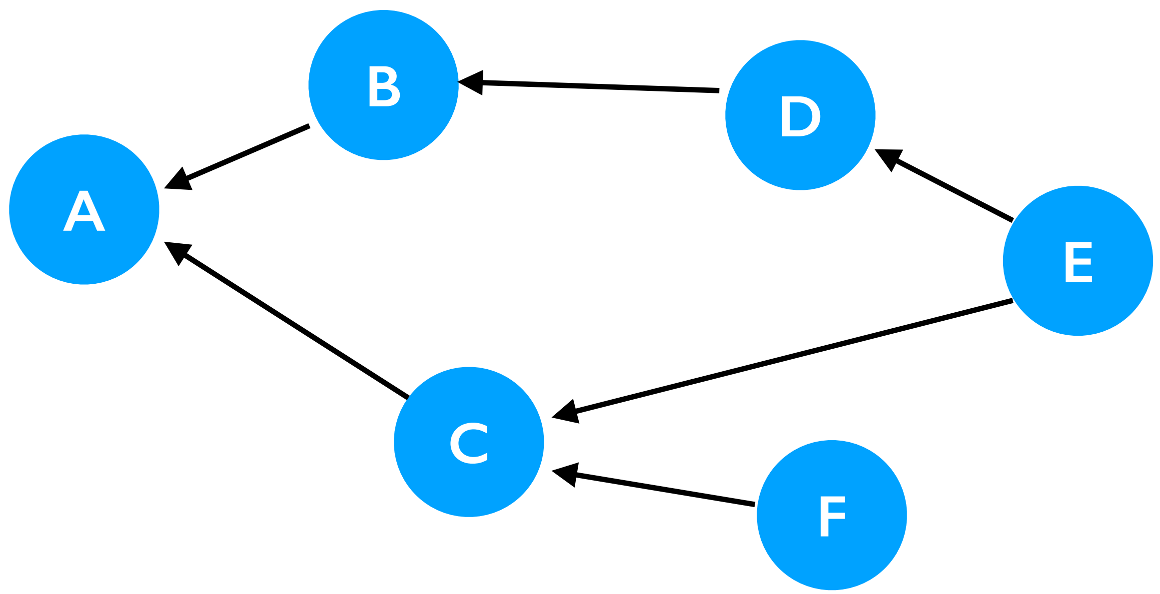
Batches

- poll returns batches (when enough data or timeout)
- batches contain some subset of partitions
- some number of messages in partition, starting at offset

Partially vs. Totally Ordered

Some things are totally ordered, like integers. Either x < y or x >= y.

Other things are partially ordered, like git commits. Sometimes you can compare, sometimes you can't!



A < B   A < C   D < E   ...

Can't compare B and C
Can't compare D and F
...

Ordering Kafka Messages

Kafka Messages are generally partially ordered (though if you have one partition only, they are totally ordered). Messages are consumed from a partition in the order they were written to that partition (no guarantees across topics or across partitions).

If A and B share the same topic and key, and B was produced after A, then:

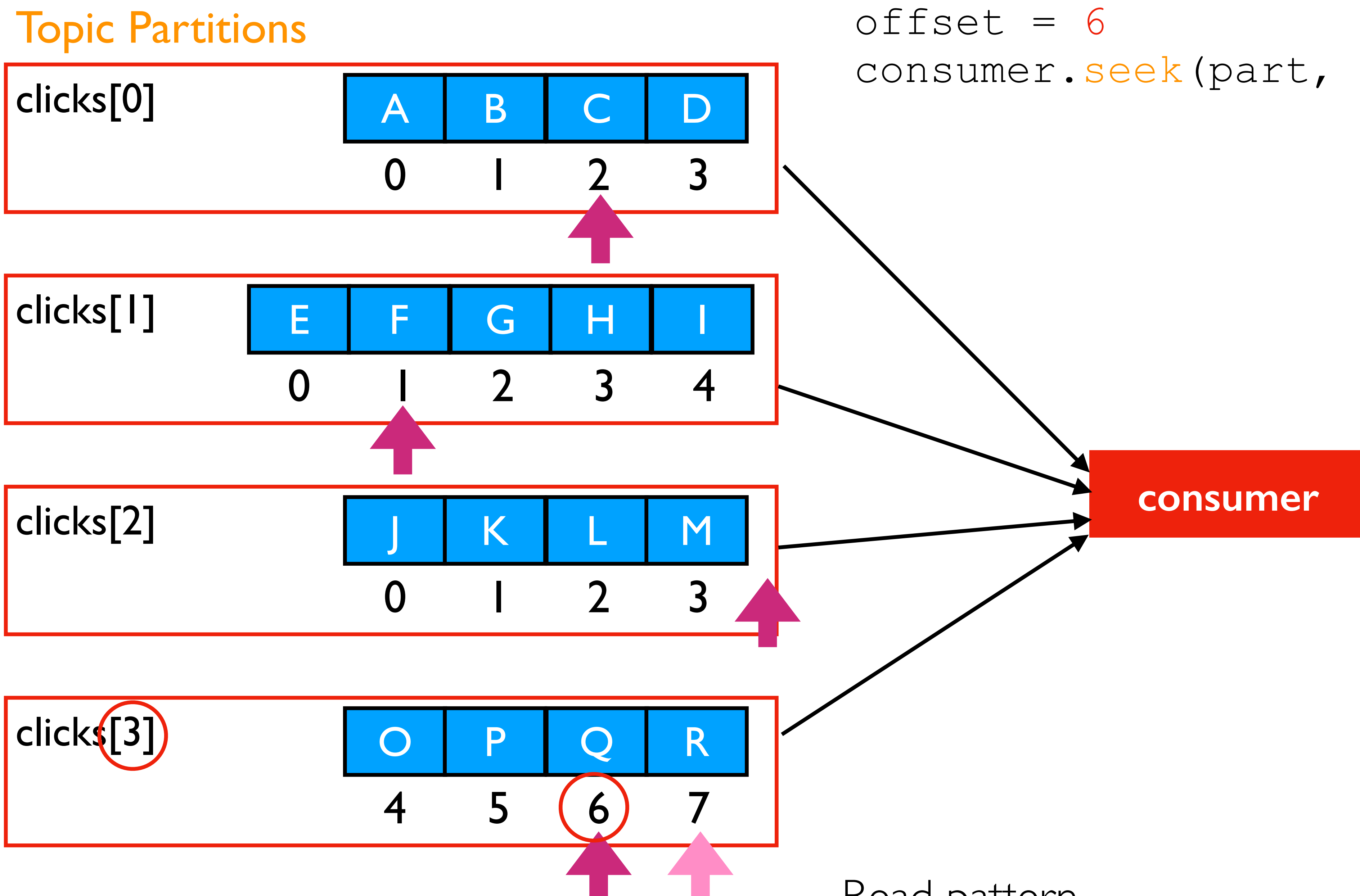
- we say B "happened after" A
- A and B will be in the same partition (assuming partition count is constant)
- each consumer group of the topic will consume A before B

Choose your key carefully! Try to create enough partitions initially and never change it (hash partitioning isn't elastic).

No keys specified => no guarantee about what order messages are consumed.

