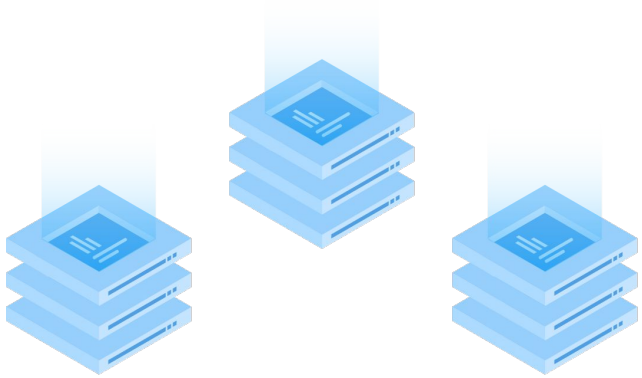
TiKV Internal

How to build a distributed transactional KV engine

PingCAP TiDB



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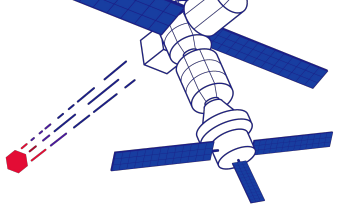

1. TiKV aerial view
2. Service layer built with gRPC
3. HA component built with Raft
4. Transaction component built with Percolator

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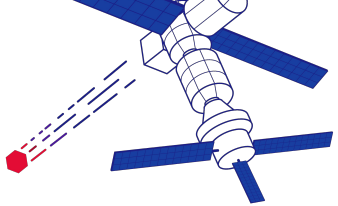

