[544] Kafka Streaming

Tyler Caraza-Harter

Outline: Kafka Streaming

Sending/Receiving Messages

- RPC (Remote Procedure Calls)
- Streaming

ETL (Extract Transform Load)

Kafka Design

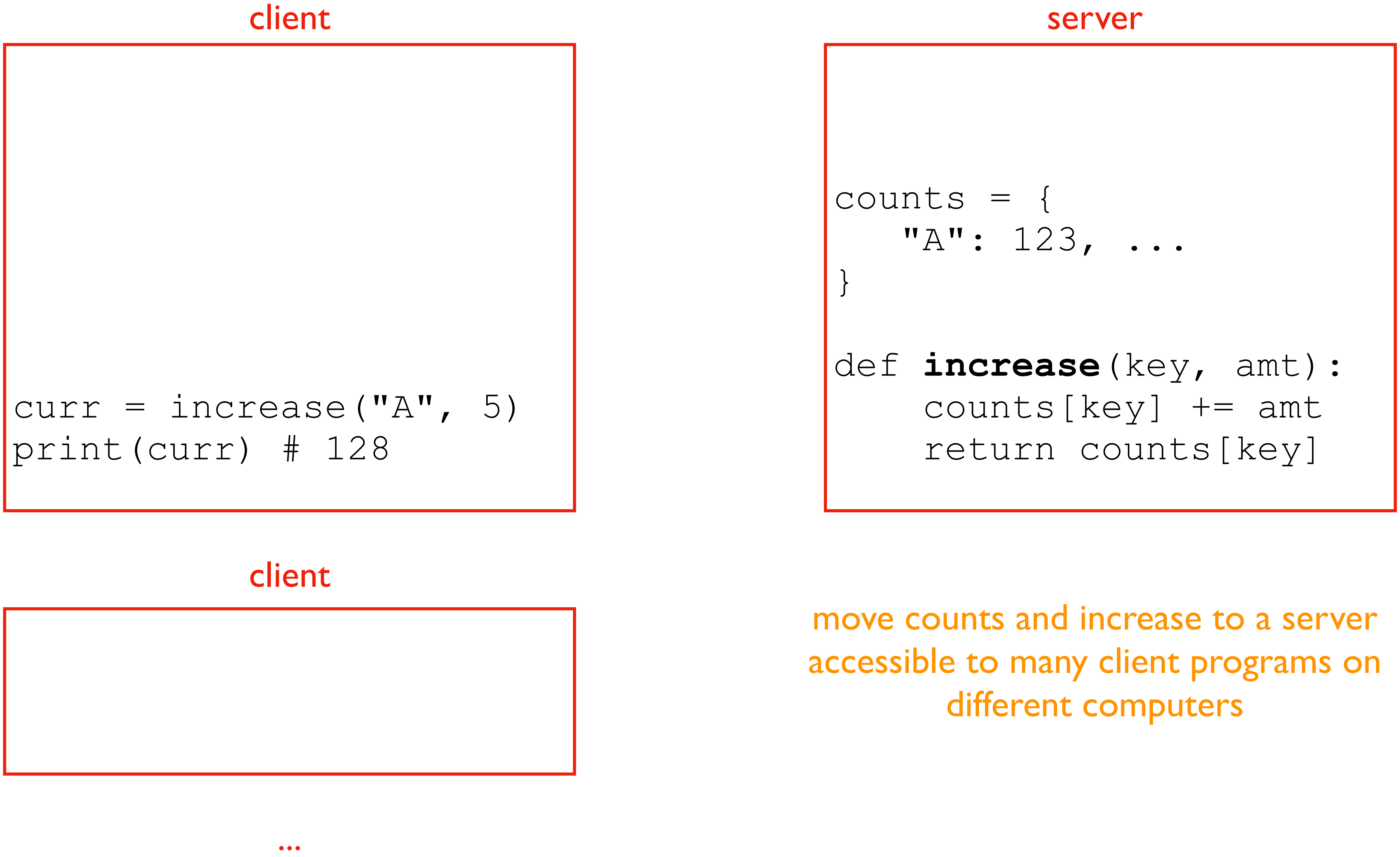
Demos

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

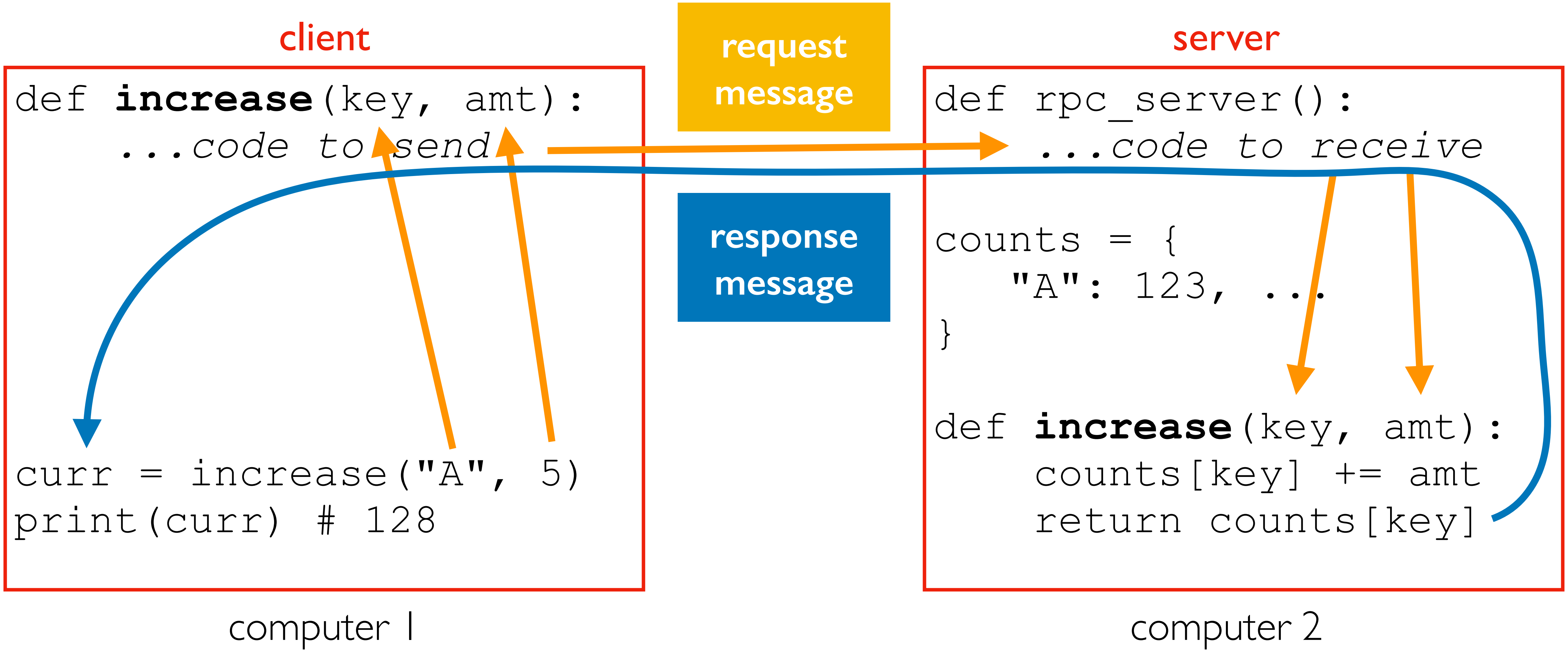
server

```
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)



client

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



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

computer 1

request message

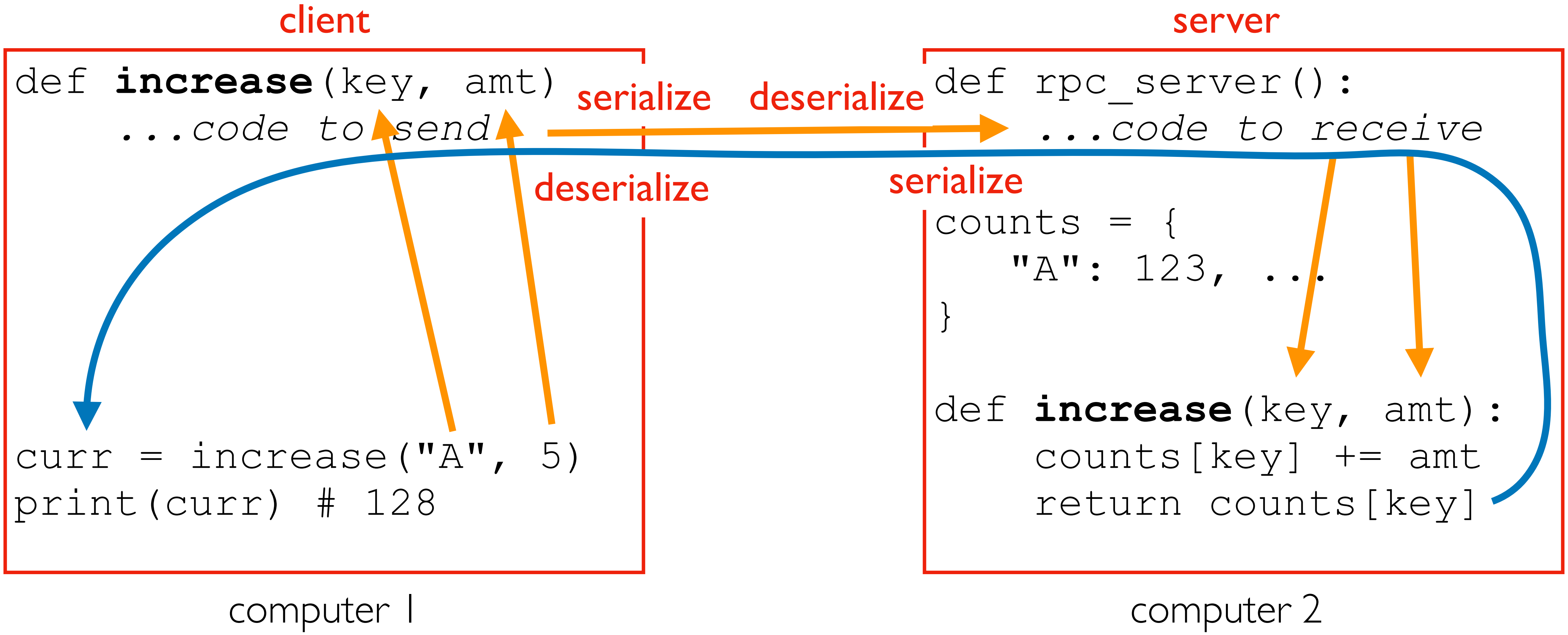
response message

server

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

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

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

computer 2

Serialization/Deserialization



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

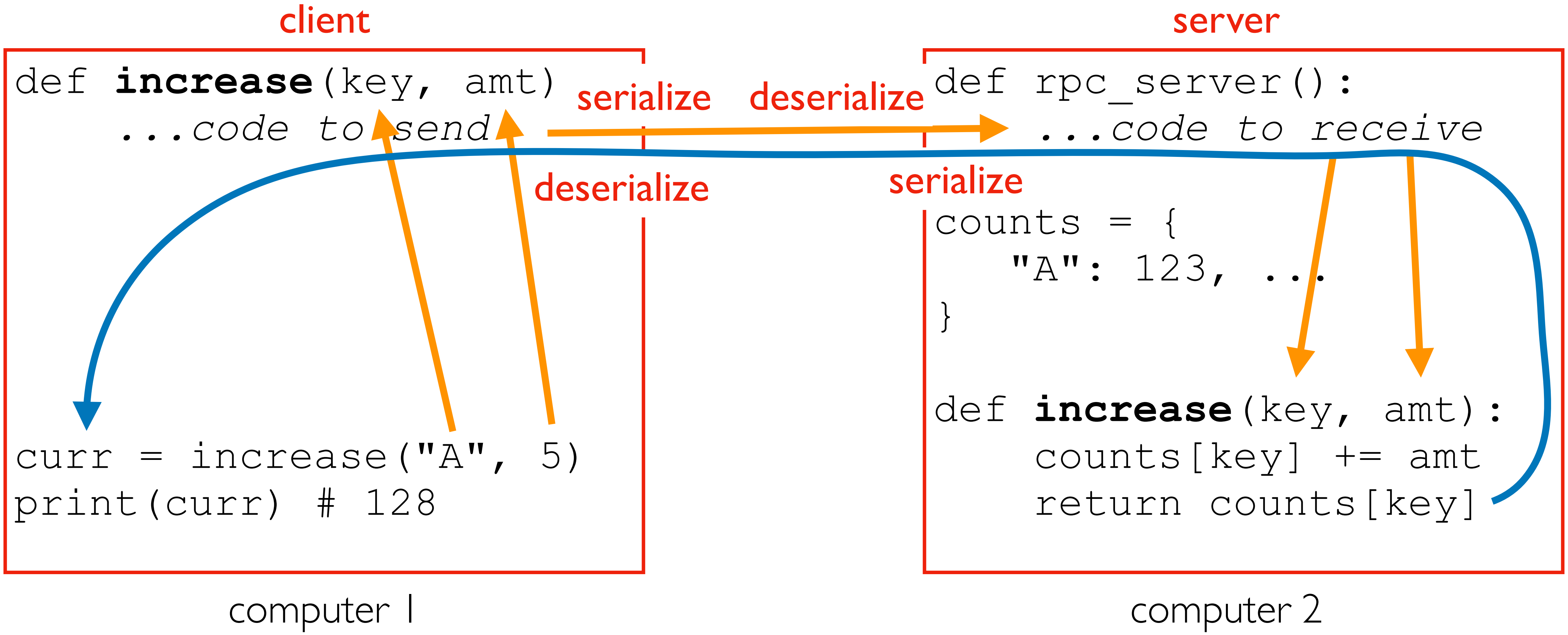
request message

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

response message

```
return val as bytes:
b'5'
```

gRPC uses protocol buffers for wire format



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

request message

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

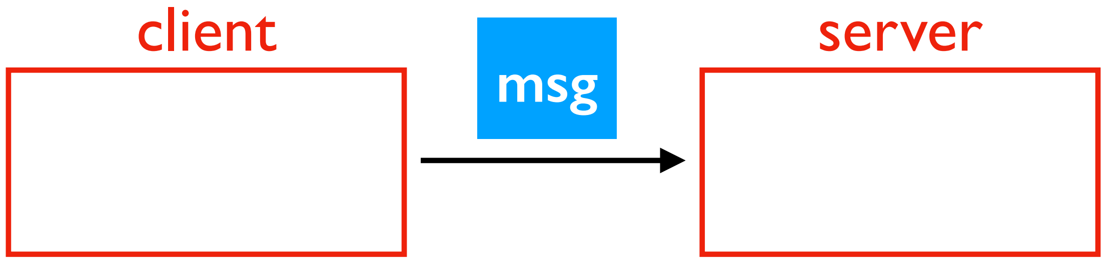
response message