Seek to an Offset

```
part = TopicPartition("clicks", 3)
offset = 6
consumer.seek(part, offset)
```



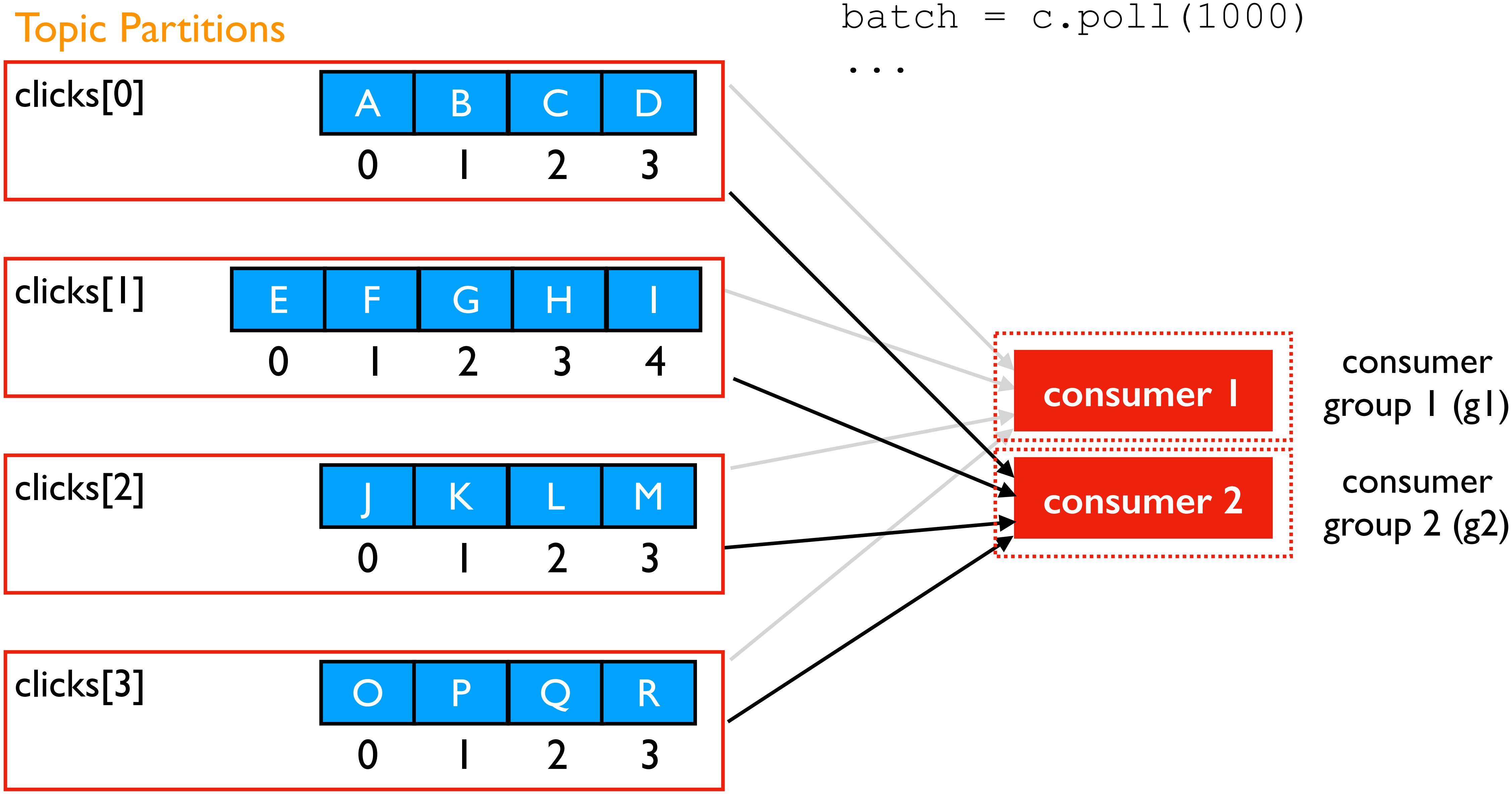
	offset
clicks[0]	2
clicks[1]	1
clicks[2]	4
clicks[3]	~~7~~ 6

Read pattern

- consumers normally read forward sequentially
- seek can jump back (or ahead)
- useful if processing batch failed: just go back and retry

Consumer Groups

```
c = KafkaConsumer("clicks",
                  group_id="g1",
                  ...)
batch = c.poll(1000)
...
```



	g1 offsets	g2 offsets
clicks[0]	2	3
clicks[1]	1	2
clicks[2]	4	4
clicks[3]	3	3

Groups

- different applications might operate independently
- they should ALL get a chance to consume messages
- need offsets for each topic/partition/consumer group combination

Consumer Groups

```
c = KafkaConsumer("clicks",
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batch = c.poll(1000)
...
```
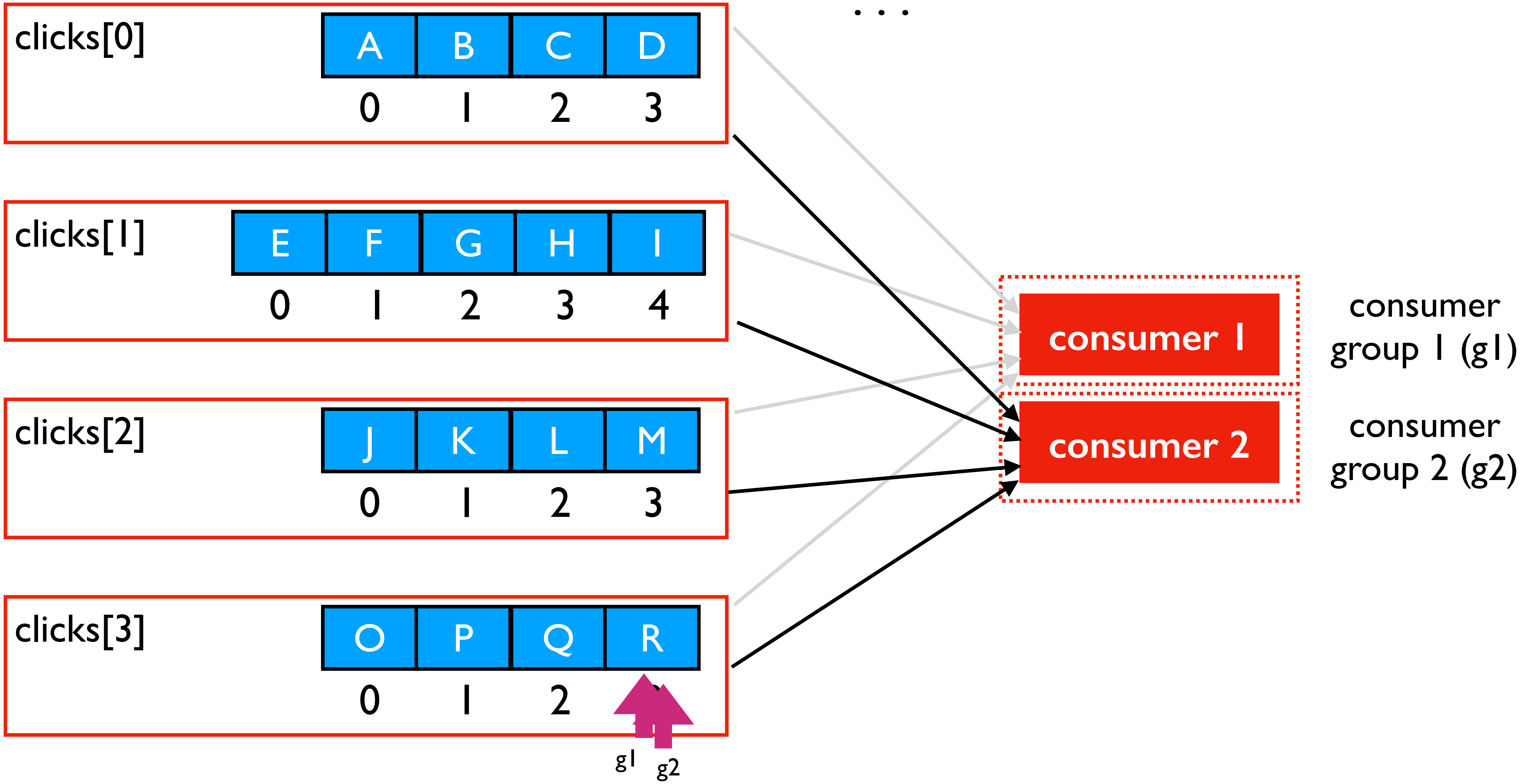