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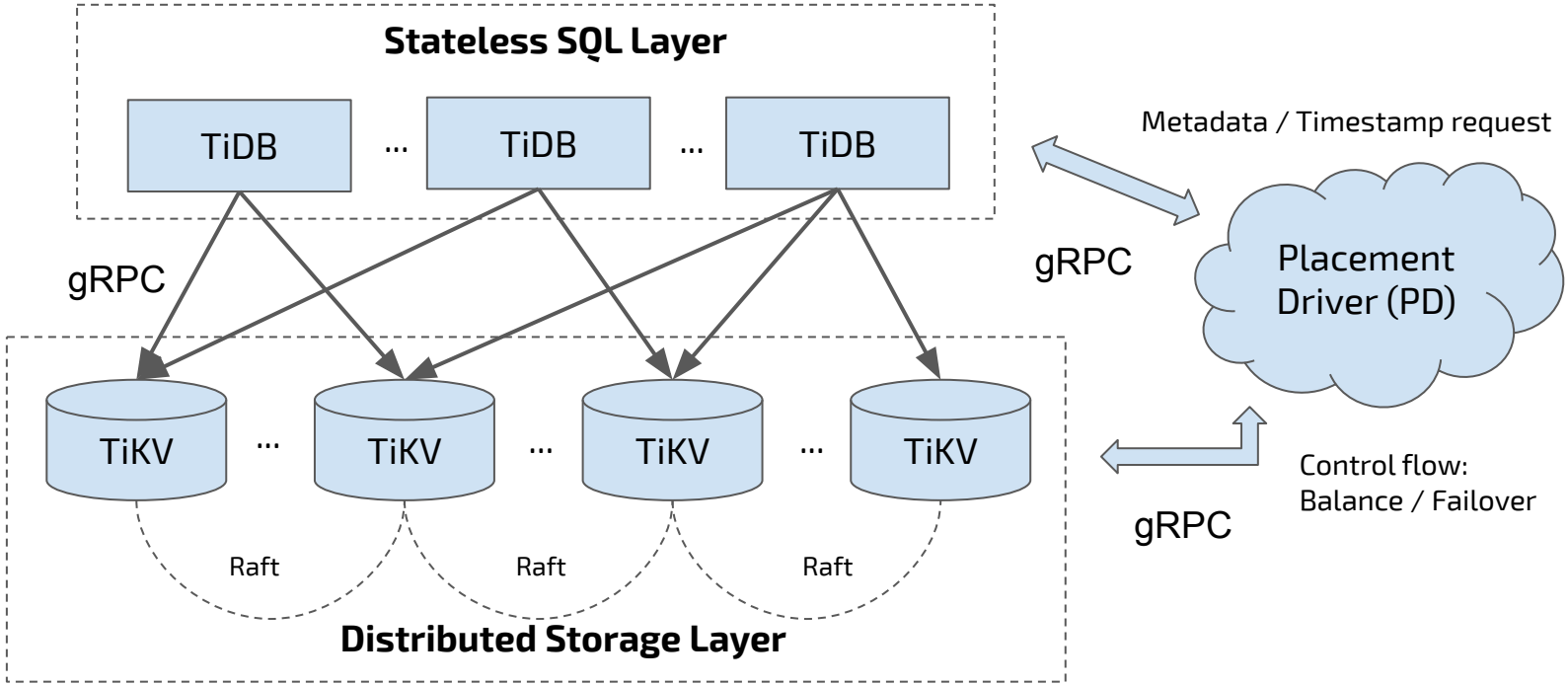
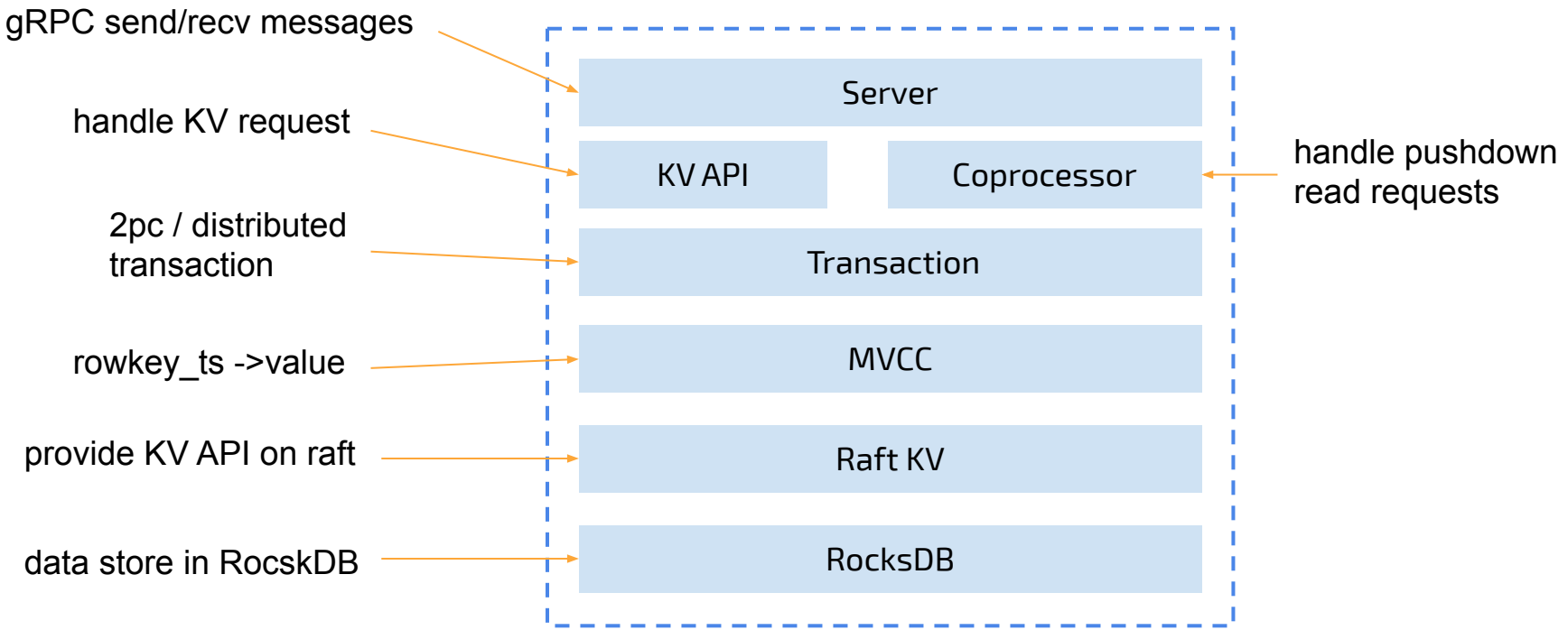
Concepts and Why

1. Why “distributed”
    a. No single point
    b. Easy to scale-out
    c. High availability
2. Why “transactional”
    a. Soul of databases