```
protobuf (ret val to bytes)
b'01000000'
(contains 128)
```

Synchronous vs. Asynchronous Communication

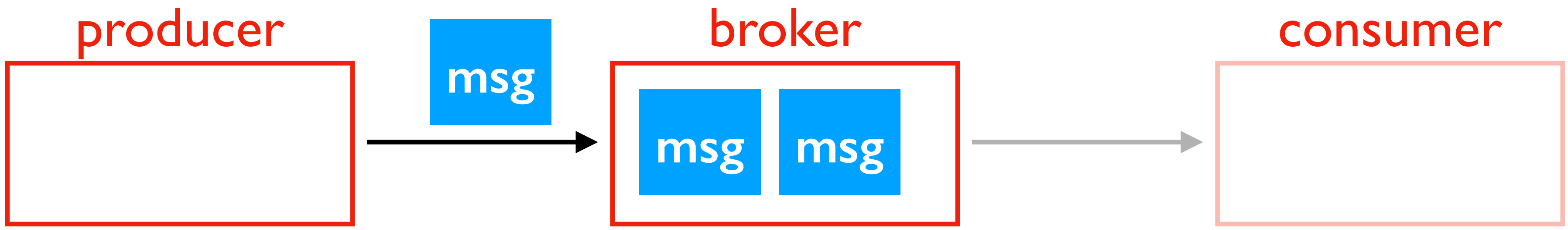
Synchronous

- 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, streaming



Outline: Kafka Streaming

Sending/Receiving Messages

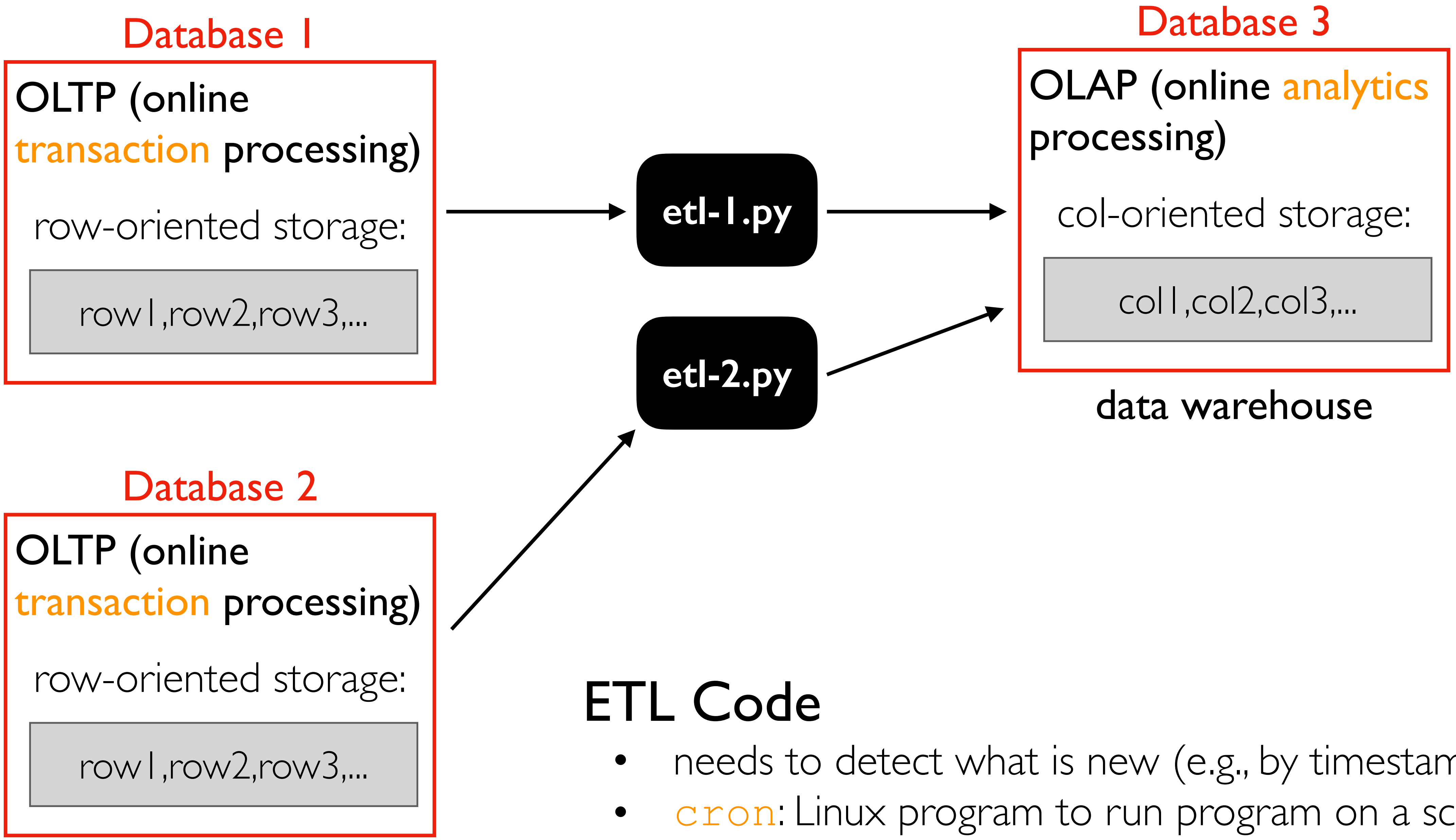
ETL (Extract Transform Load)

- Batch
- Streaming

Kafka Design

Demos

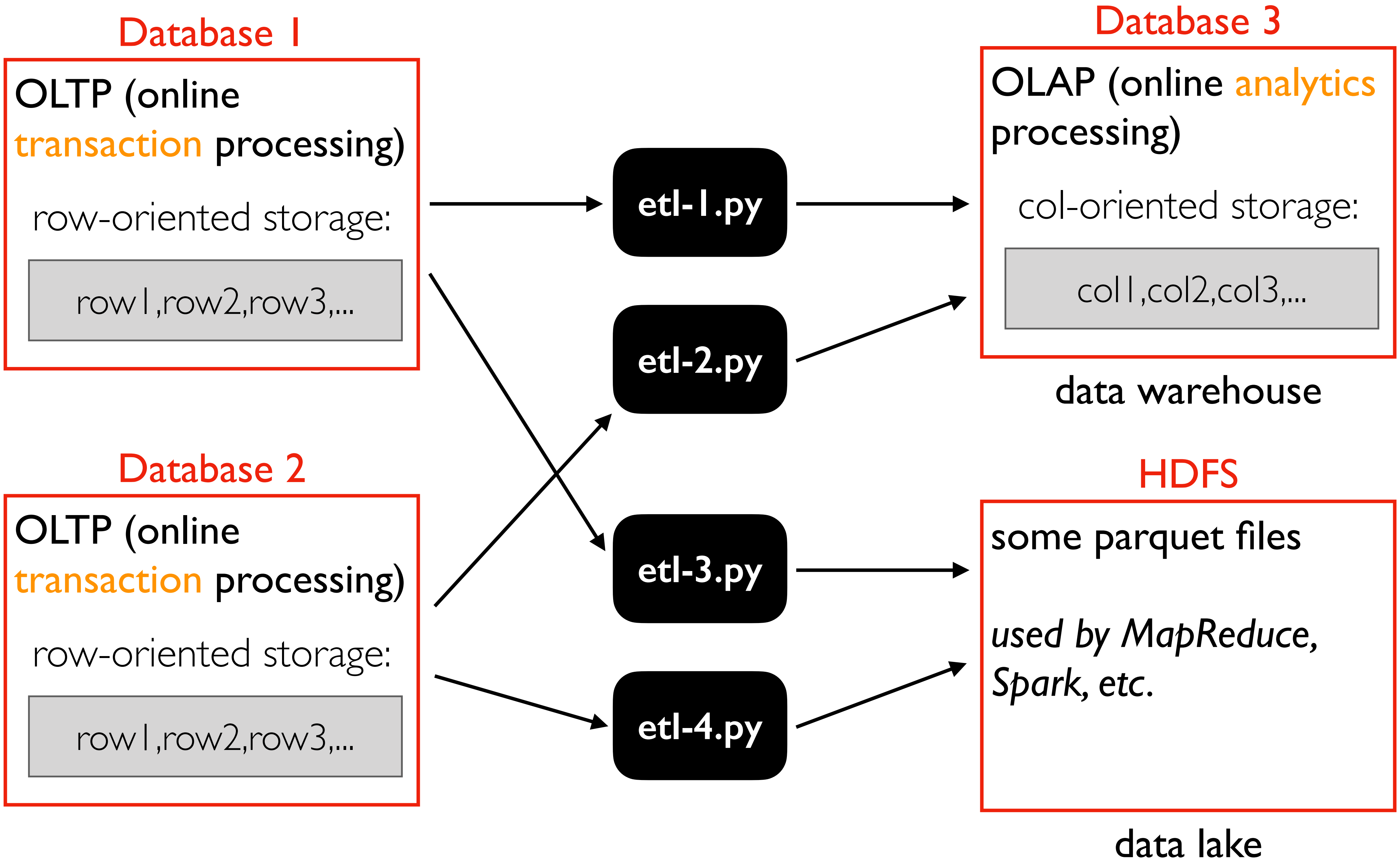
Extract Transform Load



ETL Code

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

Extract Transform Load

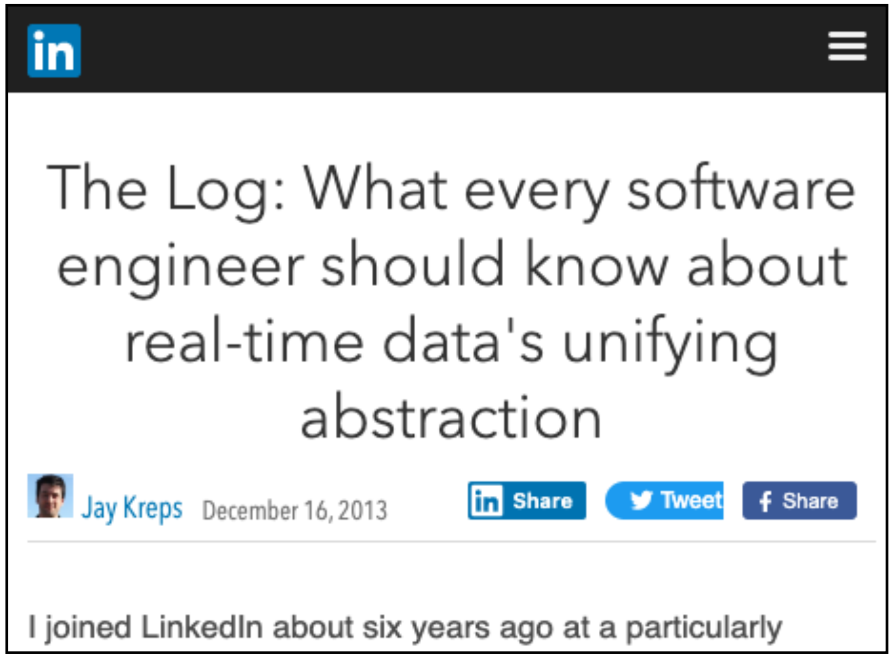


if we have **X** OLTP data bases and **Y** derivative stores, how many ETL programs must we write?

Too much ETL...

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

- Jay Krepps helped build Kafka at LinkedIn
- Later co-founded Confluent
- 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

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

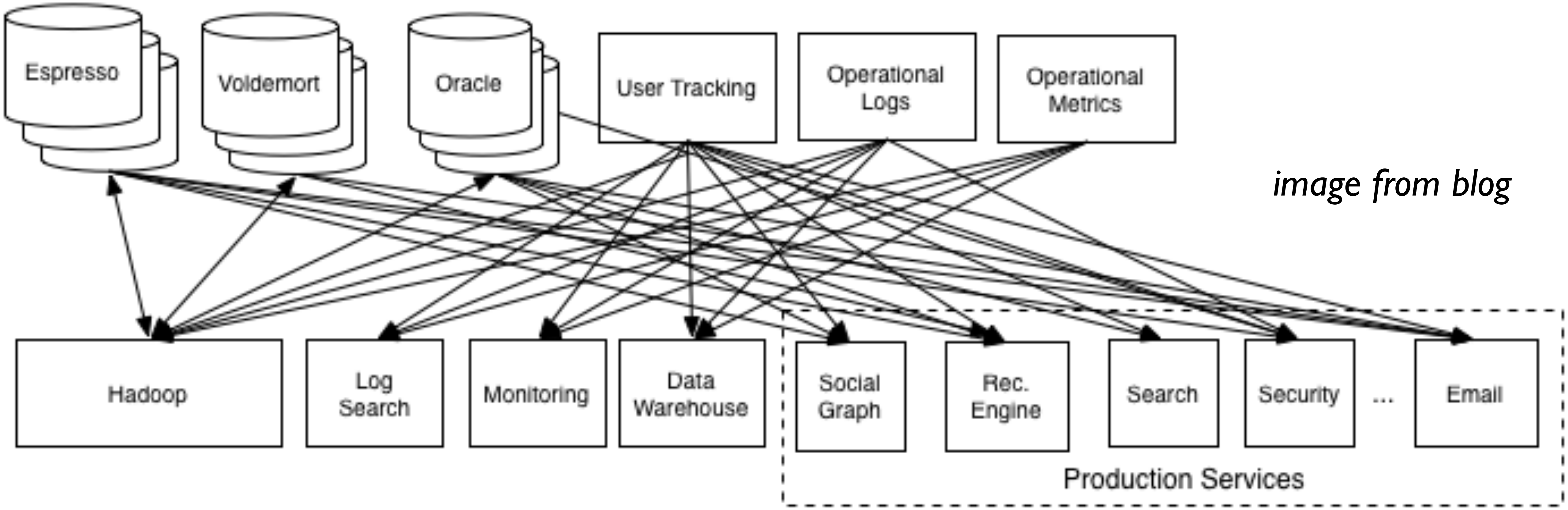