Topic Partitions



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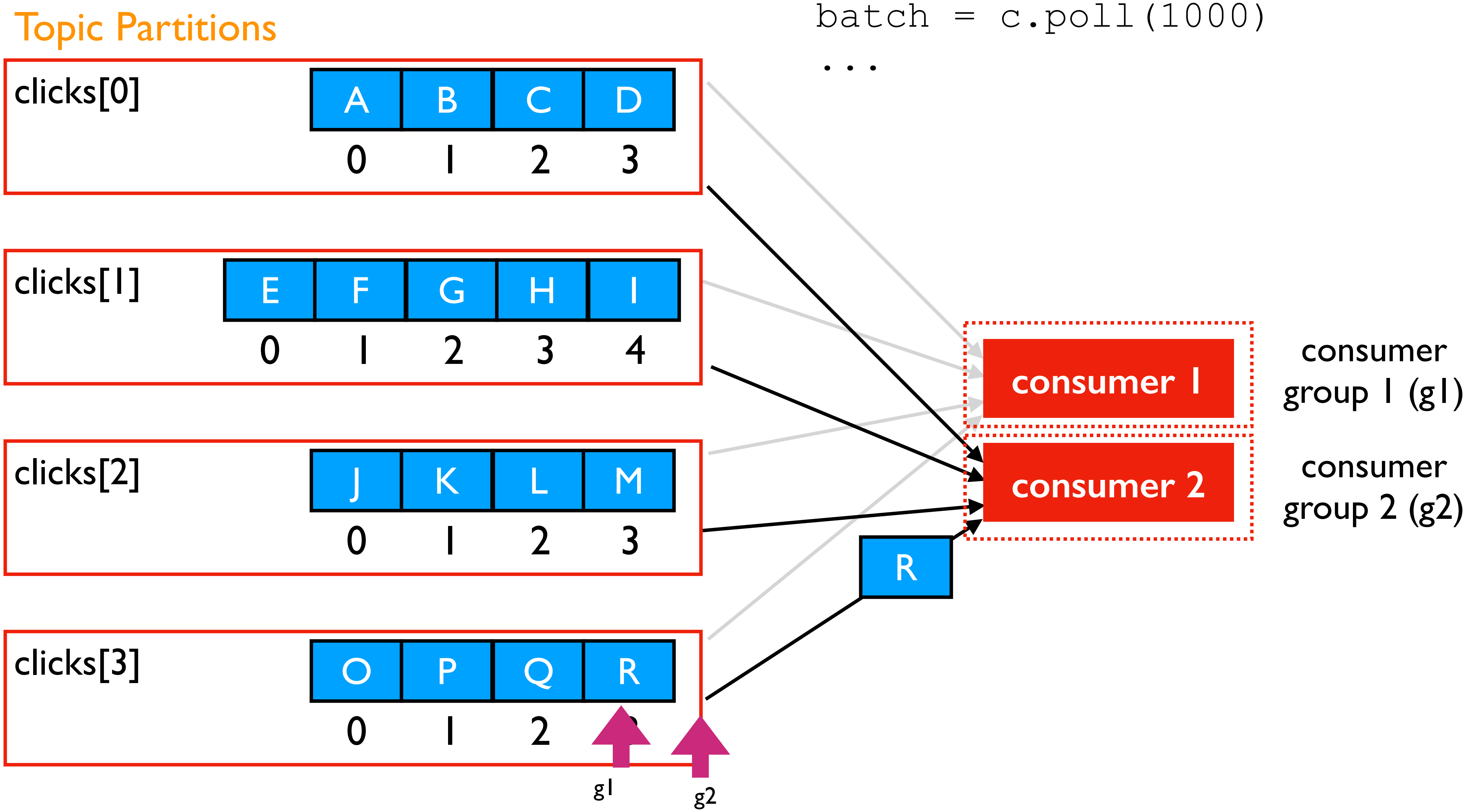

	g1 offsets	g2 offsets
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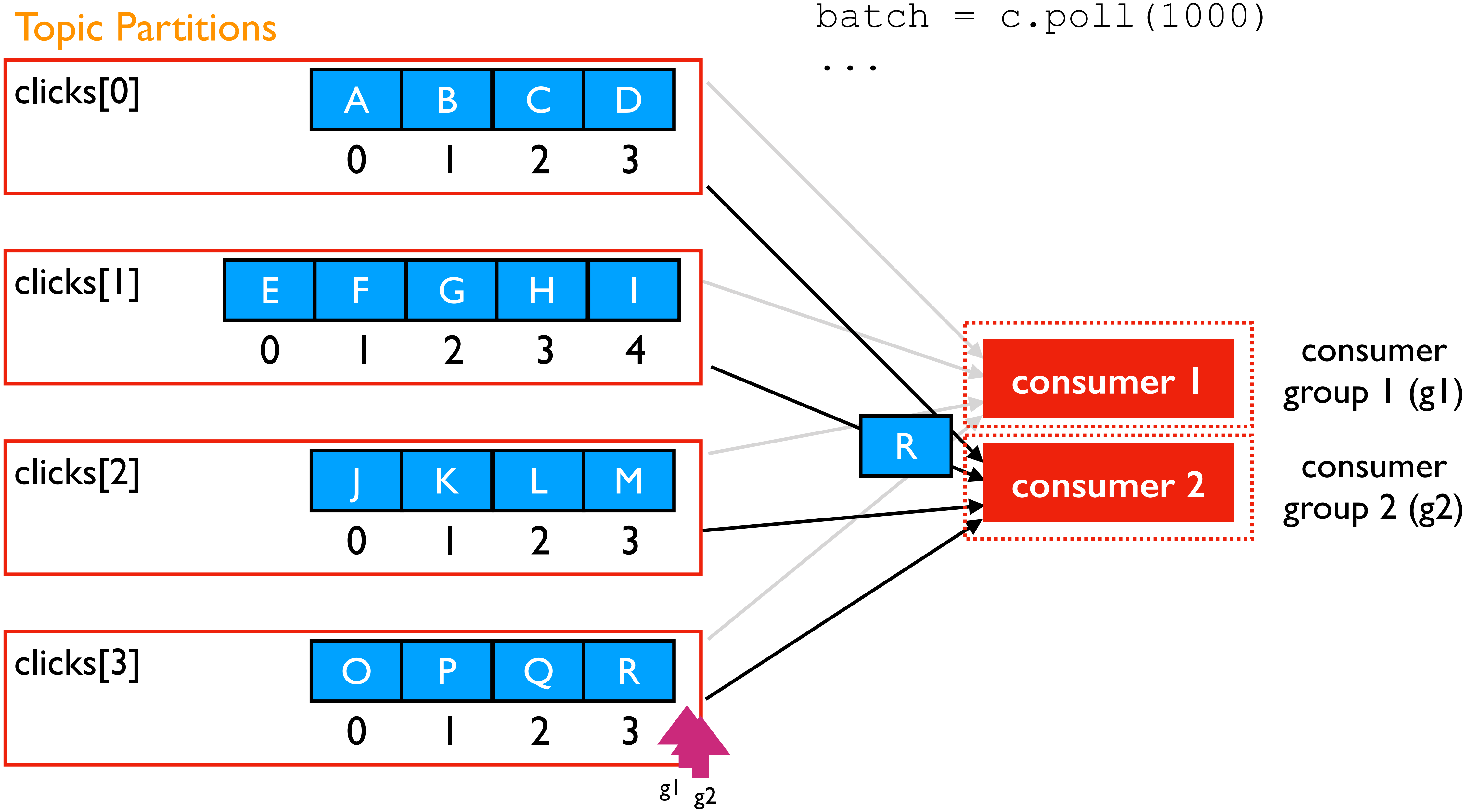