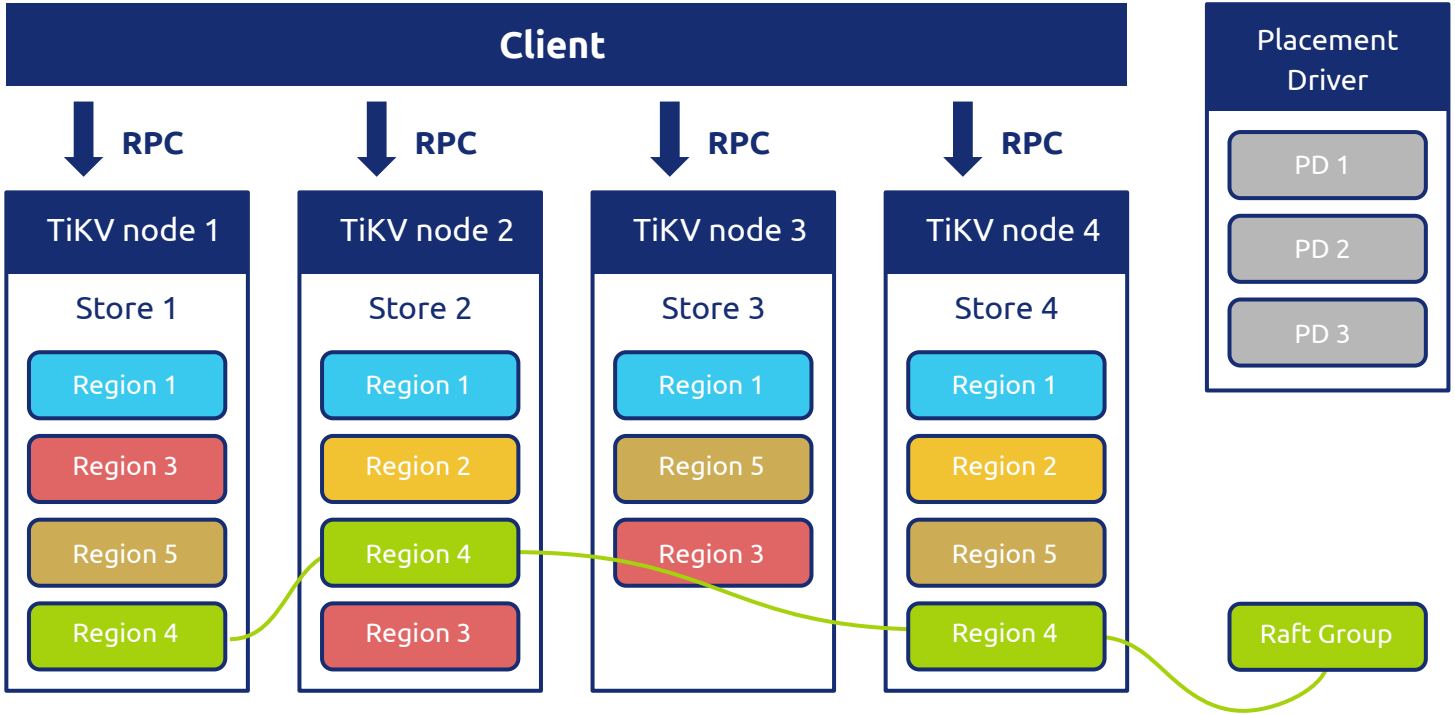
TiKV in TiDB Cluster



TiKV Layer Structure



Data Orgnization in TiKV



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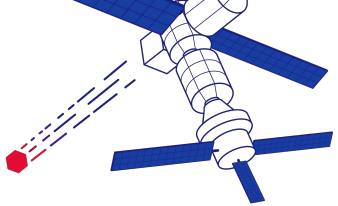

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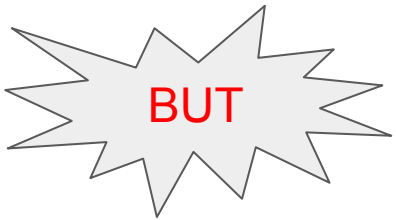
Why give up raw TCP

1. Best performance
2. Totally control about protocol
3. Free to choose network I/O model



Not friendly for clients

Why choose gRPC

1. Full features
    a. Unary, client streaming, server streaming and duplex streaming
2. Based on HTTP/2
    a. Easy to debug
    b. Built-in SSL support
3. Performance
    a. gRPC core has a nice network model (or I/O engine)
    b. gRPC coer has a nice API

