RPCs in Go

9/22/2022

Outline

RPC overview

Writing an RPC server in Go

MapReduce: fault tolerance and optimizations

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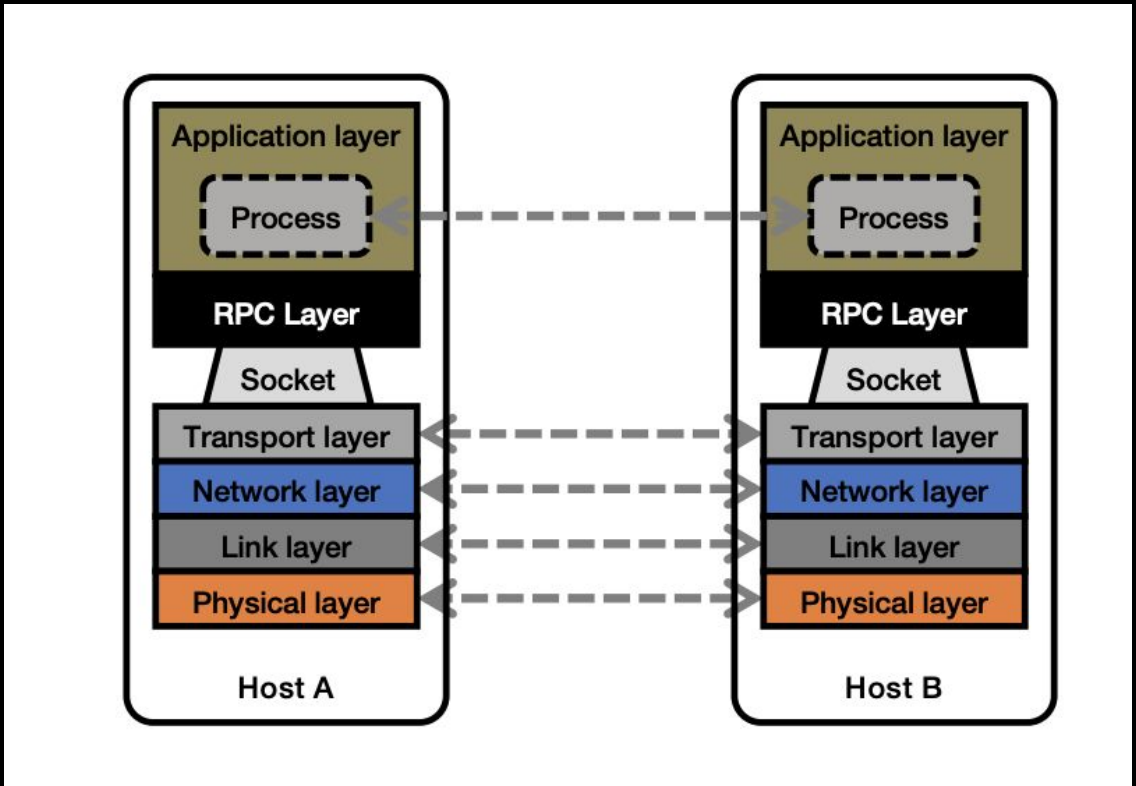
MapReduce: fault tolerance and optimizations

Remote Procedure Call



Remote Procedure Call

Calling a procedure on a remote process as if it were local

Request-response interface

- Request: arguments to remote procedure
- Response: return values of remote procedure

Examples: client-server, master-worker, peer-peer

Example: Master-Worker

```
Master {
  func LaunchTasks() {
    for worker in workers {
      // want to call Worker.RunTask(...)
    }
  }
}
```

```
Worker {
  func RunTask(index) result {
    // ...
  }
}
```

Example: Master-Worker

```
Master {
  func LaunchTasks() {
    for worker in workers {
      index = worker.Index
      address = worker.Address
      request = MakeRequest(index)
      response = sendRPC("RunTask", address, request)
      result = response.Result
      handleResult(result)
    }
  }
}
```

```
Worker {
  func RunTask(index) result {
    // ...
  }
}
```

Asynchronous RPC

Await RPC response in a separate thread

Multiple ways to implement this:

- Pass a *callback* to RPC that will be invoked later

Asynchronous RPC

Await RPC response in a separate goroutine

Multiple ways to implement this:

Pass a *callback* to RPC that will be invoked later

```
func handleResponse { ... }
sendRPC("RunTask", address, request, handleResponse)
```

Asynchronous RPC

Await RPC response in a separate thread

Multiple ways to implement this:

- Pass a *callback* to RPC that will be invoked later
- Use *channels* to communicate RPC reply back to main thread

Asynchronous RPC

Await RPC response in a separate thread

Multiple ways to implement this:

- Pass a *callback* to RPC that will be invoked later
- Use *channels* to communicate RPC reply back to main thread

```
go func(address, request string) {
  channel <- sendRPC("RunTask", address, request)
} (some_address, some_request)
handleResponse(<-channel)
```

What’s an example application where we would want asynchronous RPCs?