	g1 offsets	g2 offsets
clicks[0]	2	3
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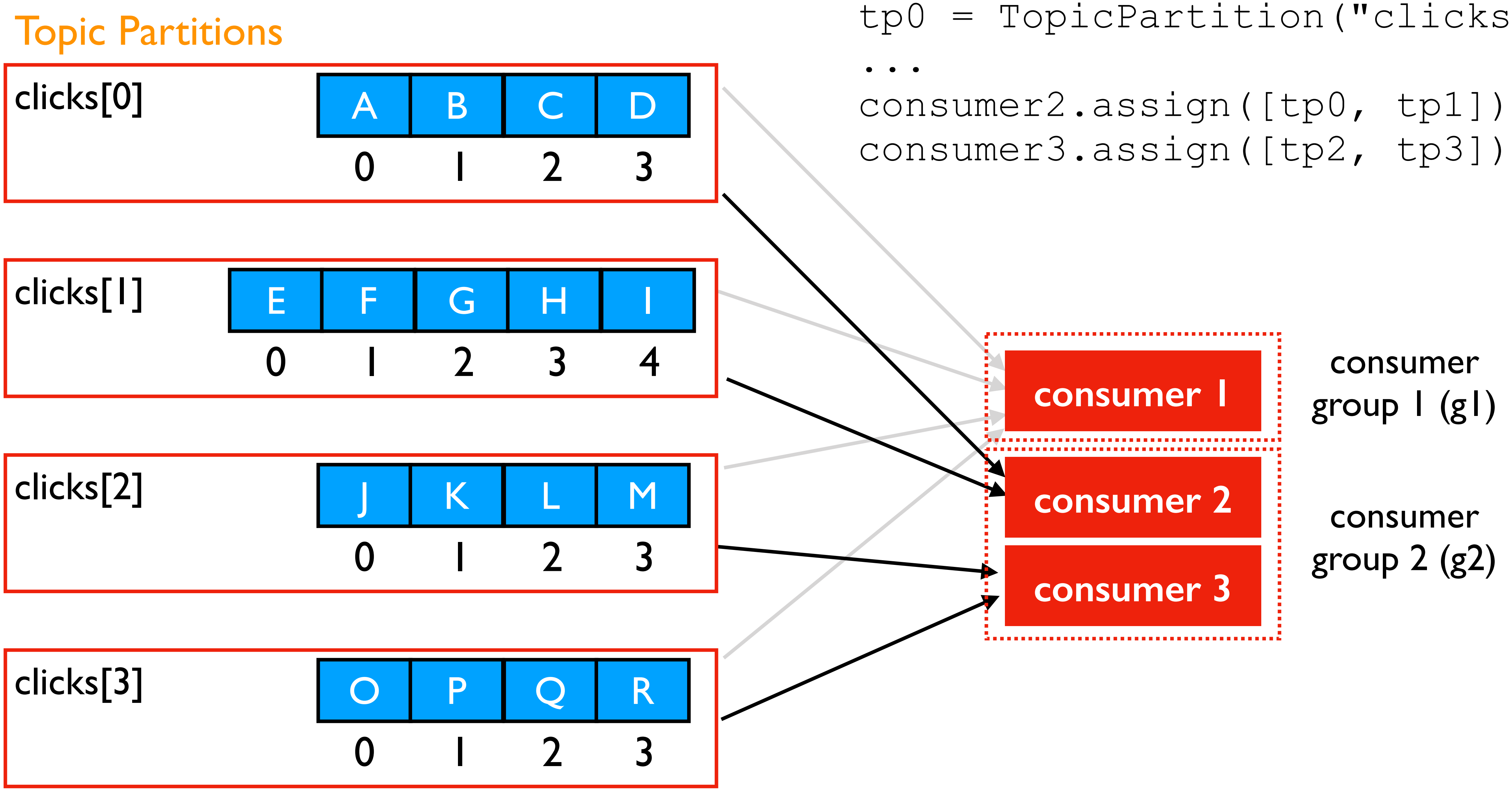
clicks[2]	4	4
clicks[3]	4	4

Groups

- different applications might operate independently
- they should ALL get a chance to consume messages
- need offsets for each topic/partition/consumer group combination

Partition Assignment: Manual

```
tp0 = TopicPartition("clicks", 0)
...
consumer2.assign([tp0, tp1])
consumer3.assign([tp2, tp3])
```