Why grpc-rs instead of others

Why not callbacks? The gRPC API is much better than raw epoll.

```
while (1) {
    grpc_event ev = grpc_completion_queue_next(comp_queue);
    if (e.type == GRPC_OP_COMPLETE) {
        struct call_context *cc = e.tag;
        char *method = grpc_slice_to_c_string(cc->details.method);
        if (strcmp(method, "/Debug/unary_example_1") == 0) {
            hanle_unary_example_1(cc);
        }
    }
}

void handle_unary_example_1(struct call_context *cc) {
    if (cc->status == 0) {
        // Handle new registered call.
    } else if (cc->status == 1) {
        // Handle request body, generate a response and then send.
    } else {
        // Sending the response success, clear.
    }
}
```

Why grpc-rs instead of others

grpc-rs is a Rust bind of gRPC based on futures.

```
impl tikvpb_grpc::Tikv for Service {
    fn coprocessor_stream(
        &mut self,
        ctx: RpcContext<'_>,
        req: Request,
        sink: ServerStreamingSink<Response>,
    ) {
        let stream = self
            .cop
            .parse_and_handle_stream_request(req, Some(ctx.peer()))
            .map(|resp| (resp, WriteFlags::default().buffer_hint(true)))
            .map_err(|e| GrpcError::RpcFailure(RpcStatus::unknown));
        ctx.spawn(sink.send_all(stream));
    }
}
```

Summary about service layer

1. gRPC encapsulates details about network I/O model
2. grpc-rs encapsulates asynchronous code into a synchronous style
3. Completion queue handles thouthands connections in just 4 threads
4. More
    a. Introduce DPDK
    b. Split codec out from service threads

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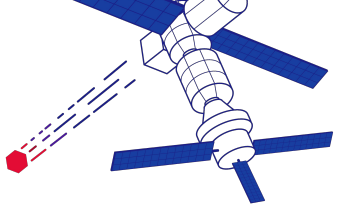

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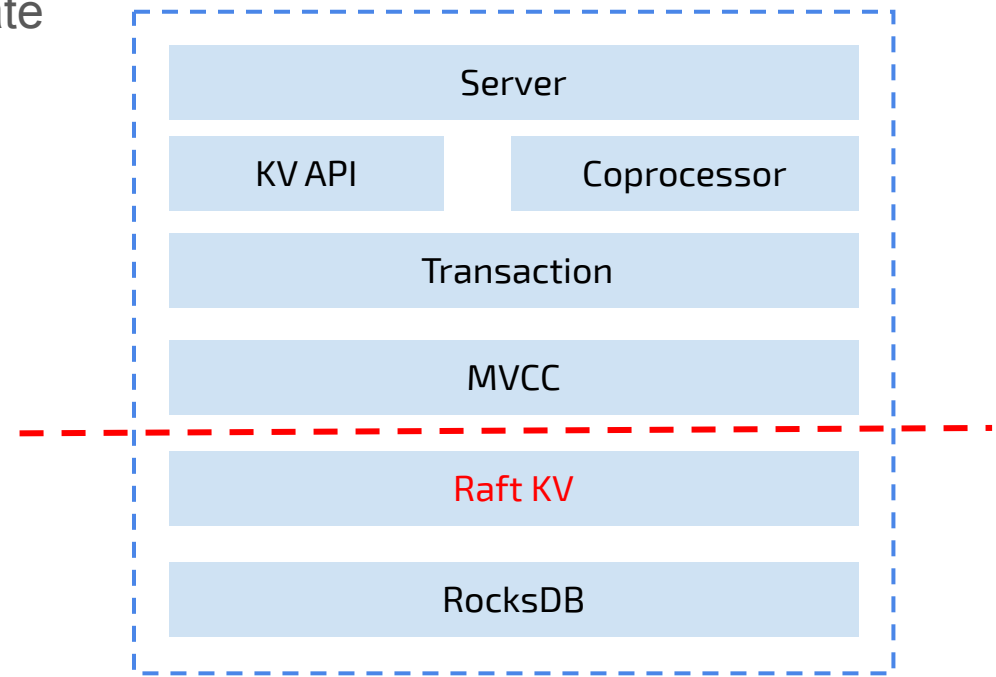
Where is the Raft component in TiKV