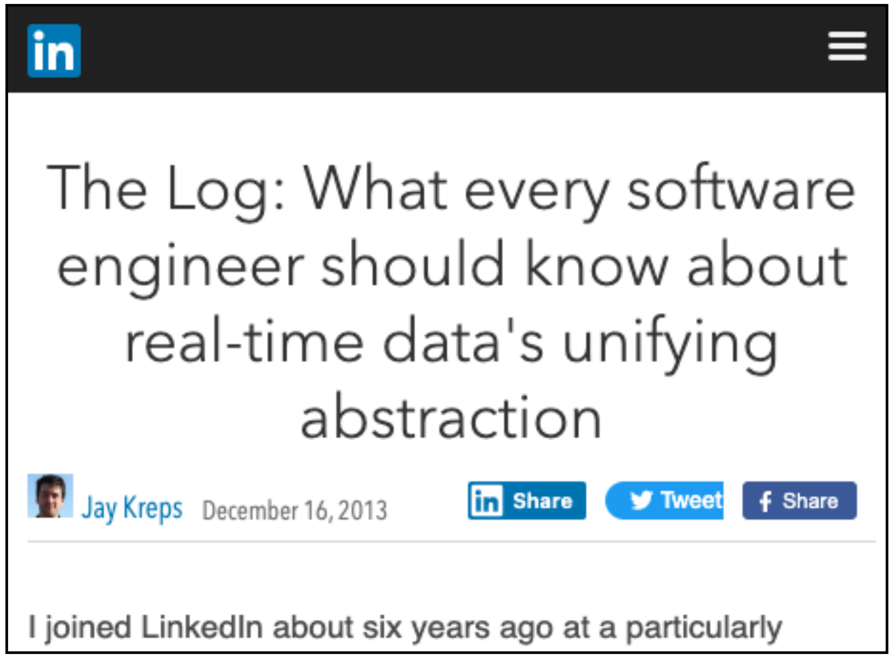


image from blog

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)



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

Jay Kreps December 16, 2013

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

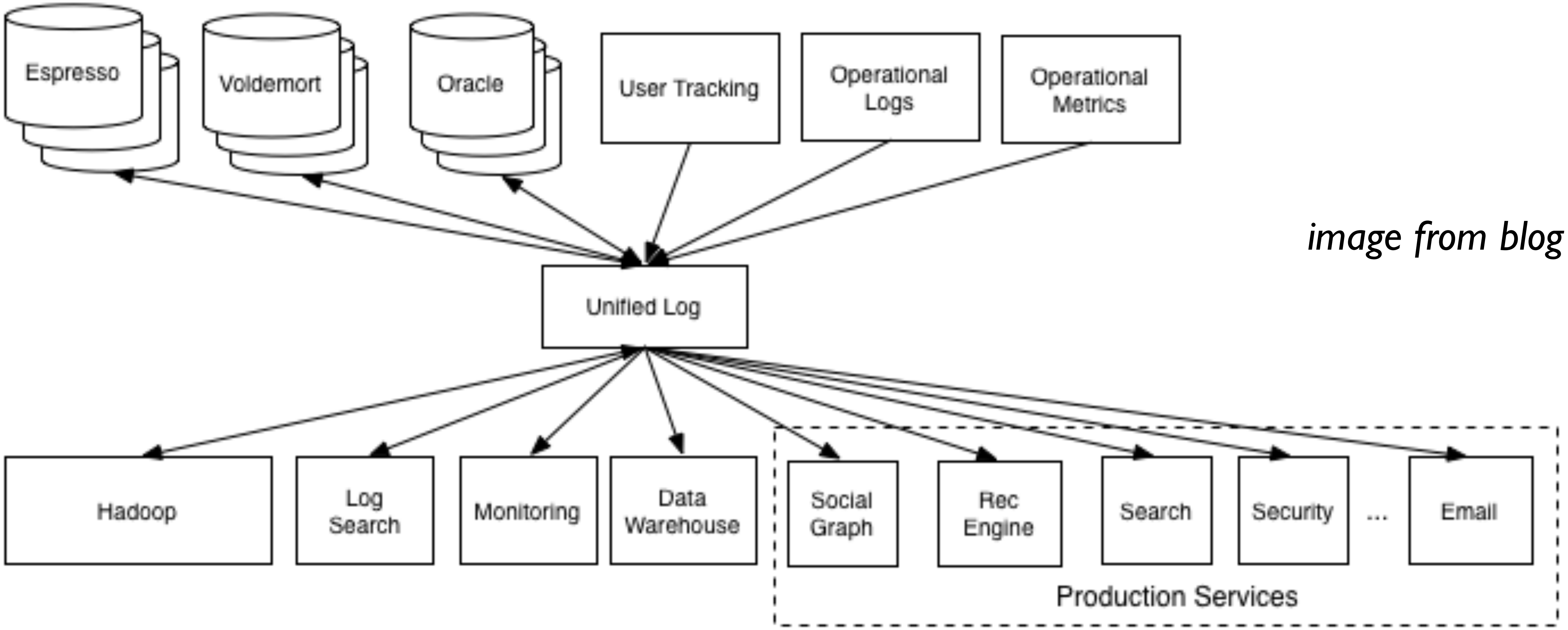


image from blog

Outline: Kafka Streaming

Sending/Receiving Messages

ETL (Extract Transform Load)

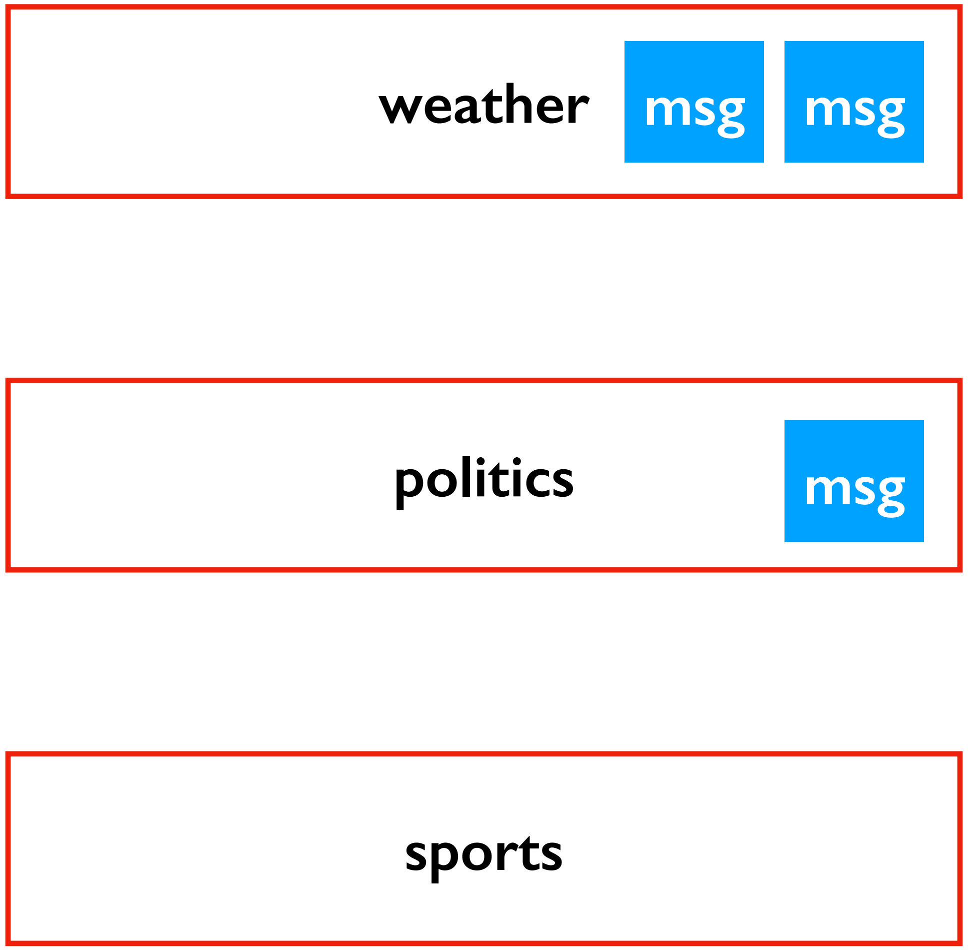
Kafka Design

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

Demos

Topics

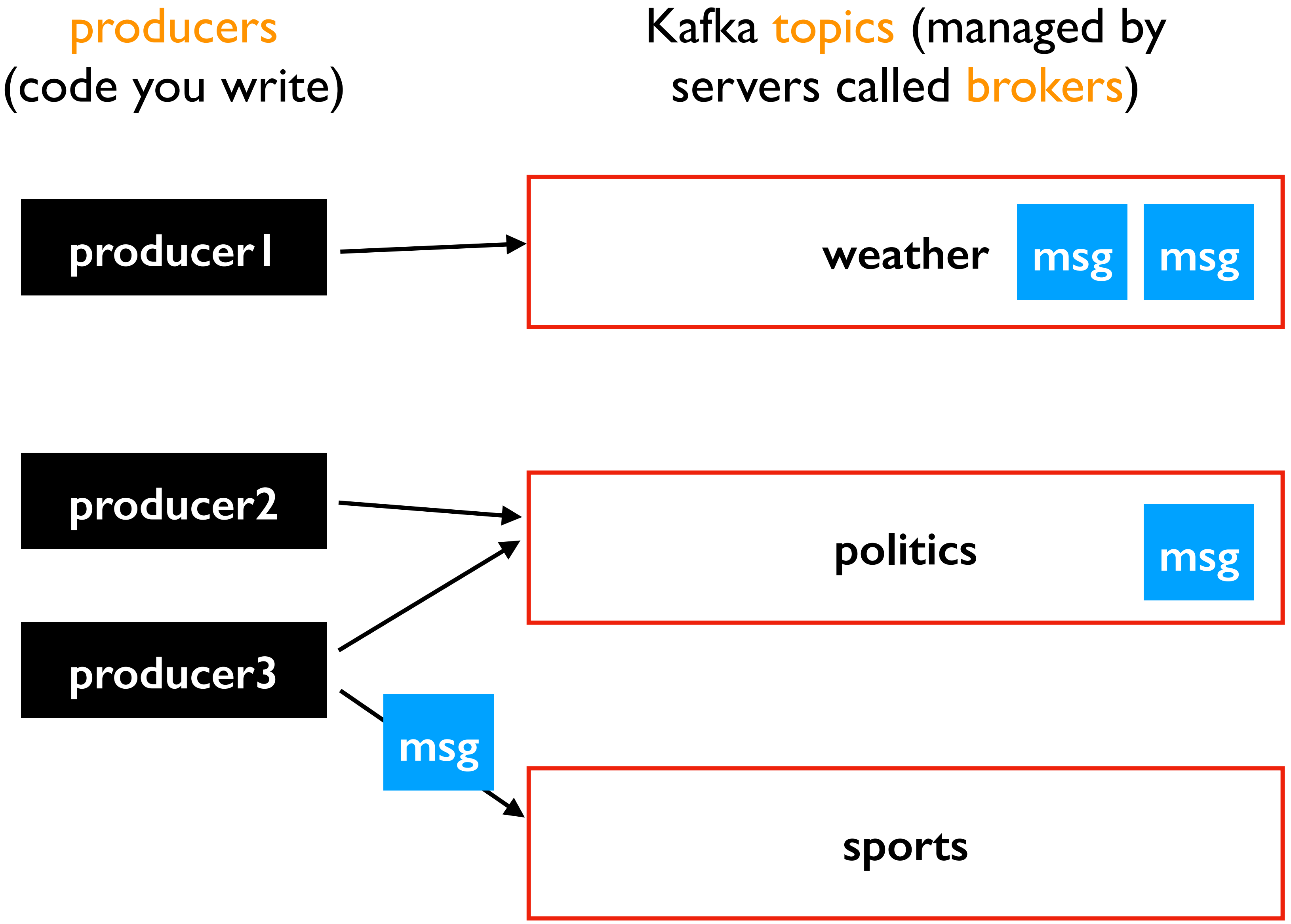
Kafka topics (managed by
servers called brokers)



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

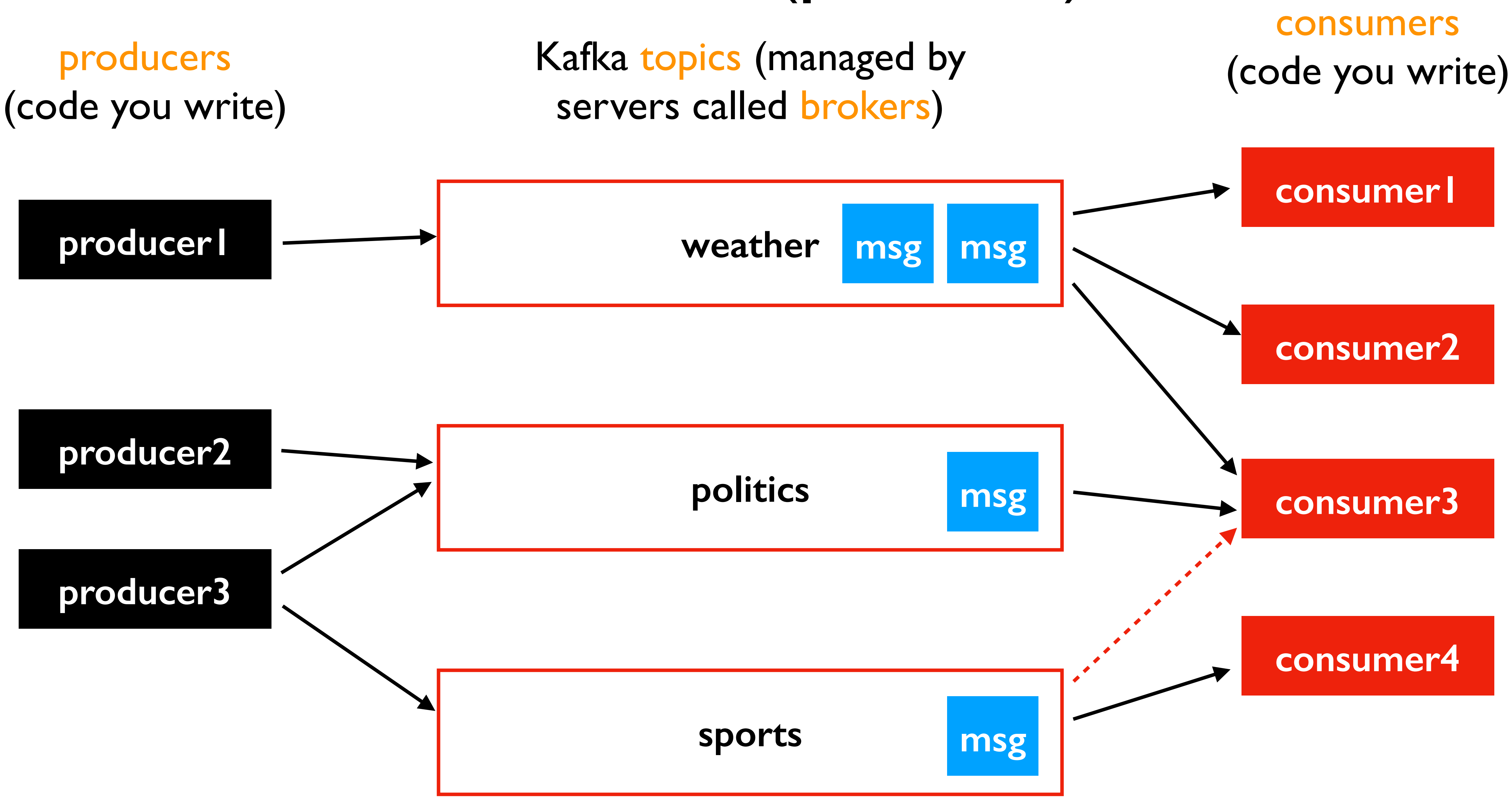
```
pip install kafka-python
```

Producers **Publish** (pub/sub)



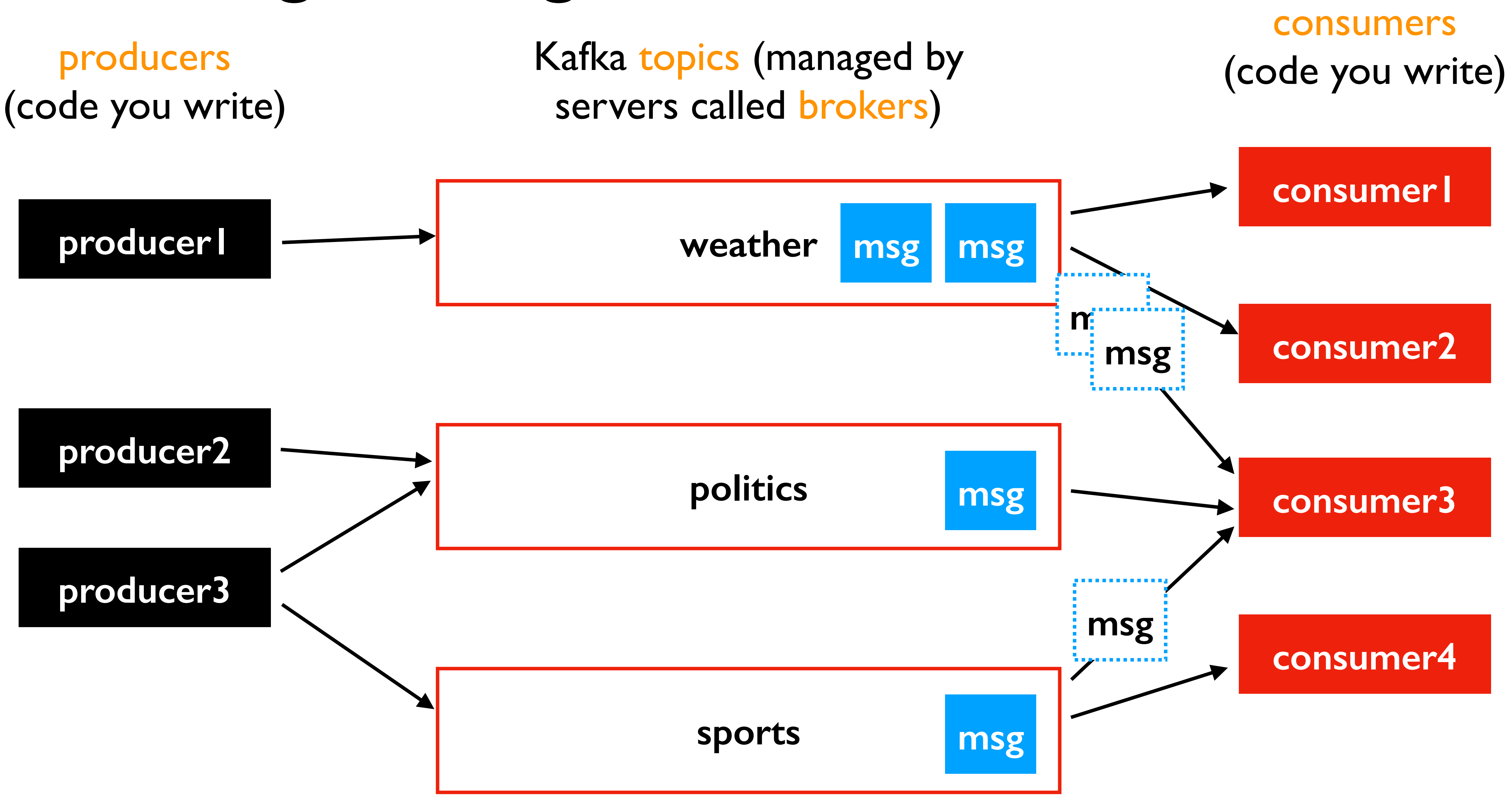
```
producer3 = KafkaProducer(...)
producer3.send("sports", ...)
```

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.

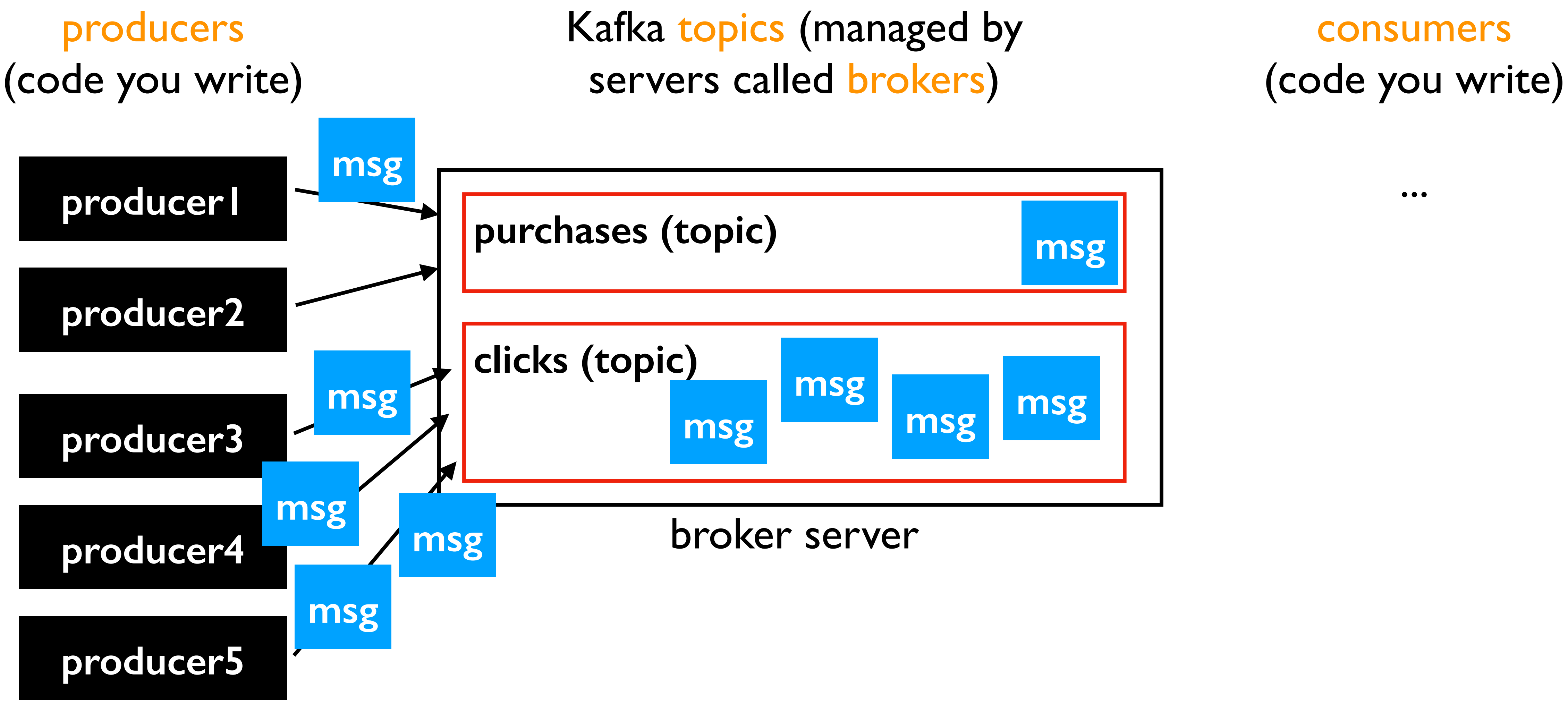
Python dict => bytes:

```
d = {...}
value = bytes(json.dumps(d))
```

Protobuf => bytes:

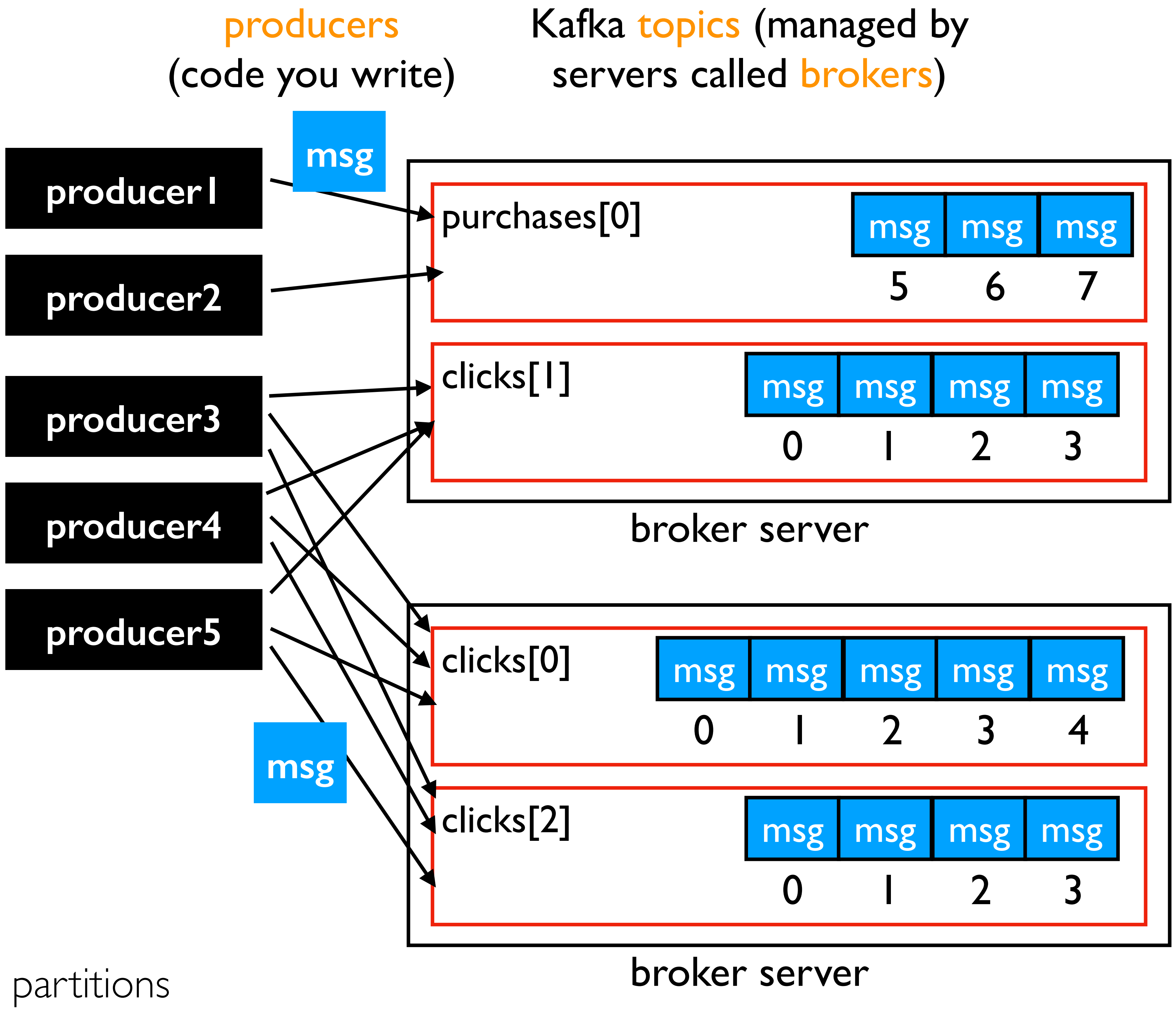
```
msg = mymod_pb2.MyMessage(...)
value = msg.SerializeToString() # actually bytes, not str
```

Scaling the Brokers



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

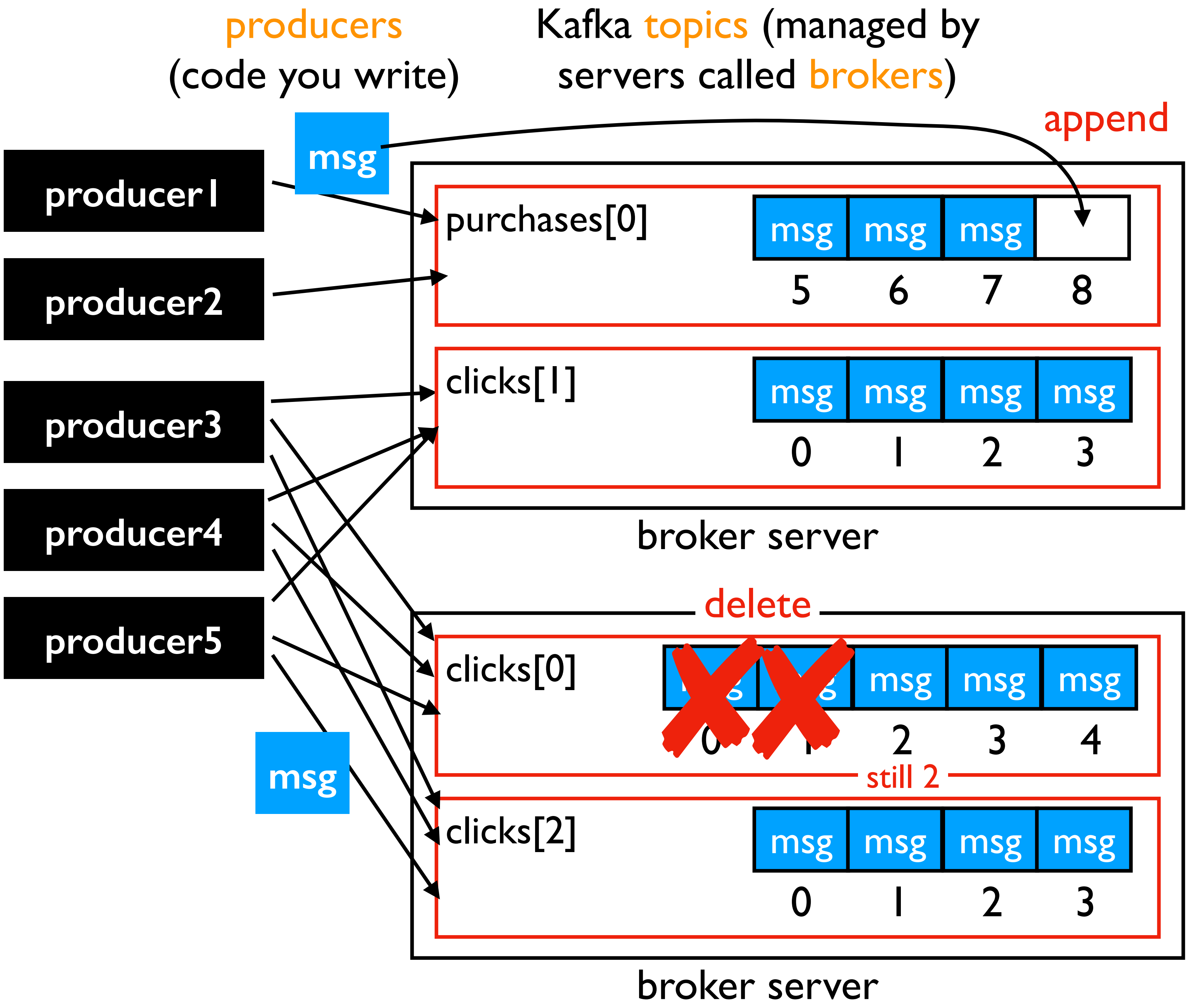
Partitions



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

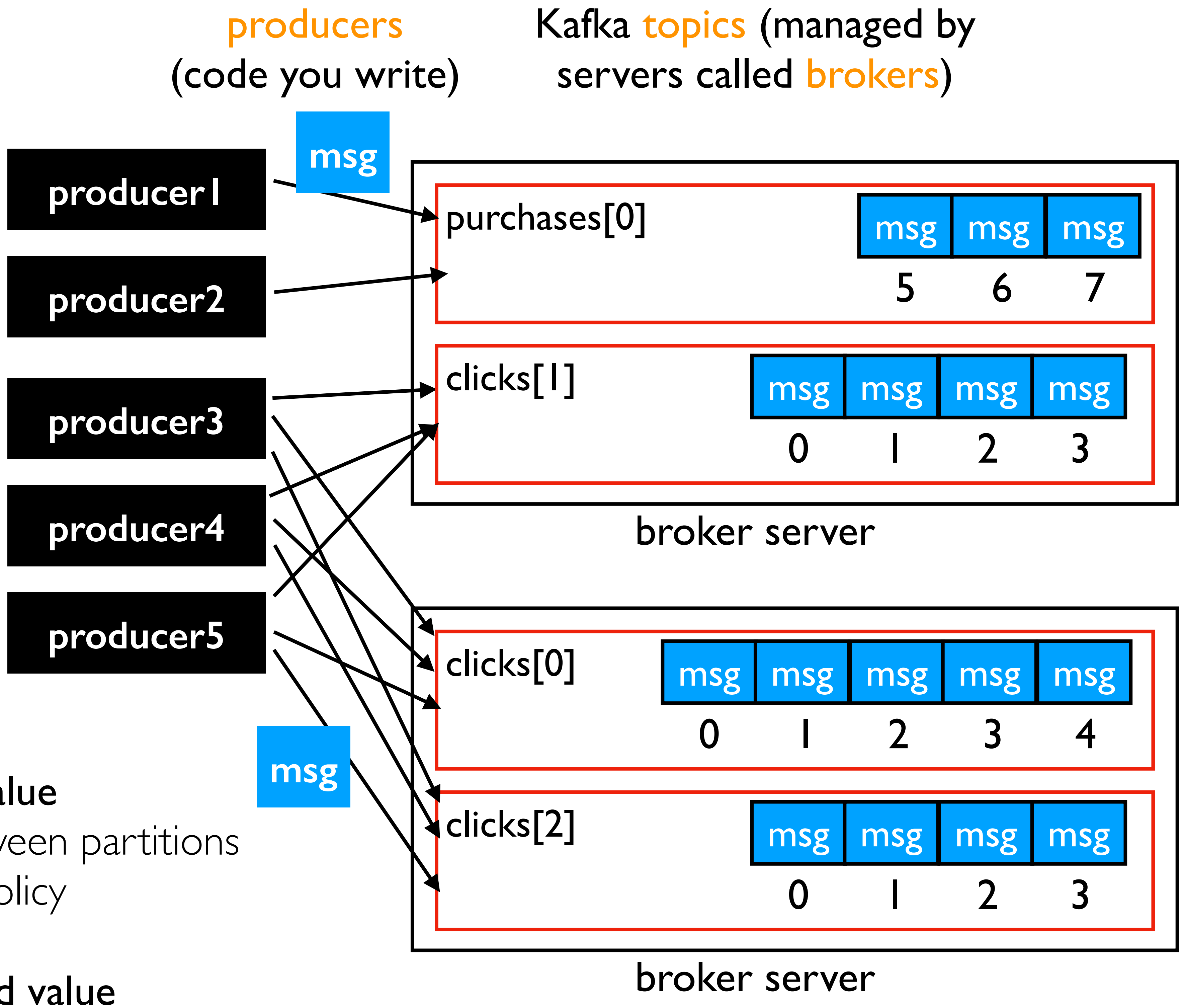
Changing Partitions



Changes

- append right
- delete left (depends on "retention" policy)
- delete doesn't change indexes

Selecting Partitions



case 1: message only has value

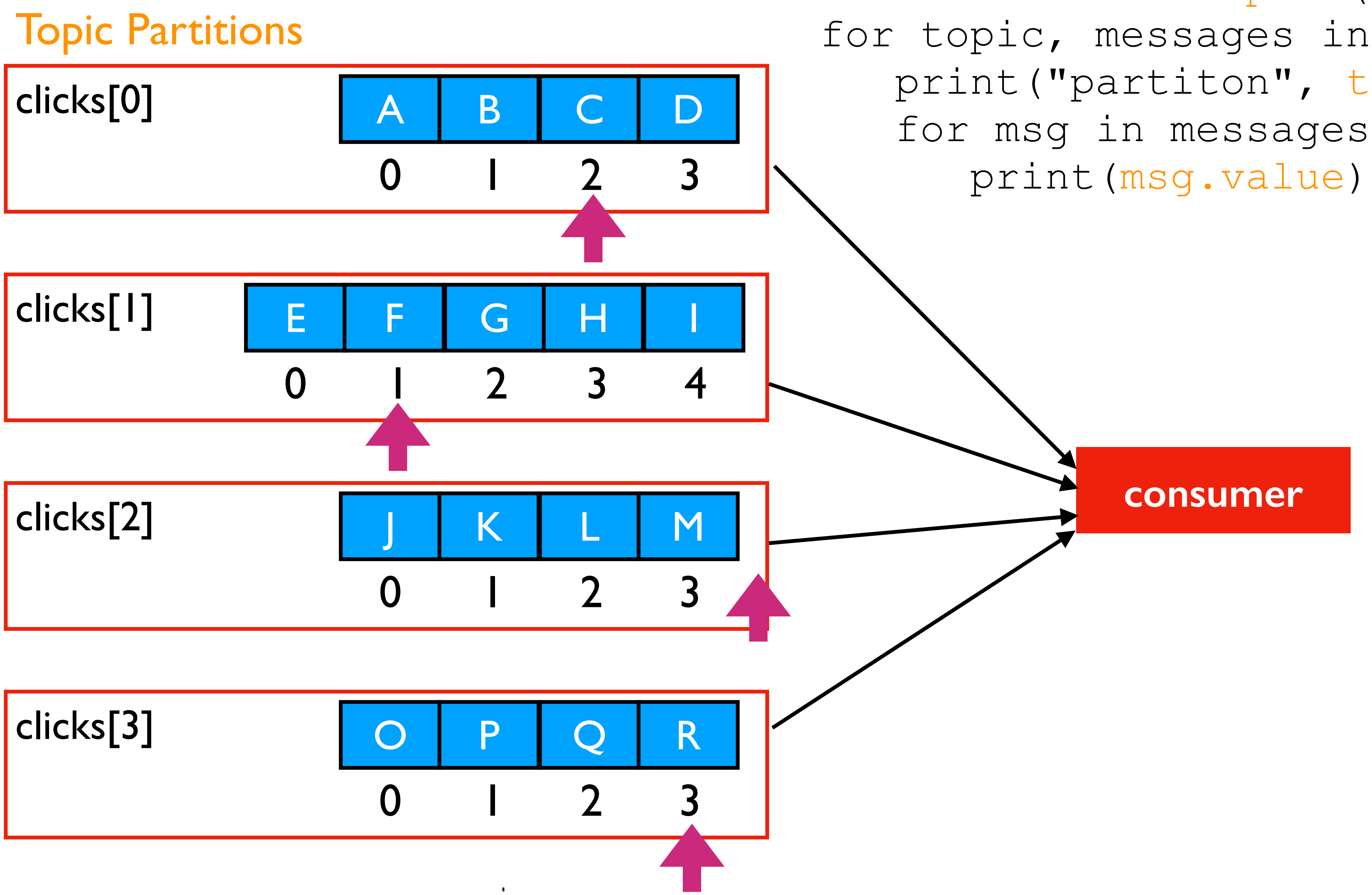
- producer rotates between partitions
- called "round robin" policy

case 2: message has key and value

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

Read Offsets

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



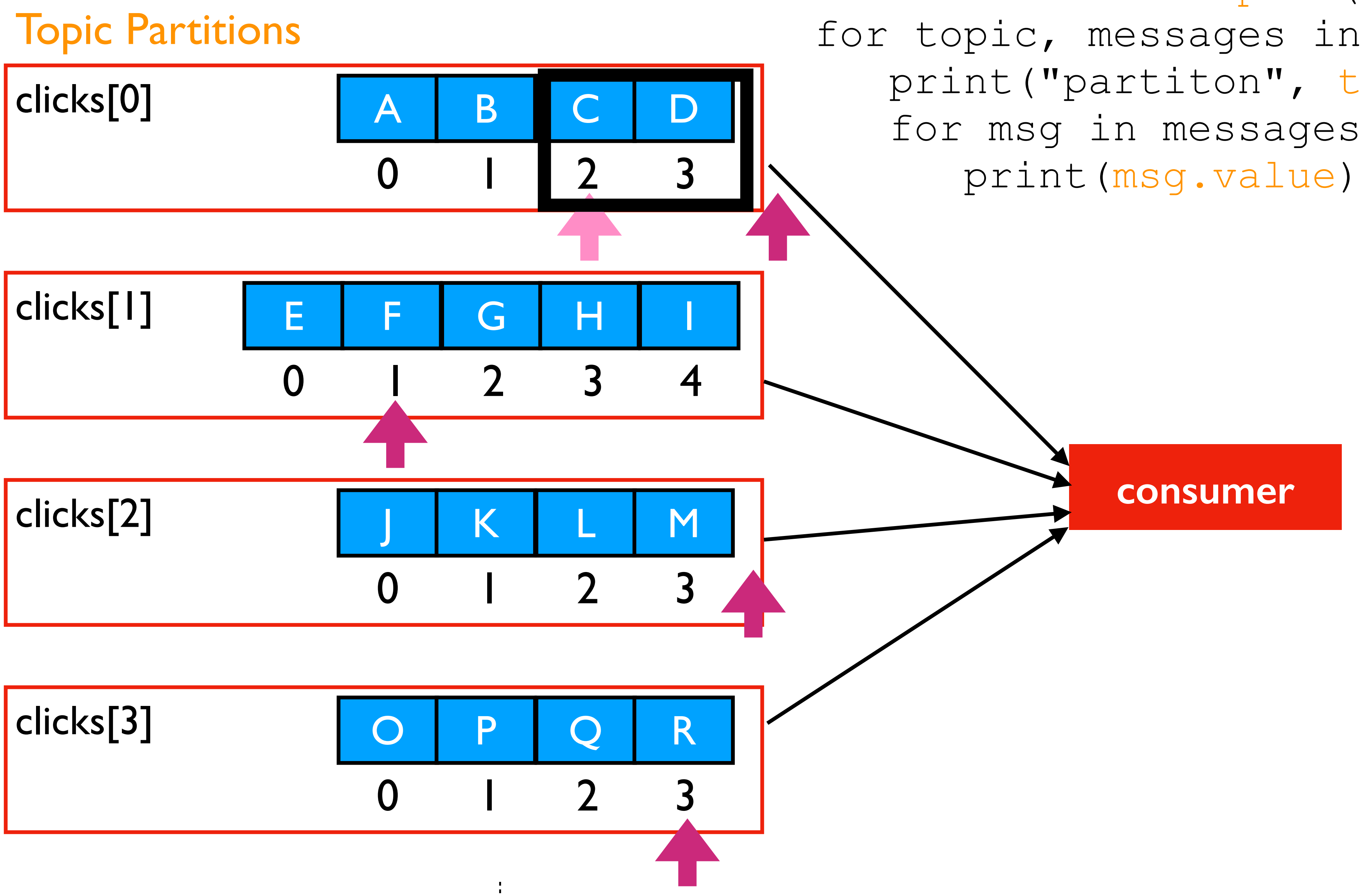
	offset
clicks[0]	2
clicks[1]	1
clicks[2]	4
clicks[3]	3

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'

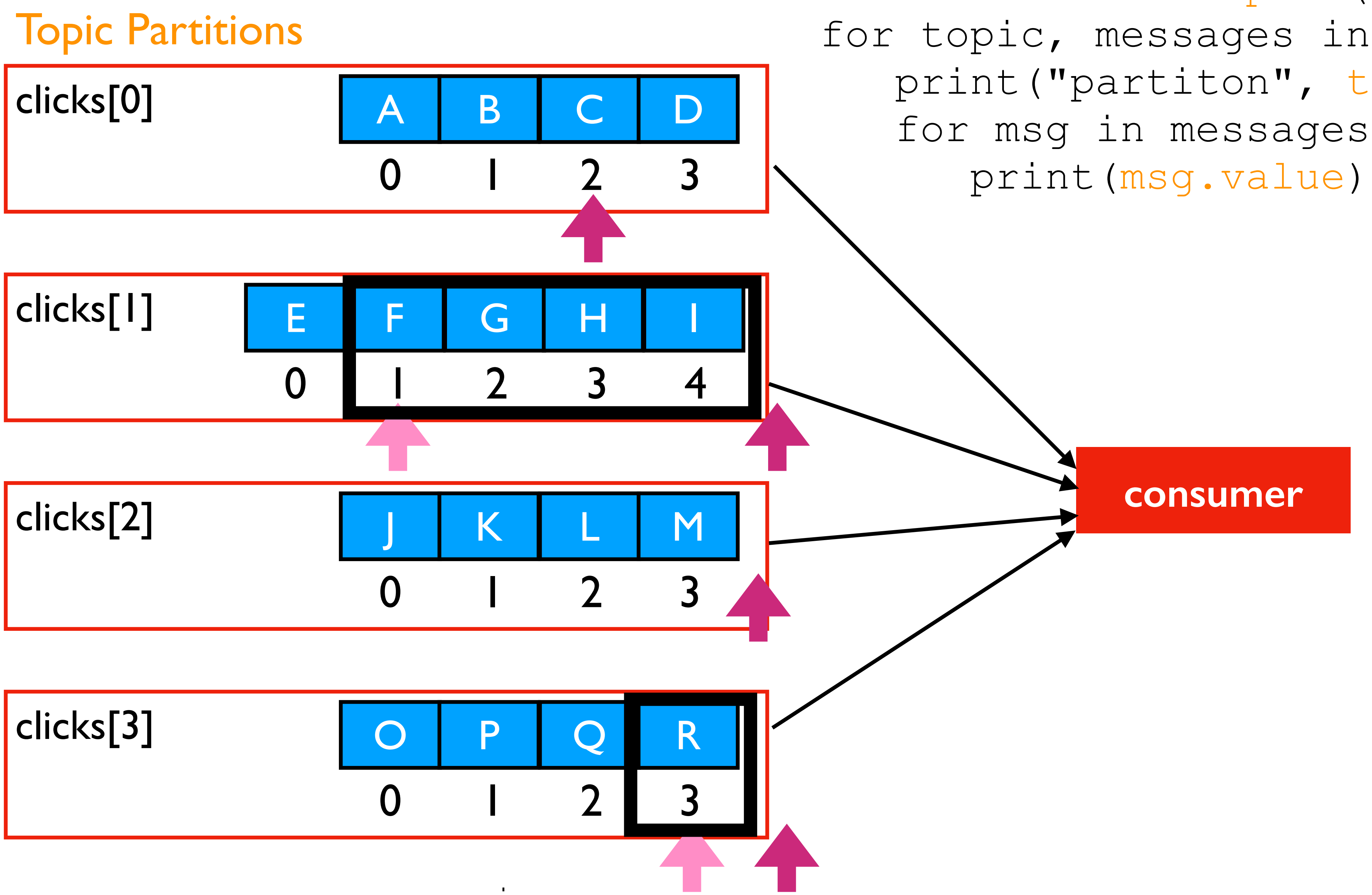
	offset
clicks[0]	2
clicks[1]	1
clicks[2]	4
clicks[3]	3

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 2

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



output:

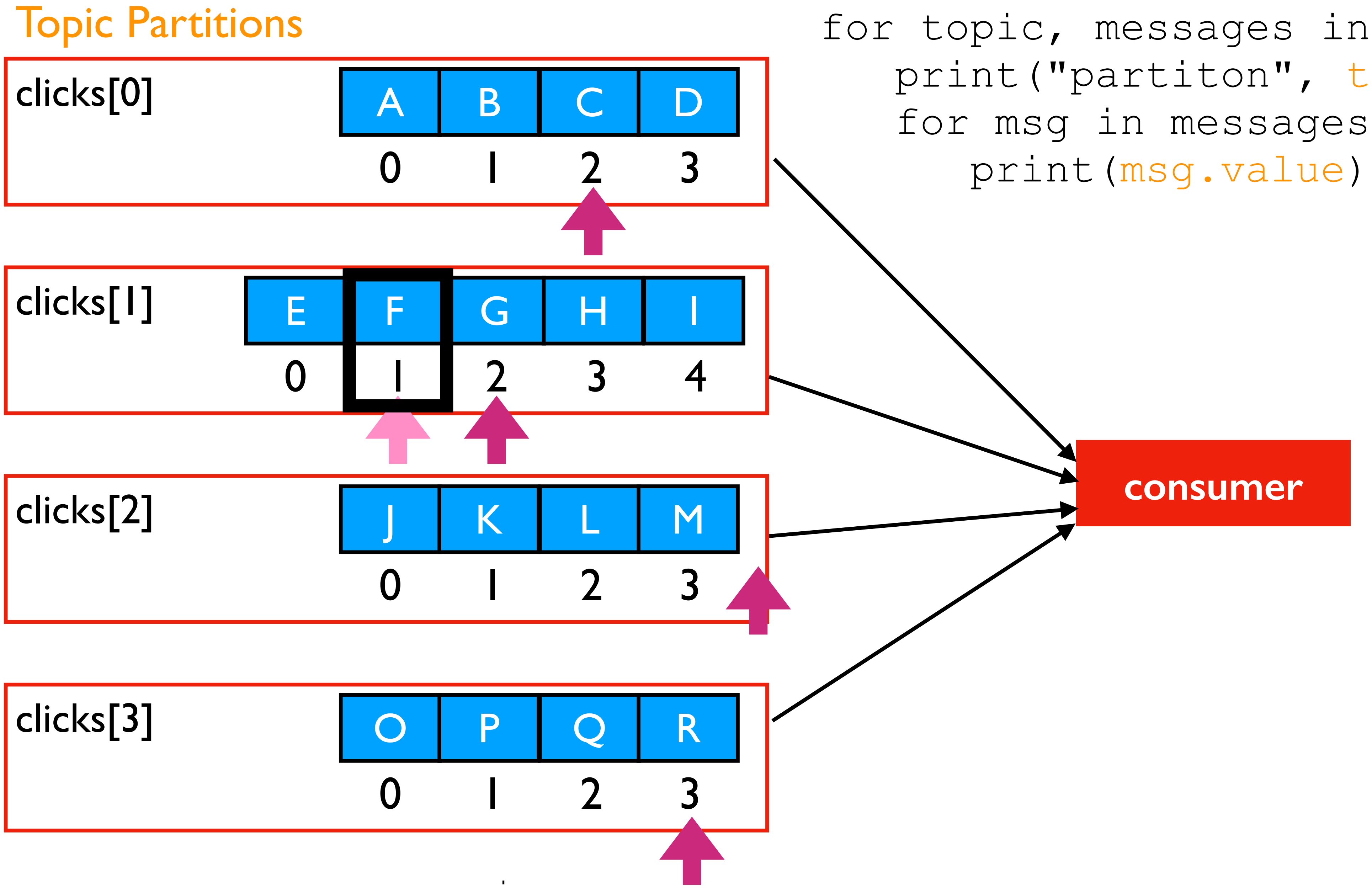
```
partition 1
b'F'
b'G'
b'H'
b'I'
partition 3
b'R'
```

	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 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]	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

Ordering Kafka Messages

Kafka Messages are partially ordered (ordering is within a partition, not between 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

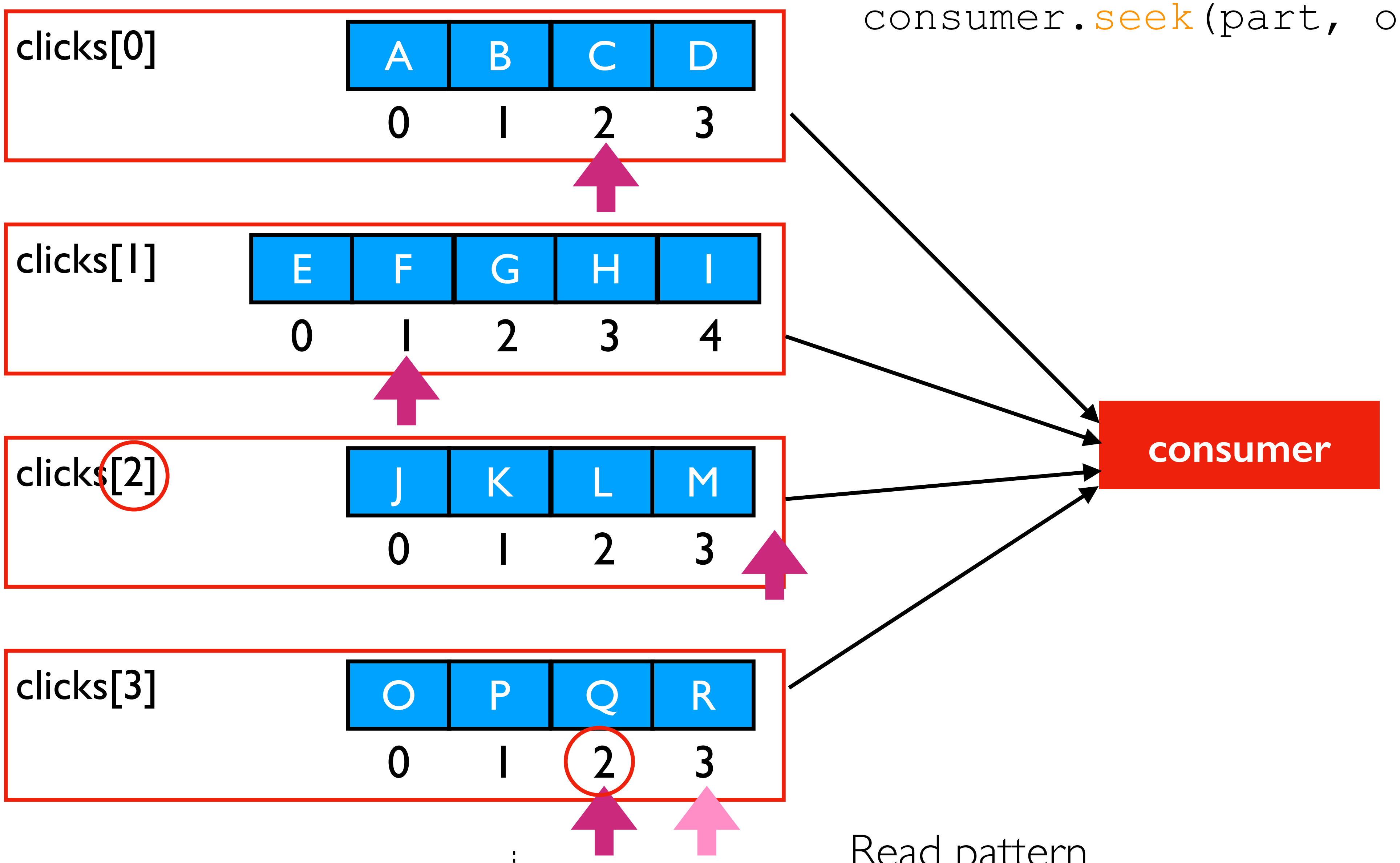
Choose your key carefully! Try to create enough partitions initially and never change it.

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

Seek to an Offset