Outline

MapReduce: fault tolerance and optimizations

RPC overview

Writing an RPC server in Go

Go RPCs

Implementation in built-in library `net/rpc` requires 3 steps:

1. Write stub receiver methods of the form:

```
func (t *T) MethodName(args T1, reply *T2) error
```

2. Register receiver methods

3. Create a listener (i.e., server) that accepts requests

Go example: Word count client

```
func makeRequest(input string, serverAddr string) (map[string]int, error) {
    client, err := rpc.Dial("tcp", serverAddr)
    checkError(err)
    args := WordCountRequest{input}
    reply := WordCountReply{make(map[string]int)}
    err = client.Call("WordCountServer.Compute", args, &reply)
    if err != nil {
        return nil, err
    }
    return reply.Counts, nil
}
```

Go example: Word count client

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func makeRequest(input string, serverAddr string) (map[string]int, error) {
    client, err := rpc.Dial("tcp", serverAddr)
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    err = client.Call("WordCountServer.Compute", args, &reply)
    if err != nil {
        return nil, err
    }
    return reply.Counts, nil
}
```

Go example: Word count server

```
type WordCountServer struct {
    addr string
}

type WordCountRequest struct {
    Input string
}

type WordCountReply struct {
    Counts map[string]int
}
```

```
func (*WordCountServer) Compute(
        request WordCountRequest,
        reply *WordCountReply) error {
    counts := make(map[string]int)
    input := request.Input
    tokens := strings.Fields(input)
    for _, t := range tokens {
        counts[t] += 1
    }
    reply.Counts = counts
    return nil
}
```

Go example: Word count server

```
type WordCountServer struct {
    addr string
}

type WordCountRequest struct {
    Input string
}

type WordCountReply struct {
    Counts map[string]int
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```

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func (*WordCountServer) Compute(
        request WordCountRequest,
        reply *WordCountReply) error {
    counts := make(map[string]int)
    input := request.Input
    tokens := strings.Fields(input)
    for _, t := range tokens {
        counts[t] += 1
    }
    reply.Counts = counts
    return nil
}
```

Go example: Word count server

```
func (server *WordCountServer) Listen() {
    rpc.Register(server)
    listener, err := net.Listen("tcp", server.addr)
    checkError(err)
    go func() {
        rpc.Accept(listener)
    }()
}
```

Go example: Word count server

```
func (server *WordCountServer) Listen() {
    rpc.Register(server)
    listener, err := net.Listen("tcp", server.addr)
    checkError(err)
    go func() {
        rpc.Accept(listener)
    }()
}
```

Go example: Word count server

```
func (server *WordCountServer) Listen() {
    rpc.Register(server)
    listener, err := net.Listen("tcp", server.addr)
    checkError(err)
    go func() {
        rpc.Accept(listener)
    }()
}
```

Go example: Word count client-server

```
func main() {
    serverAddr := "localhost:8888"
    server := WordCountServer{serverAddr}
    server.Listen()
    input1 := "hello I am good hello bye bye bye bye good night hello"
    wordcount, err := makeRequest(input1, serverAddr)
    checkError(err)
    fmt.Printf("Result: %v\n", wordcount)
}
```

```
Result: map[hello:3 I:1 am:1 good:2 bye:4 night:1]
```

Is this synchronous or asynchronous?

```
func makeRequest(input string, serverAddr string) (map[string]int, error) {
    client, err := rpc.Dial("tcp", serverAddr)
    checkError(err)
    args := WordCountRequest{input}
    reply := WordCountReply{make(map[string]int)}
    err = client.Call("WordCountServer.Compute", args, &reply)
    if err != nil {
        return nil, err
    }
    return reply.Counts, nil
}
```

Making client asynchronous