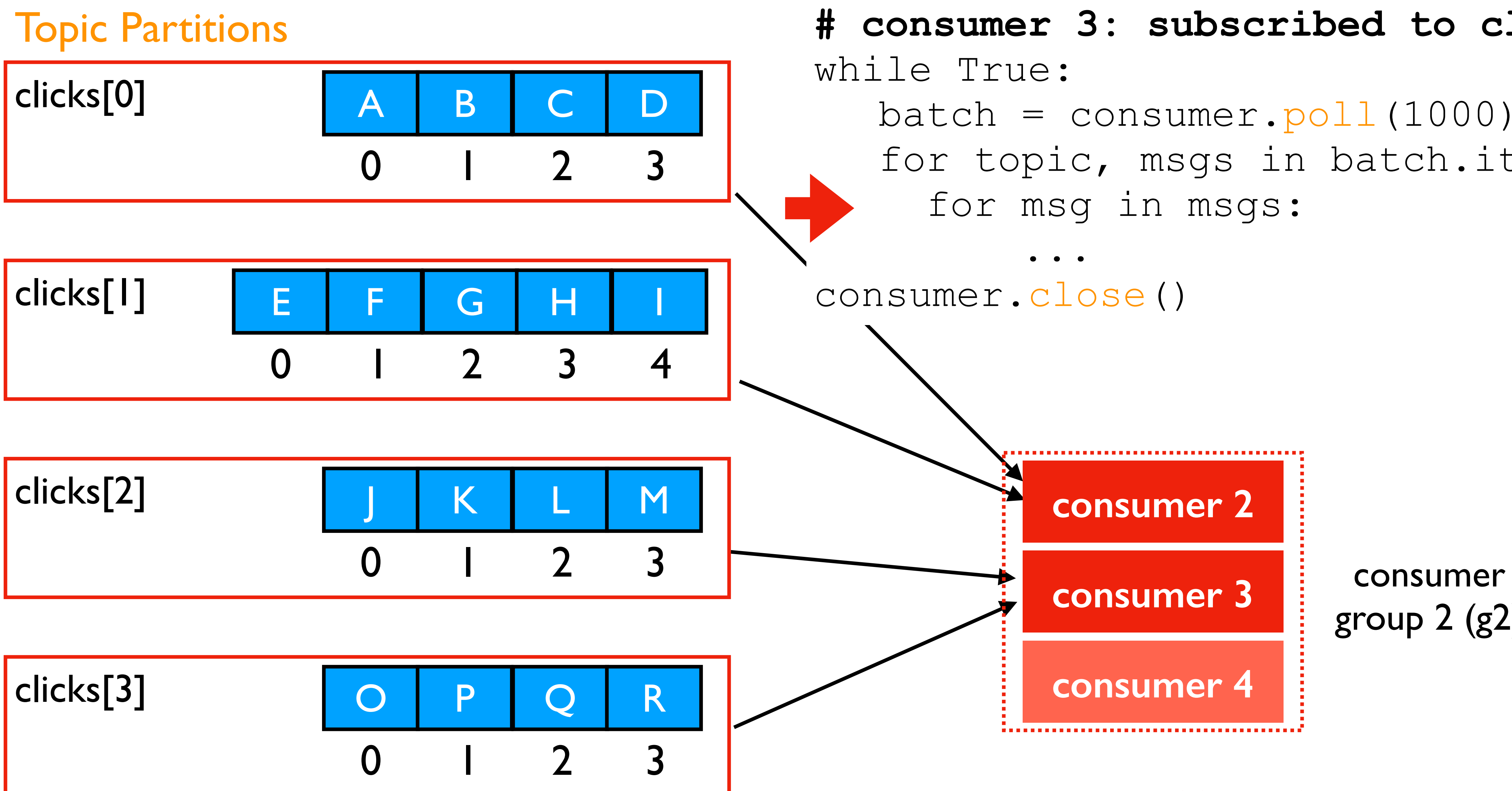
partition offsets, per group

	g1 offsets	g2 offsets
clicks[0]	2	3
clicks[1]	1	2
clicks[2]	4	4
clicks[3]	4	4

partition assignments, per group

	g1 assignment	g2 assignment
clicks[0]	consumer 1	consumer 2
clicks[1]	consumer 1	consumer 2
clicks[2]	consumer 1	consumer 3
clicks[3]	consumer 1	consumer 3

Partition Assignment: Automatic




```
# consumer 3: subscribed to clicks
while True:
    batch = consumer.poll(1000)
    for topic, msgs in batch.items():
        for msg in msgs:
            ...
consumer.close()
```

partition assignments, per group

	g1 assignment	g2 assignment
clicks[0]	consumer 1	consumer 2
clicks[1]	consumer 1	consumer 2
clicks[2]	consumer 1	consumer 3
clicks[3]	consumer 1	consumer 3

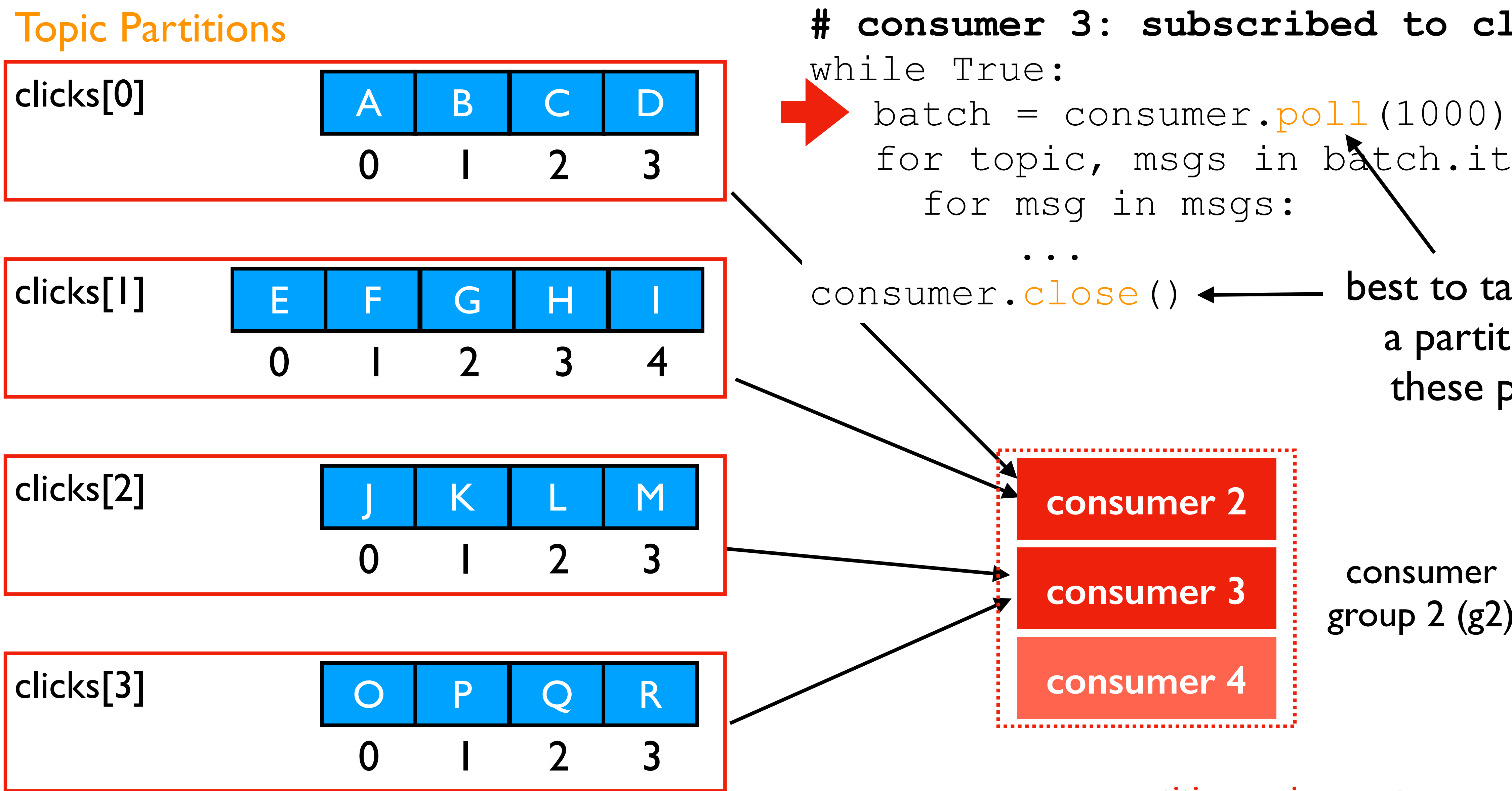
Assignment and re-assignment

- by default, consumers are automatically assigned partitions when they start polling
- **challenge:** Kafka shouldn't re-assign a partition in the middle of a batch (might double process messages)