```
part = TopicPartition("clicks", 3)
offset = 2
consumer.seek(part, offset)
```

Topic Partitions



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

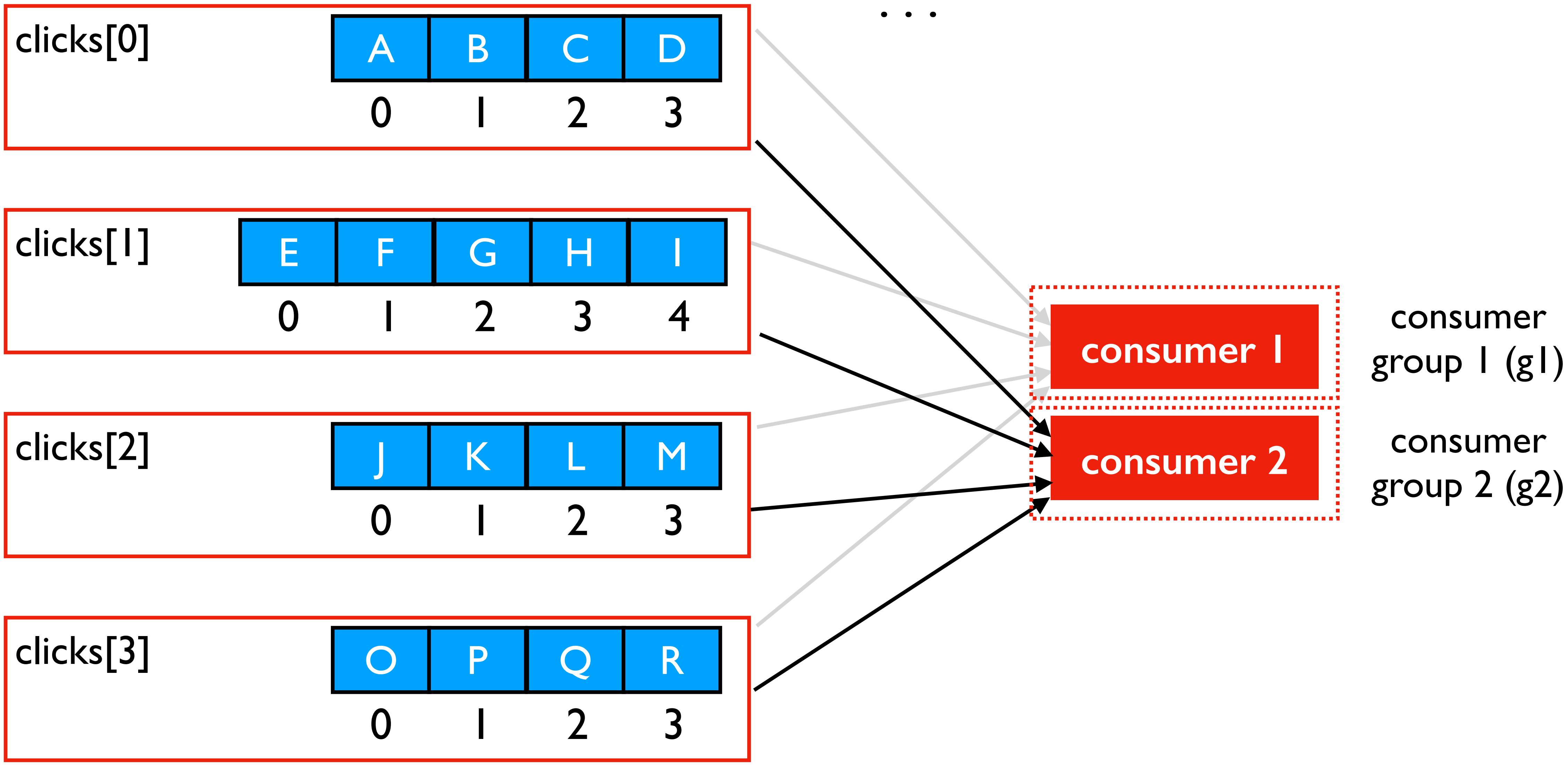
Read pattern

- 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)
...
```