```
func makeRequest(input string, serverAddr string) chan Result {
    client, err := rpc.Dial("tcp", serverAddr)
    checkError(err)
    args := WordCountRequest{input}
    reply := WordCountReply{make(map[string]int)}
    ch := make(chan Result)
    go func() {
        err := client.Call("WordCountServer.Compute", args, &reply)
        if err != nil {
            ch <- Result{nil, err} // something went wrong
        } else {
            ch <- Result{reply.Counts, nil} // success
        }
    }()
    return ch
}
```

Making client asynchronous

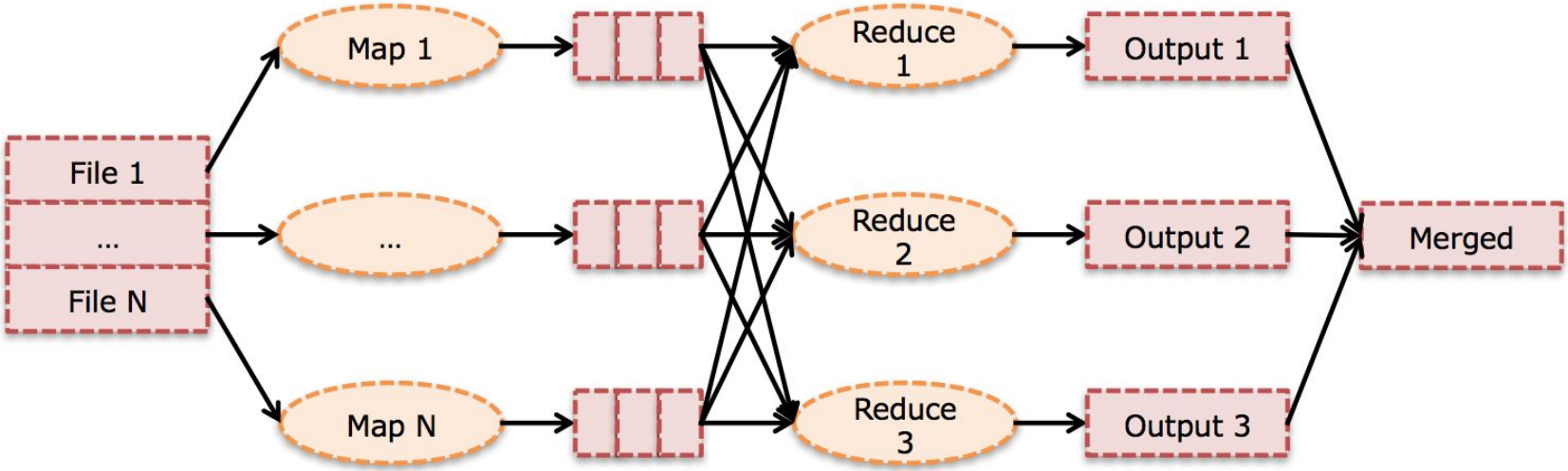
```
func makeRequest(input string, serverAddr string) *Call {
    client, err := rpc.Dial("tcp", serverAddr)
    checkError(err)
    args := WordCountRequest{input}
    reply := WordCountReply{make(map[string]int)}
    return client.Go("WordCountServer.Compute", args, &reply, nil)
}
```