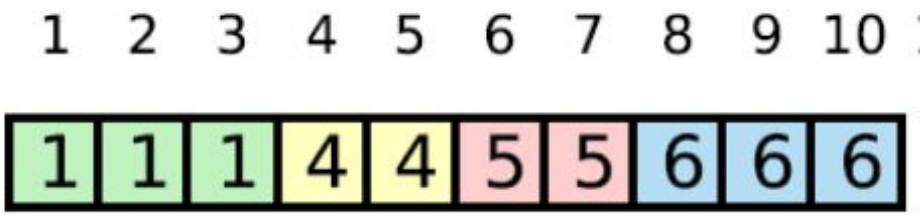
Raft KV module uses raft-rs crate

source path: src/raftstore/store/



Raft basic: Consistency

- Consistency
  - Data is orgnizated as a sorted vector, named as Raft log
  - Elements are attached with terms, and at most 1 leader in each term

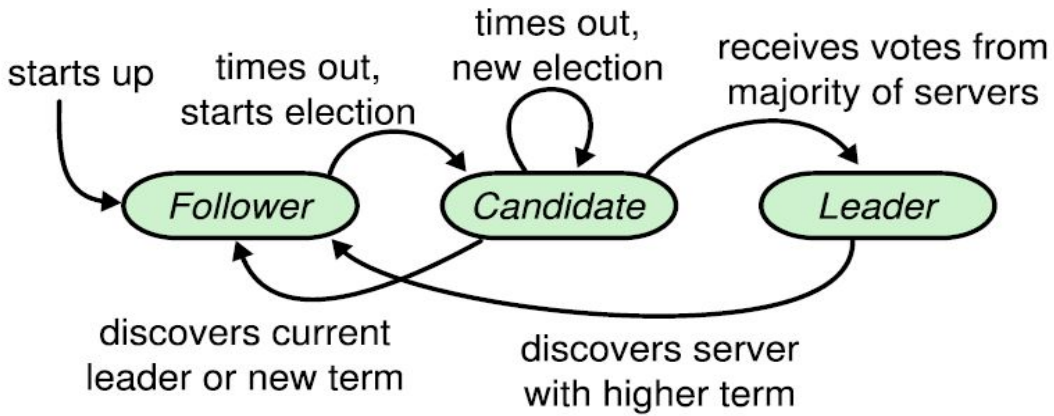


  - Commit an entry needs ACKs from majority replicas
  - New elected leader must contains all committed entries

Raft basic: Election

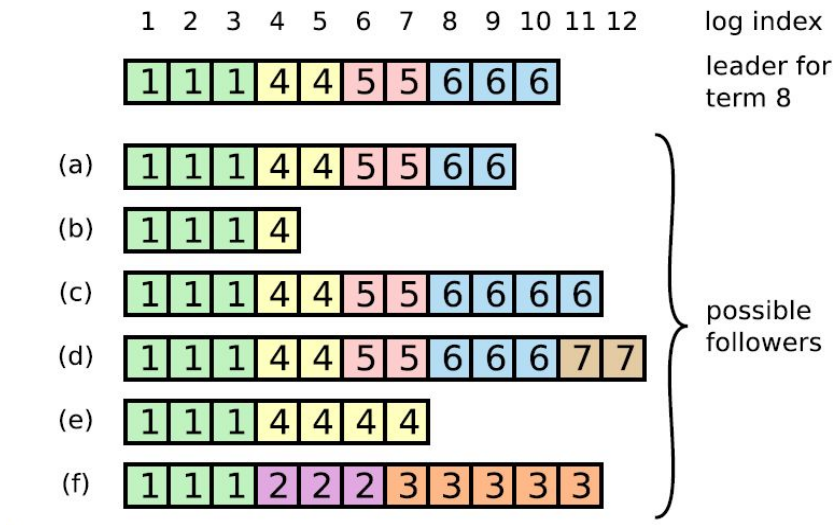
```
follower -> candidate || candidate -> candidate || leader -> candidate:
    self.term += 1

receive(vote_msg[term, index]):
    if self.has_voted:
        return rejected
    else if (term, index) is greater:
        return vote
    else:
        return reject
```