Topic Partitions



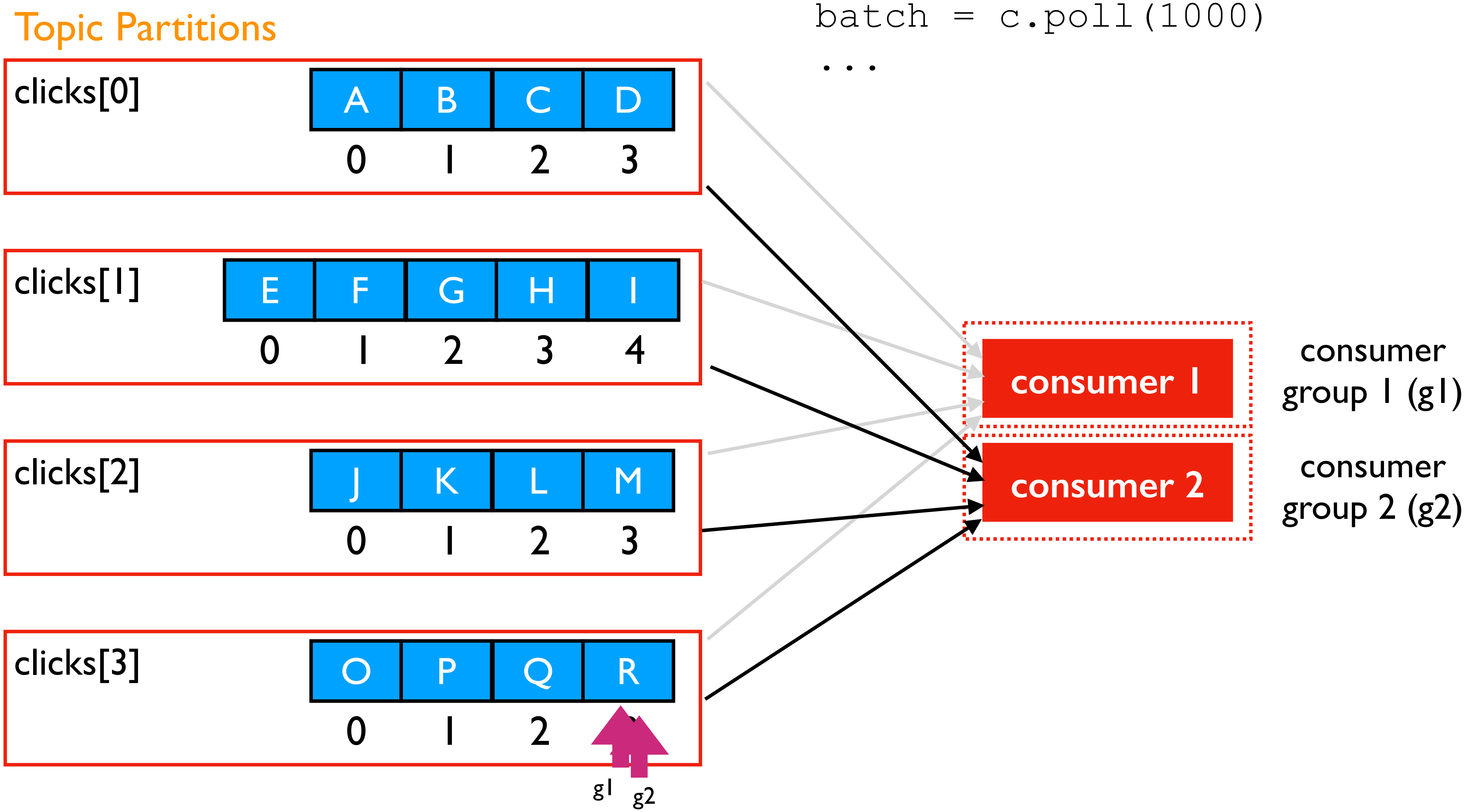
	g1 offsets	g2 offsets
clicks[0]	2	3
clicks[1]	1	2
clicks[2]	4	4
clicks[3]	3	3

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",
                  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