Partition Assignment: Automatic

```
# consumer 3: subscribed to clicks
while True:
    batch = consumer.poll(1000)
    for topic, msgs in batch.items():
        for msg in msgs:
            ...
consumer.close()
```

best to take away a partition at these points



partition assignments, per group

	g1 assignment	g2 assignment
clicks[0]	consumer 1	consumer 2
clicks[1]	consumer 1	consumer 2
clicks[2]	consumer 1	consumer 3
clicks[3]	consumer 1	consumer 3

Assignment and re-assignment

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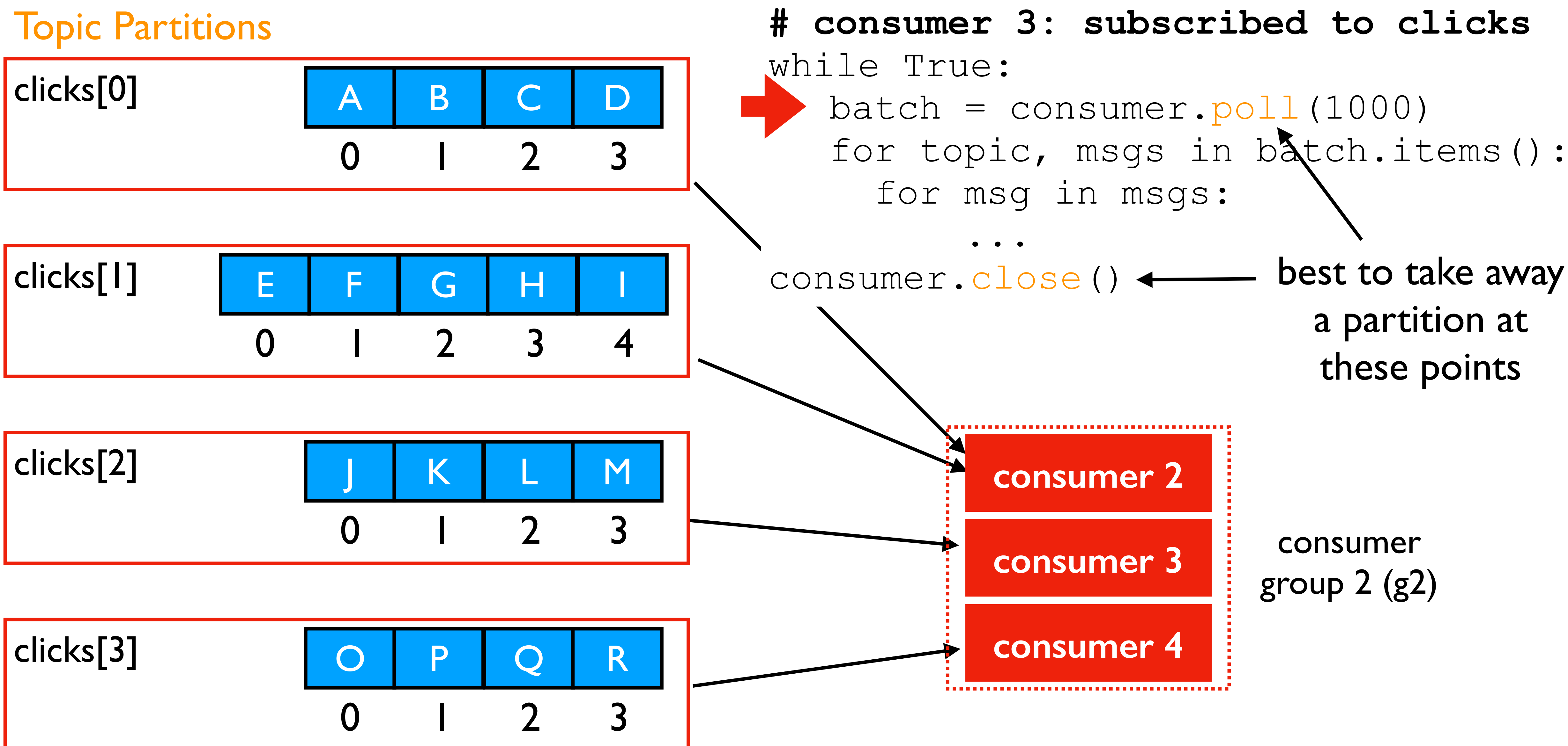
Partition Assignment: Automatic




```
# consumer 3: subscribed to clicks
while True:
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consumer.close()
```