Raft basic: Log Replication

1. Followers can have more logs than leader
2. Entries with higher term will overwrite others
3. Commit an entry needs ACKs from a majority
4. Leader can only commit entries in its term



Multi-Raft in TiKV:

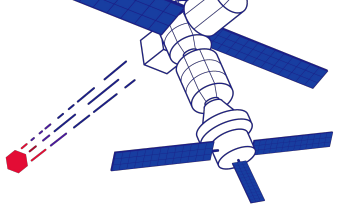
raft-rs example

```
let node = raft::RawNode::new();
loop {
    while let Some(raft_msg) = node.receiver.try_recv() {
        // Handle all received raft messages.
        node.step(raft_msg);
    }
    if time_to_tick { // Tick the raft node.
        node.tick();
        time_to_tick = now();
    }
    let ready = node.ready();
    if ready.has_snapshot() { // Apply snapshot.
    } else if !ready.entries.is_empty() { // Persist new appended raft logs.
    }
    if !ready.committed_entries.is_empty() {
        // Send commmitted entries to apply threads or apply them here.
    }
    send_raft_messages(&ready.messages); // Send out raft messages.
    node.advance(ready); // Finish a ready.
}
```

Summary about Raft component

1. Basic Raft: concepts and algorithm
2. More to learn in TiKV
    a. region split and merge
    b. thread model about `raftstore`
3. More to implement
    a. configuration change on received instead of applied
    b. flexible Raft
    c. follower replication

Agenda



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Transaction Model

- Inspired by Google Percolator
- 3 column families
  - **cf:lock**: An uncommitted transaction is writing this cell; contains the location/pointer of primary lock
  - **cf: write**: it stores the commit timestamp of the data
  - **cf: data**: Stores the data itself

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Transaction Model

Bob wants to transfer 7$ to Joe

Key	Bal: Data	Bal: Lock	Bal: Write
Bob	6: 5: $10	6: 5:	6: data @ 5 5:
Joe	6: 5: $2	6: 5:	6: data @ 5 5:

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Transaction Model (prewrite)

Key	Bal: Data	Bal: Lock	Bal: Write
Bob	7: $3 6: 5: $10	7: I am Primary 6: 5:	7: 6: data @ 5 5:
Joe	6: 5: $2	6: 5:	6: data @ 5 5:

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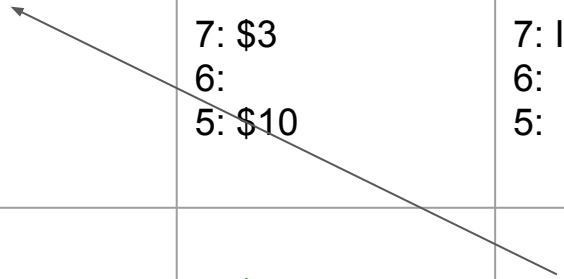
Transaction Model (prewrite)

Key	Bal: Data	Bal: Lock	Bal: Write
Bob	7: $3 6: 5: $10	7: I am Primary 6: 5:	7: 6: data @ 5 5:
Joe	7: $9 6: 5: $2	7:Primary@Bob.bal 6: 5:	7: 6: data @ 5 5:



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Transaction Model (commit)

Key	Bal: Data	Bal: Lock	Bal: Write
Bob	8: 7: $3 6: 5: $10	8: 7: ~~I am Primary~~ 6: 5:	8: data @ 7 7: 6: data @ 5 5:
Joe	8: 7: $9 6: 5: $2	8: 7:Primary@Bob 6: 5:	8: 7: 6: data @ 5 5:

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Transaction Model (read)

Key	Bal: Data	Bal: Lock	Bal: Write
Bob	8: 7: $3 6: 5: $10	8: 7: ~~I am Primary~~ f ② 6: 5:	8: data @ 7 ③ 7: 6: data @ 5 5:
Joe	8: 7: $9 6: 5: $2	8: 7:Primary@Bob ① 6: 5:	8: data @ 7 ④ 7: 6: data @ 5 5:

Summary about transaction component

1. Think more
    a. snapshot isolation & write skew
    b. pessimistic lock
    c. put short value in cf write
2. More to implement
    a. optimize to not fetch commit ts
    b. 1PC for single region/store transactions

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Thank You!

Any Questions ?

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