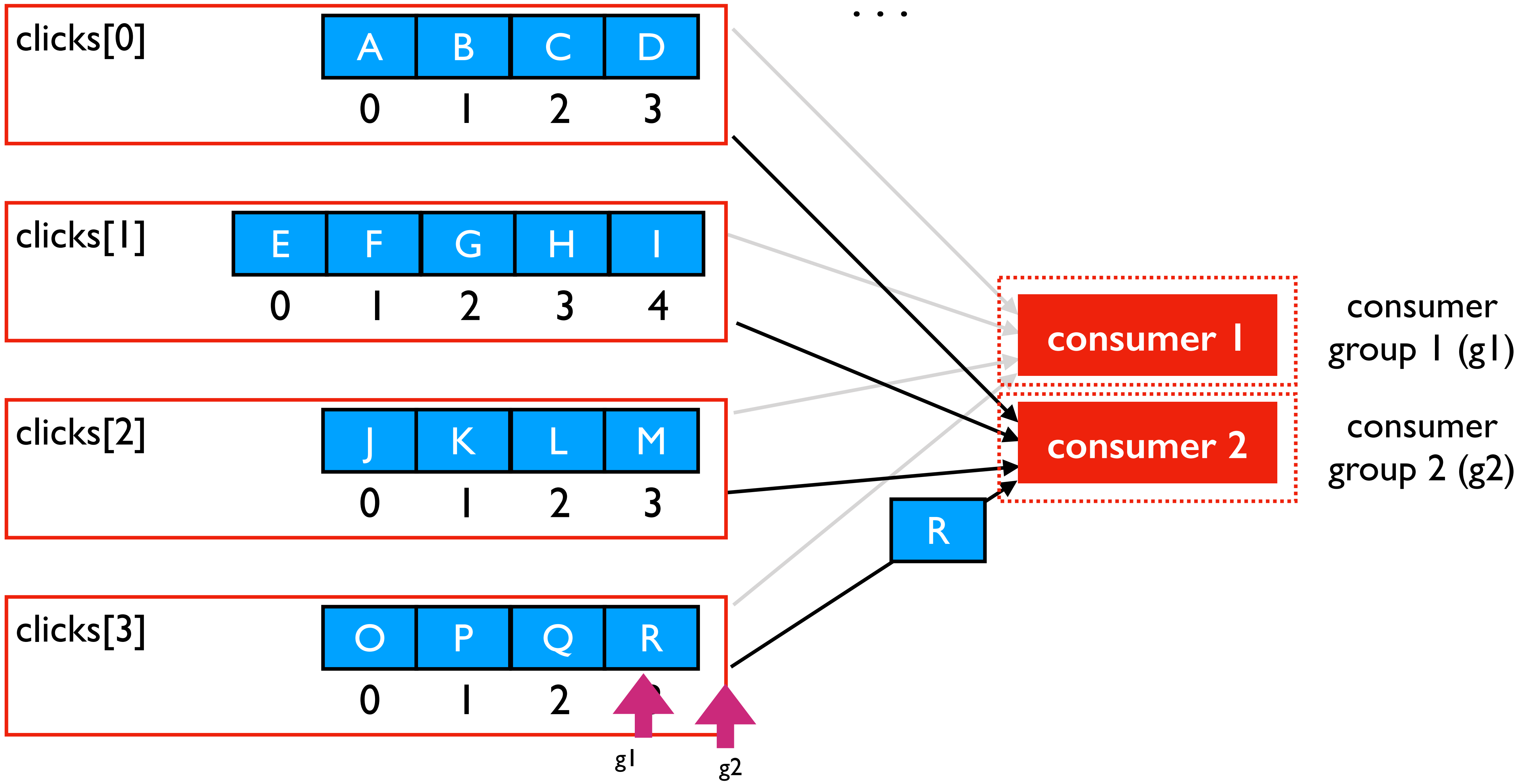
Groups

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

Topic Partitions



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

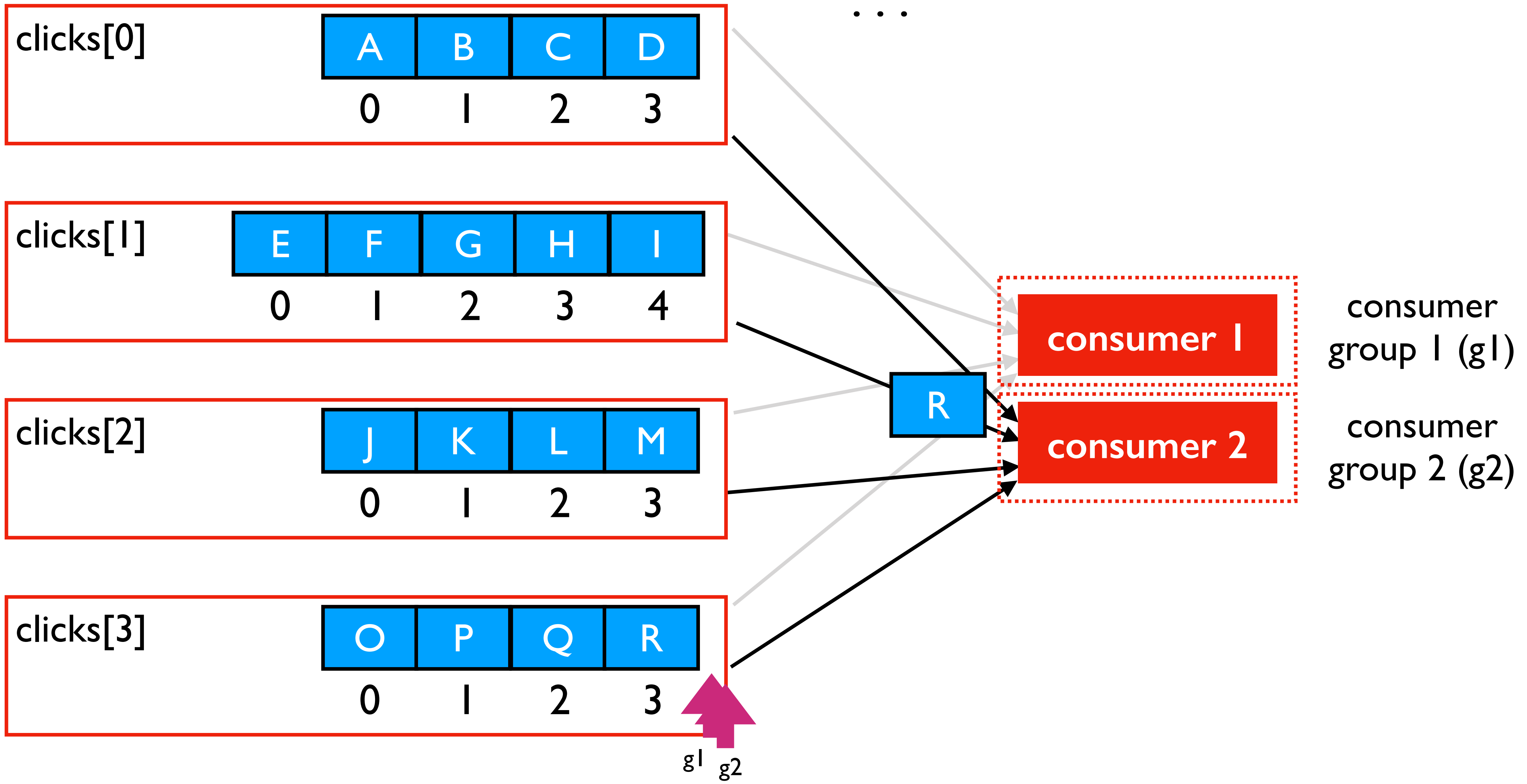
Groups

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

Consumer Groups

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

Topic Partitions



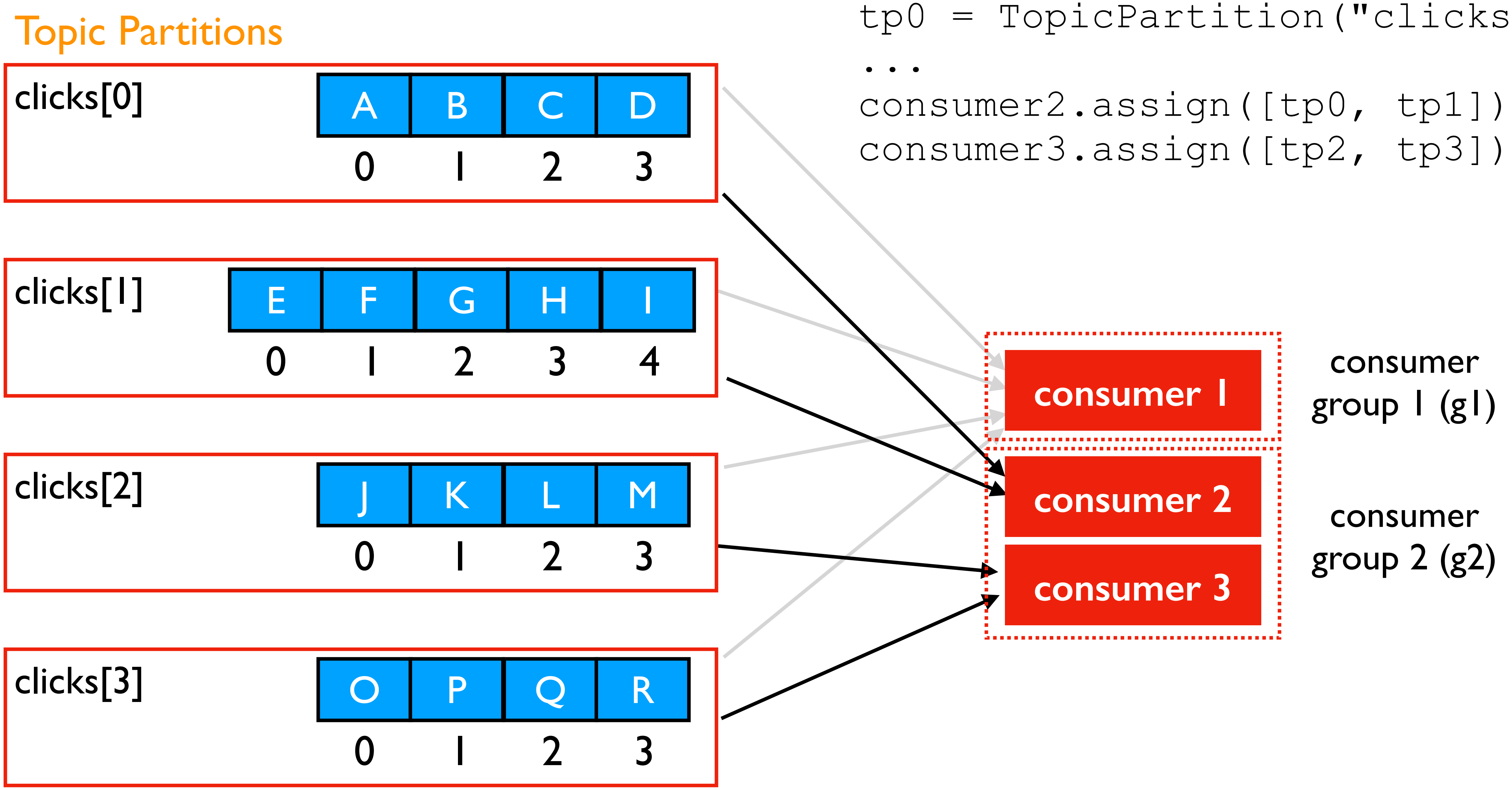
	g1 offsets	g2 offsets
clicks[0]	2	3
clicks[1]	1	2
clicks[2]	4	4
clicks[3]	4	4