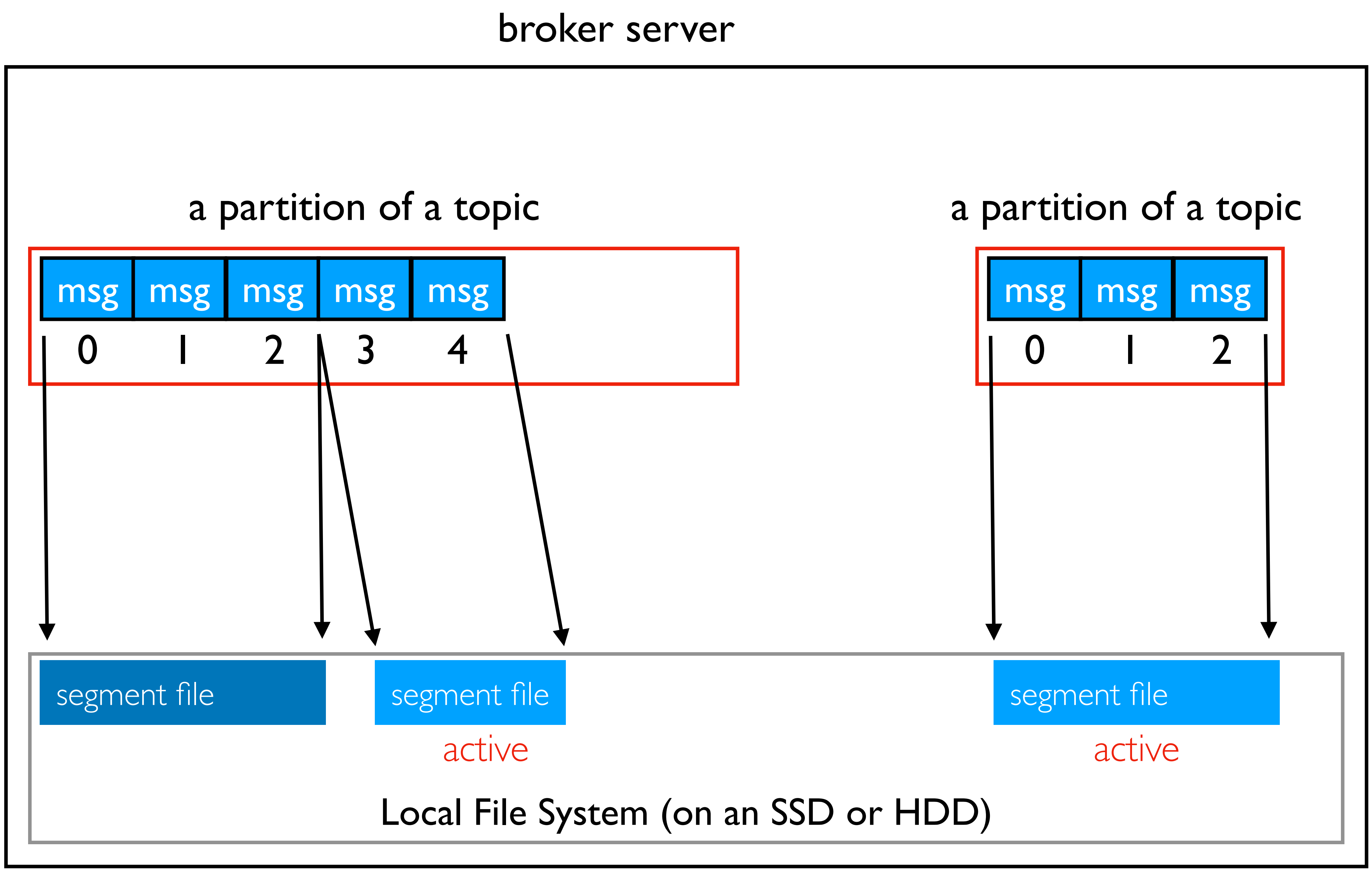
partition assignments, per group

	g1 assignment	g2 assignment
clicks[0]	consumer 1	consumer 2
clicks[1]	consumer 1	consumer 2
clicks[2]	consumer 1	consumer 3
clicks[3]	consumer 1	consumer 4

Assignment and re-assignment

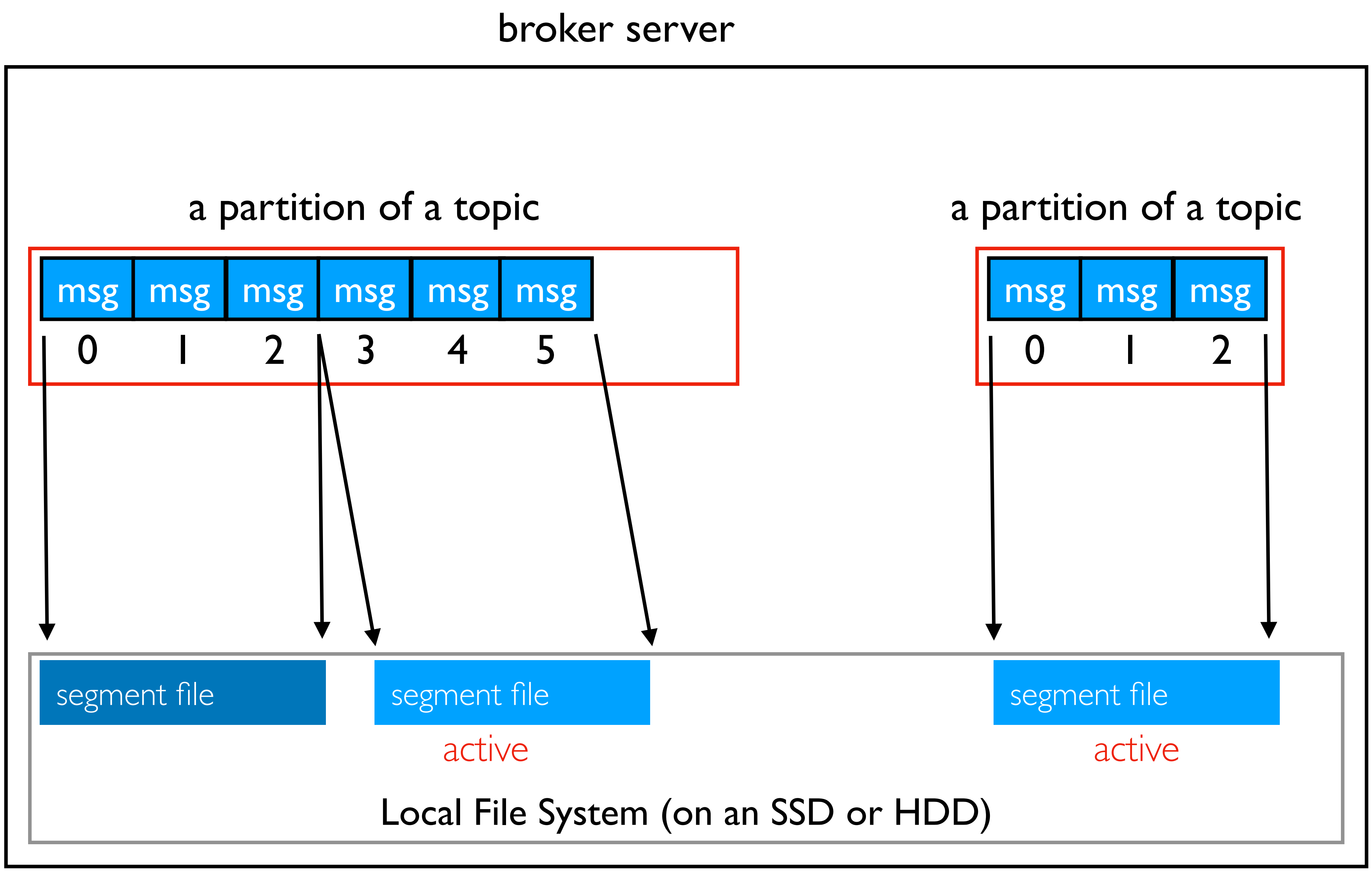
- by default, consumers are automatically assigned partitions when they start polling
- **challenge:** Kafka shouldn't re-assign a partition in the middle of a batch (might double process messages)

Segment Files: Log Rollover and Deletion



- partitions are divided into consecutive regions and saved in segment files
- all new data is sequentially written to the end of an active segment