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])
```



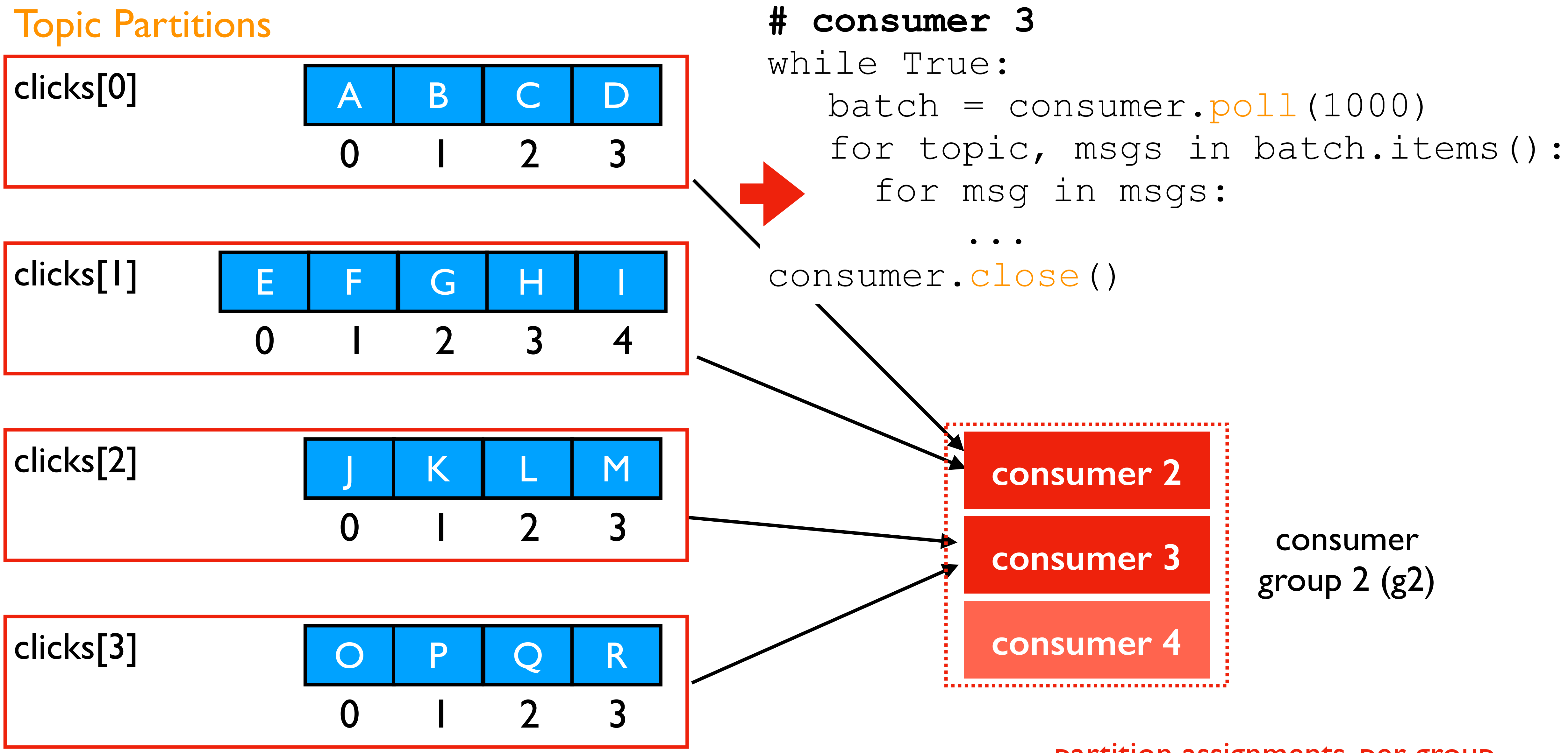
partition offsets, per group

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

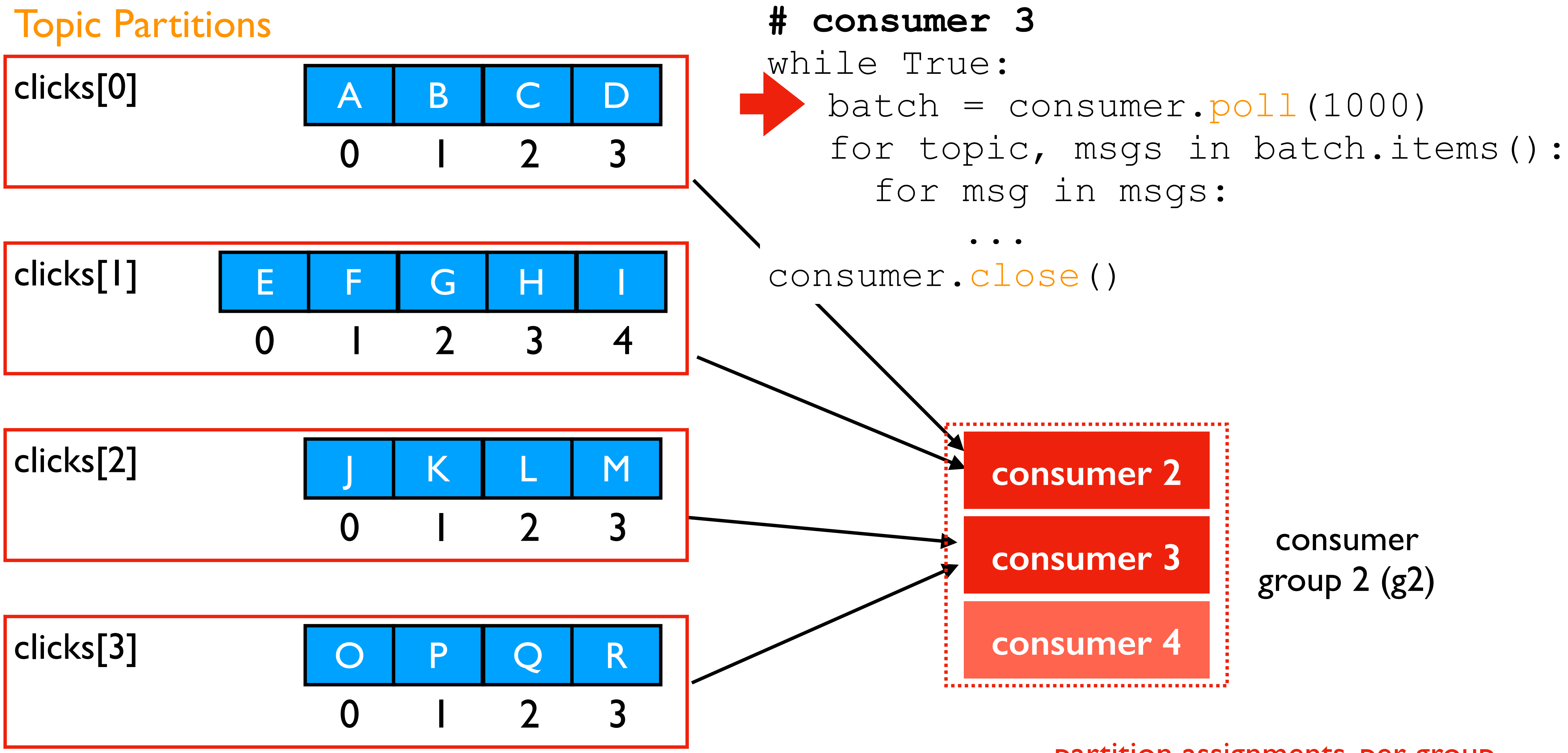
partition assignments, per group

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

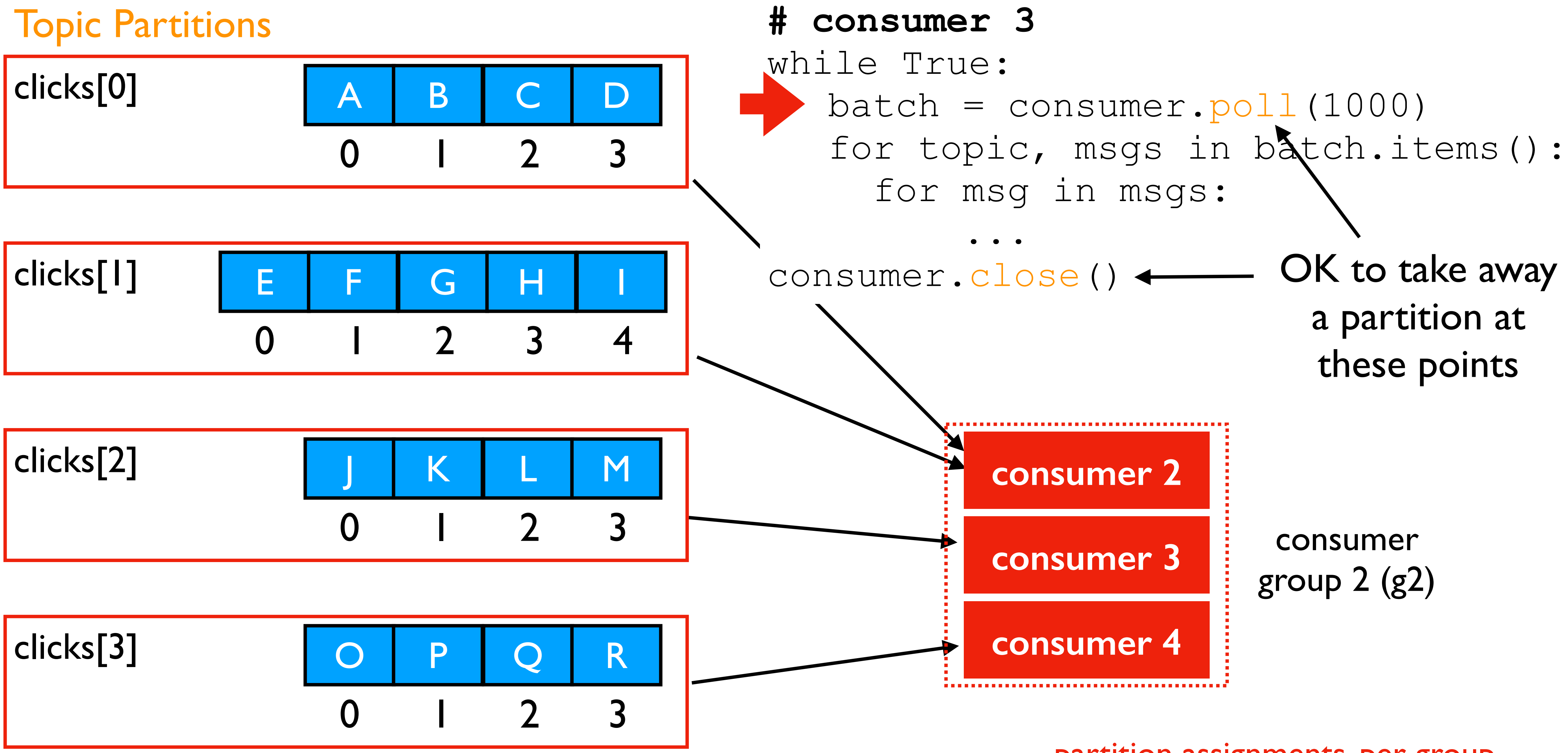
partition assignments, per group

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

OK to take away a partition at these points

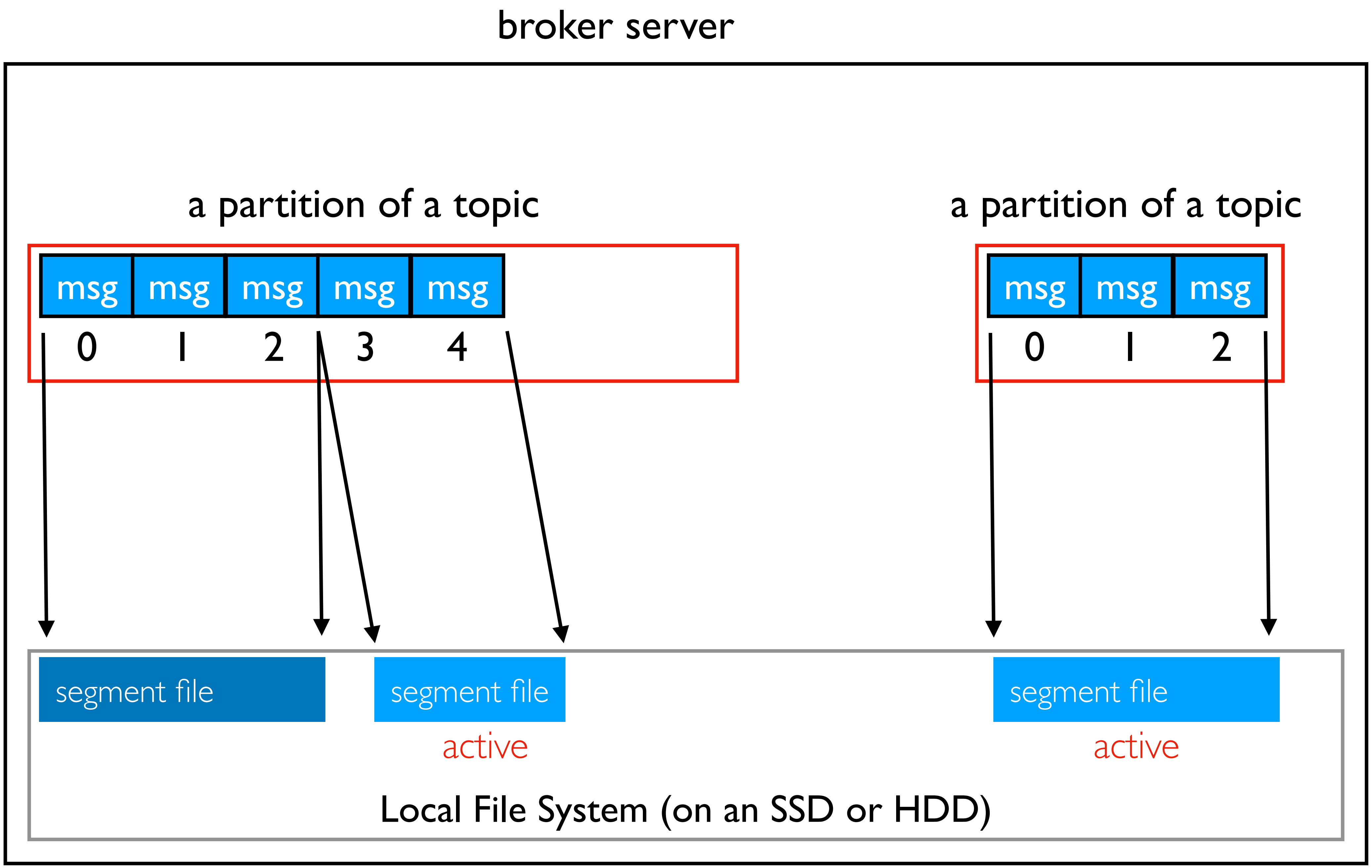
partition assignments, per group

	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 4

Assignment and re-assignment

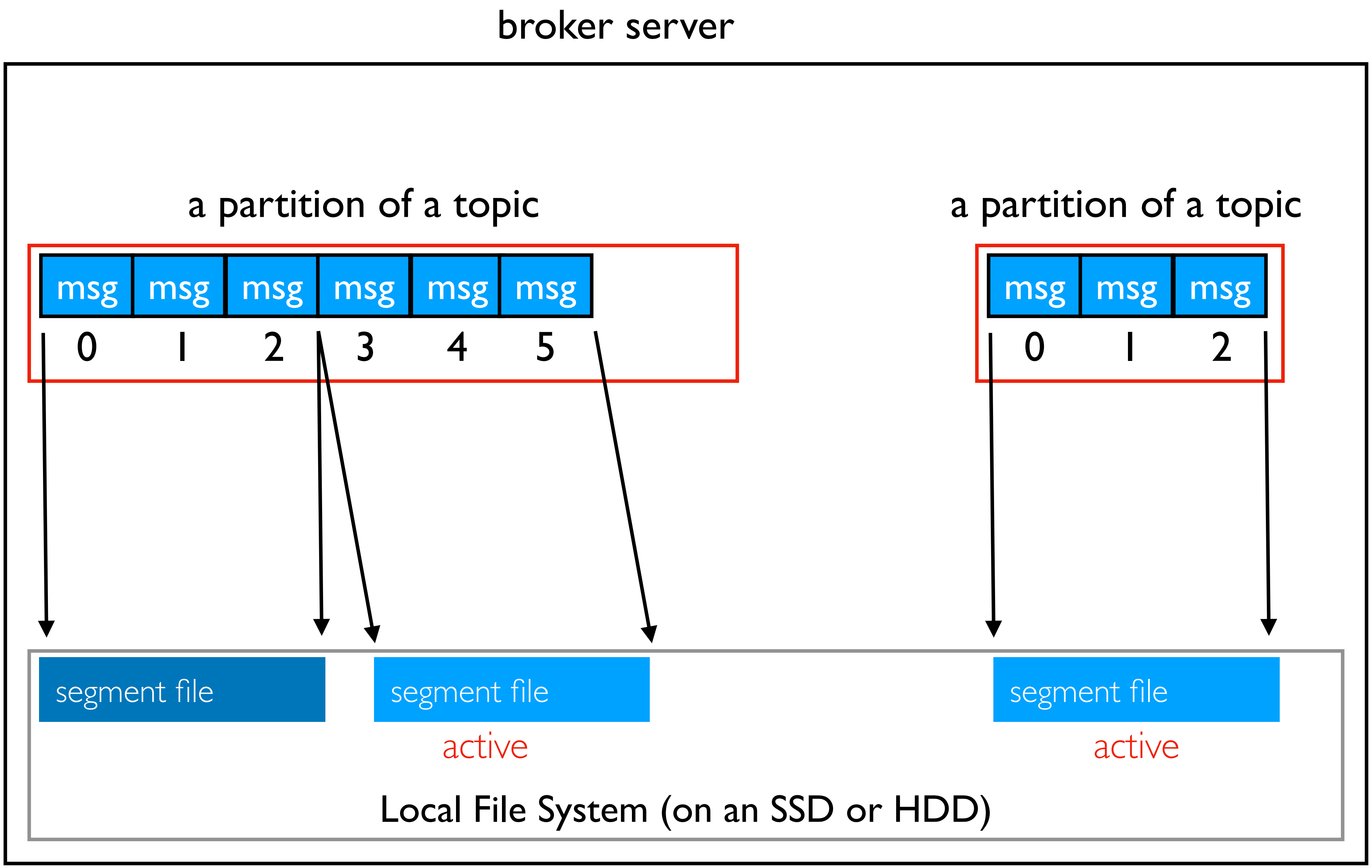
- by default, consumers are automatically assigned partitions when they start polling
- **challenge:** Kafka shouldn't re-assign a partition in the middle of a batch (might double process messages)

Segment Files: Log Rollover and Deletion



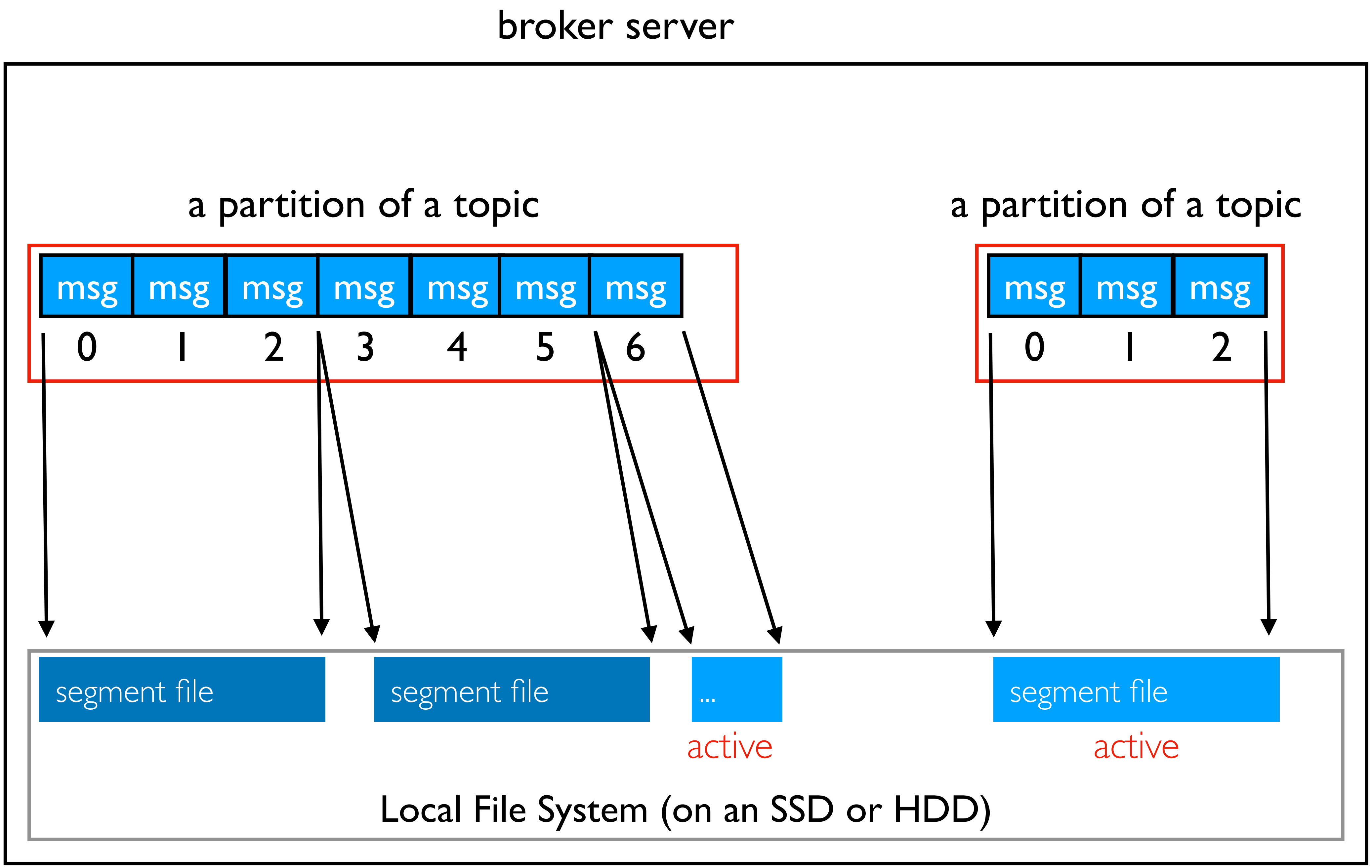
- partitions are divided into consecutive regions and saved in segment files
- all new data is sequentially written to the end of an active segment

Segment Files: Log Rollover and Deletion



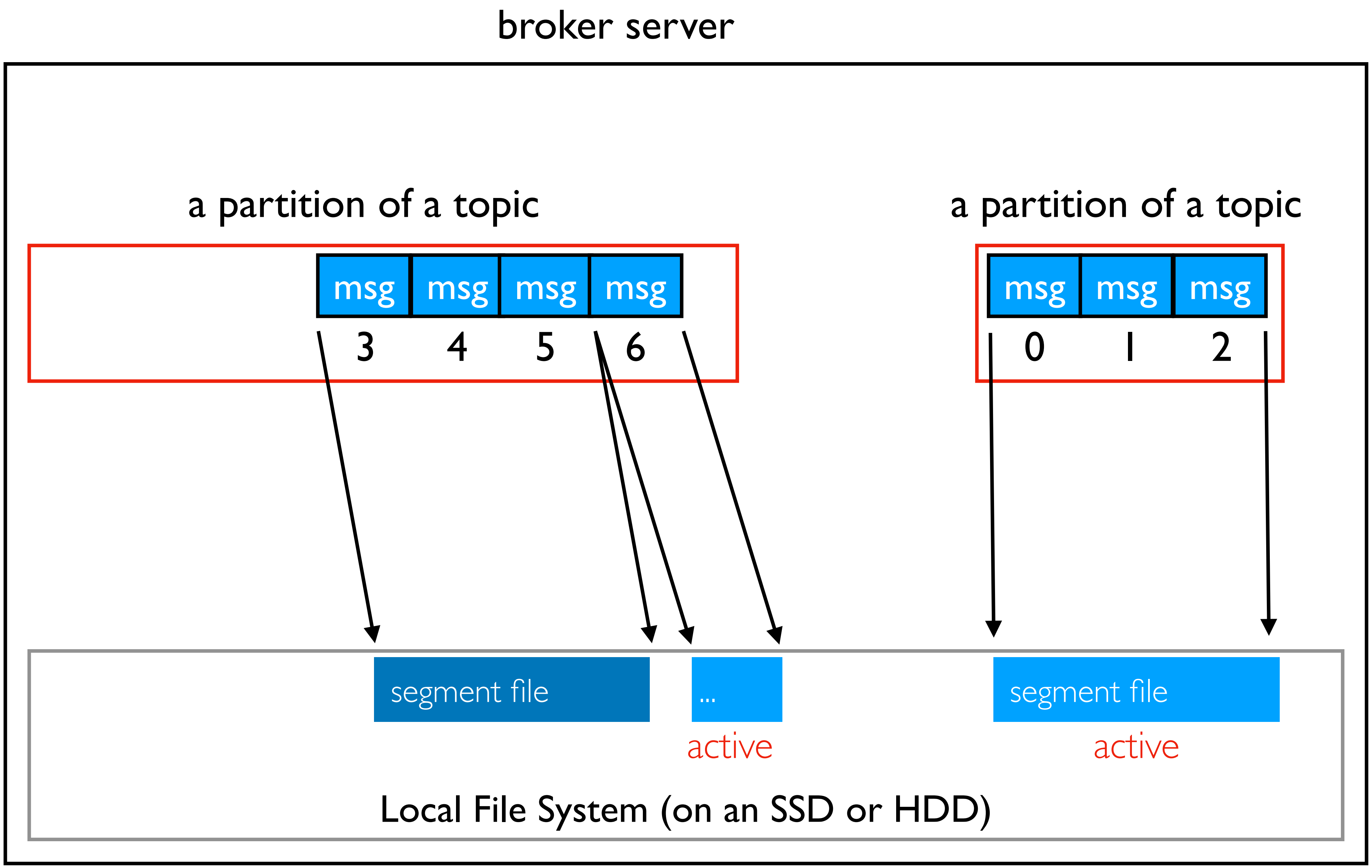
- partitions are divided into consecutive regions and saved in segment files
- all new data is sequentially written to the end of an active segment

Segment Files: Log Rollover and Deletion



- 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

Outline: Kafka Streaming

Sending/Receiving Messages

ETL (Extract Transform Load)

Kafka Design

Demos