Segment Files: Log Rollover and Deletion



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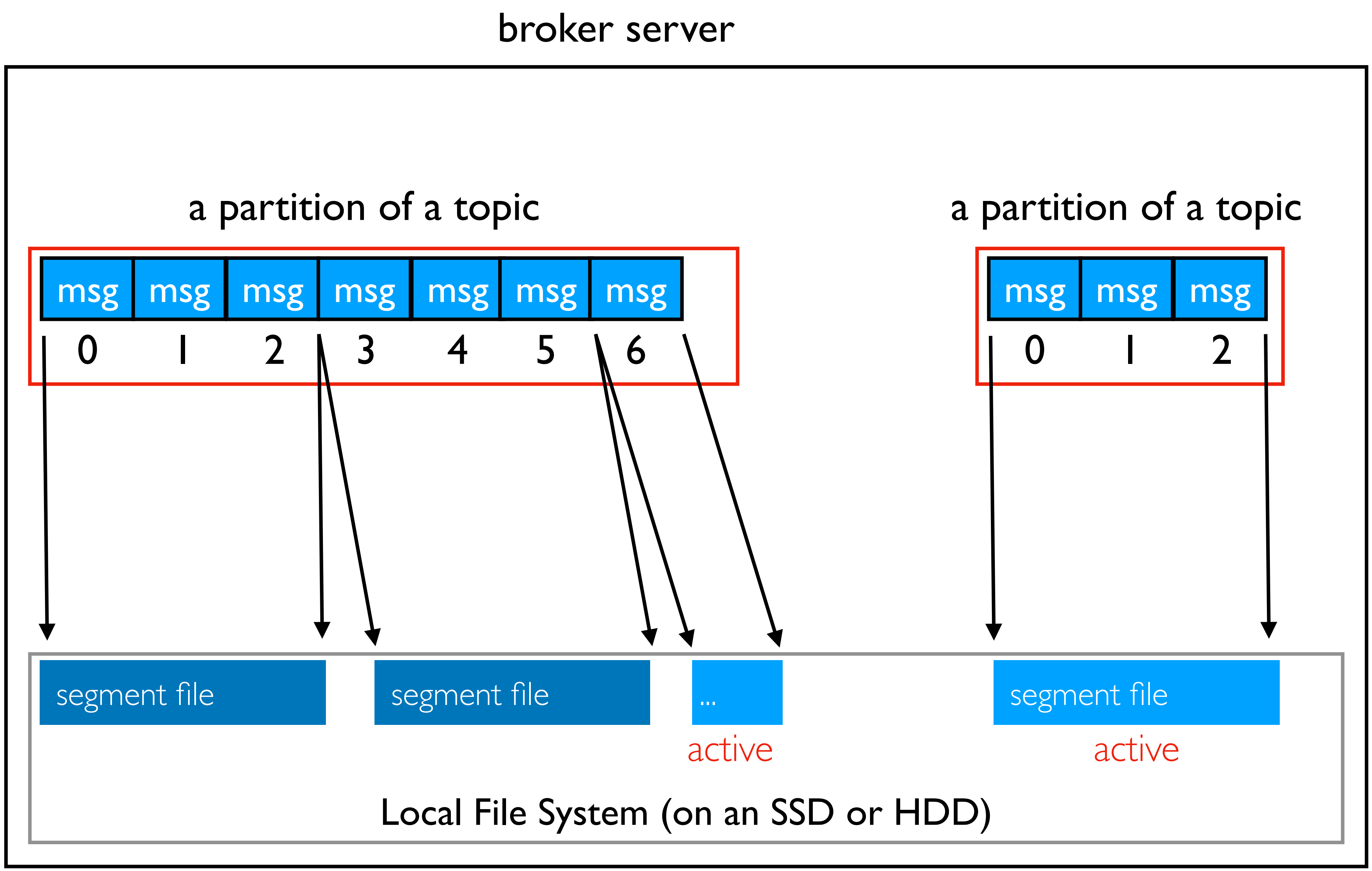
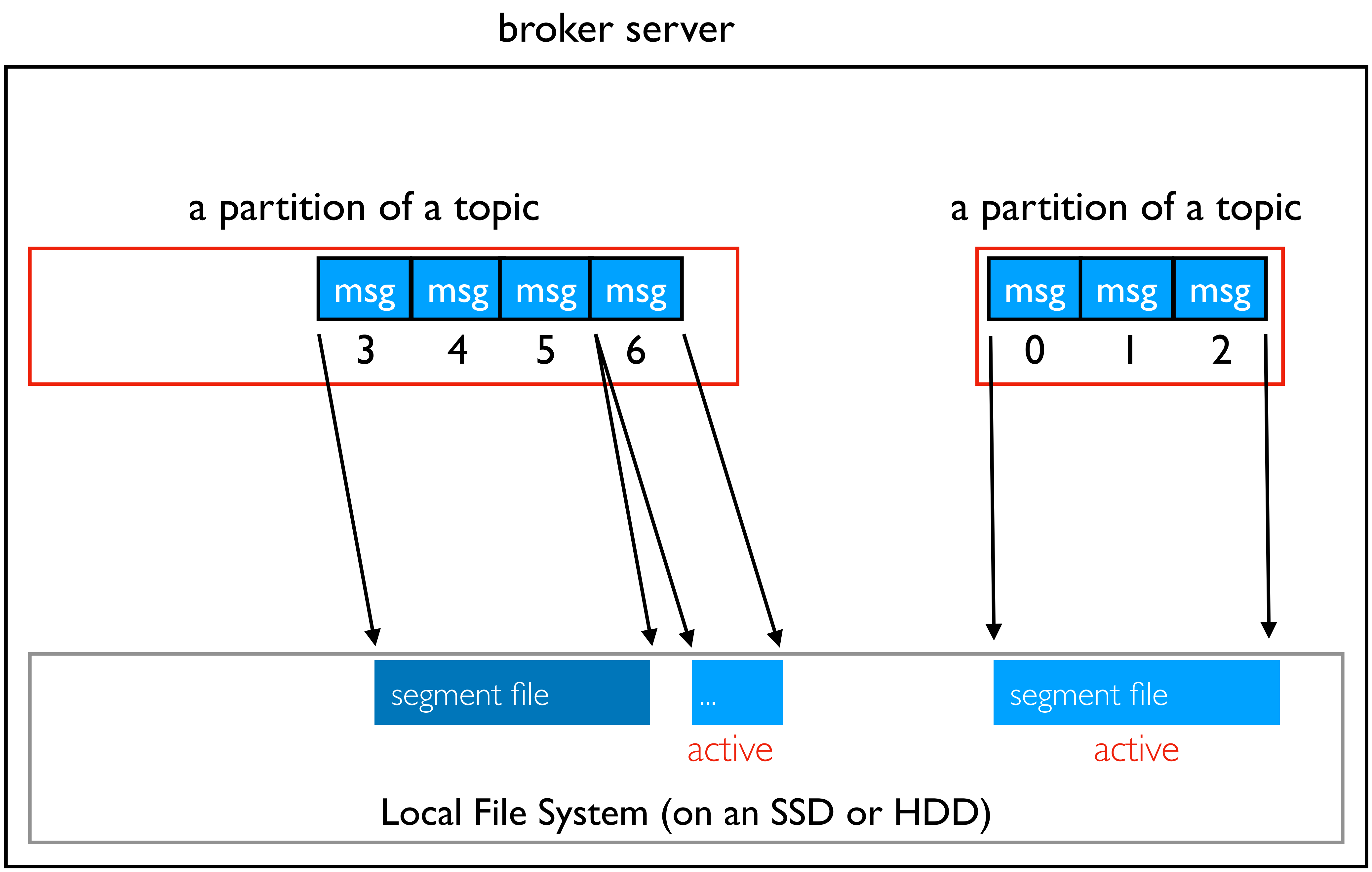
Segment Files: Log Rollover and Deletion



- rollover: current segment is finalized (no more changes)
- new segment is created and becomes active

Segment Files: Log Rollover and Deletion



- deletion: old segment is deleted
- always starts from smallest offset
- active segment is NEVER deleted

Log Policy

Rollover and retention policies are configurable in Kafka.

Rollover

- setting 1: max segment age (log.roll.hours=7 day by default)
- setting 2: max segment size (log.segment.bytes=1GB by default)
- rollover happens when segment gets too big or too old (whichever happens first)

Retention/Deletion

- setting 1: log age cutoff (log.retention.hours=7 days by default)
- setting 2: log size cutoff (log.retention.bytes=disabled by default)
- deletion happens on oldest segment when log is too big or has records too old
- note: age cutoff applies to newest messages in a segment, so there will probably be some older ones in the same segment past the cutoff. *Not useful for legal compliance with data retention laws.*

https://www.conduktor.io/blog/understanding-kafkas-internal-storage-and-log-retention/

TopHat