```
call := makeRequest(...)
<-call.Done
checkError(call.Error)
handleReply(call.Reply)
```

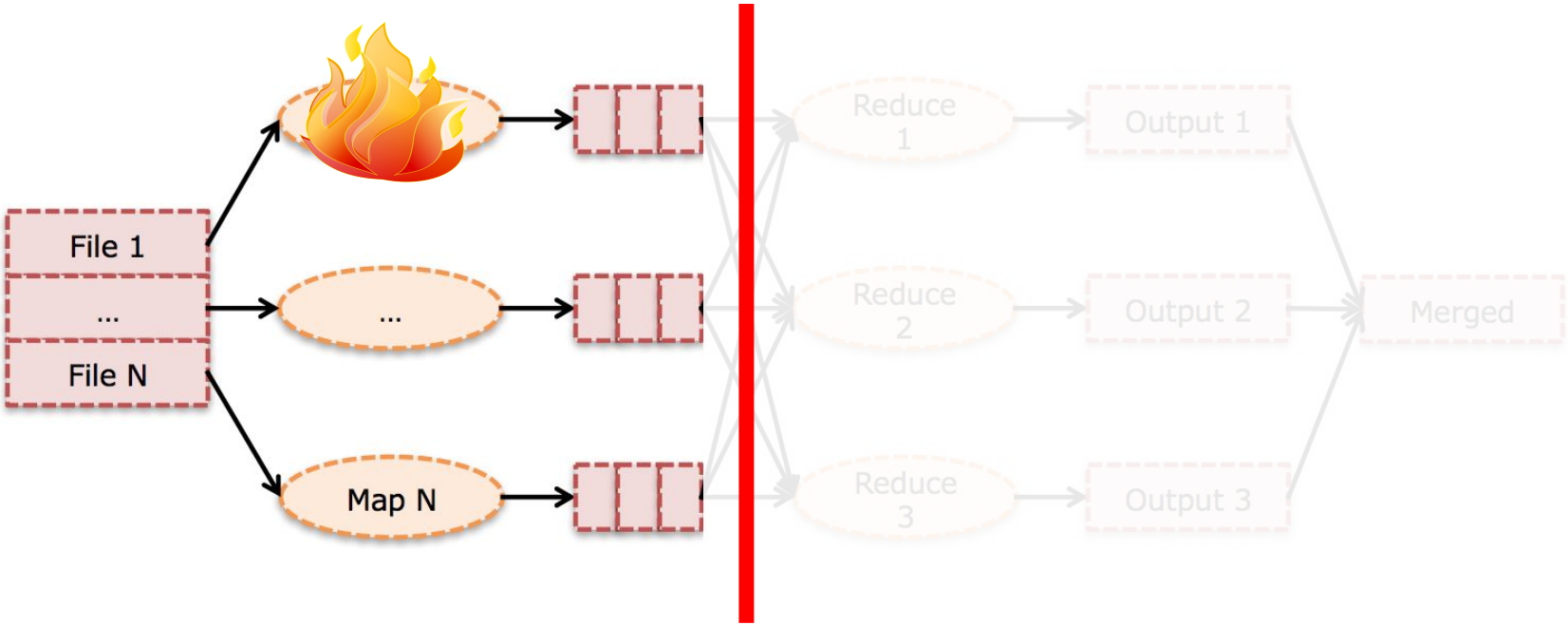
Exercise: Cristian’s algorithm

Implement a `CristianServer` that other machines sync their local time to

MapReduce: Fault Tolerance

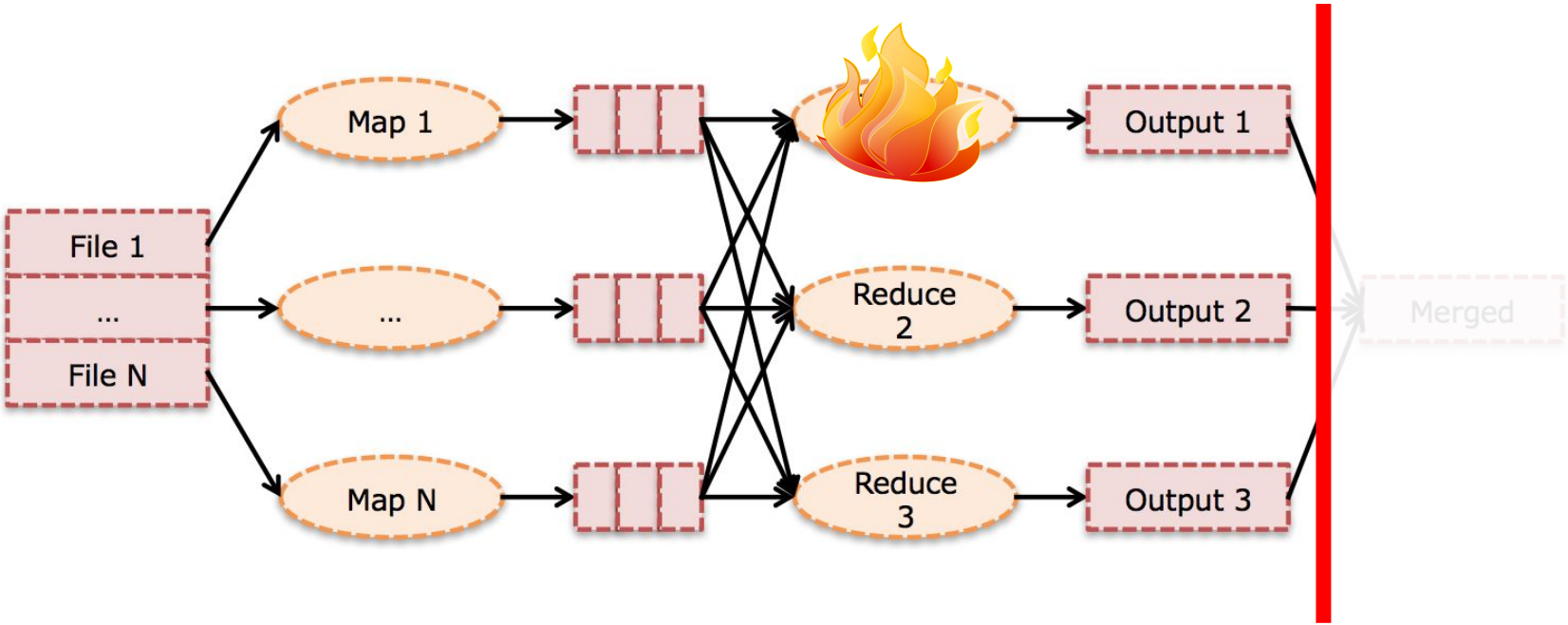


MapReduce: Fault Tolerance



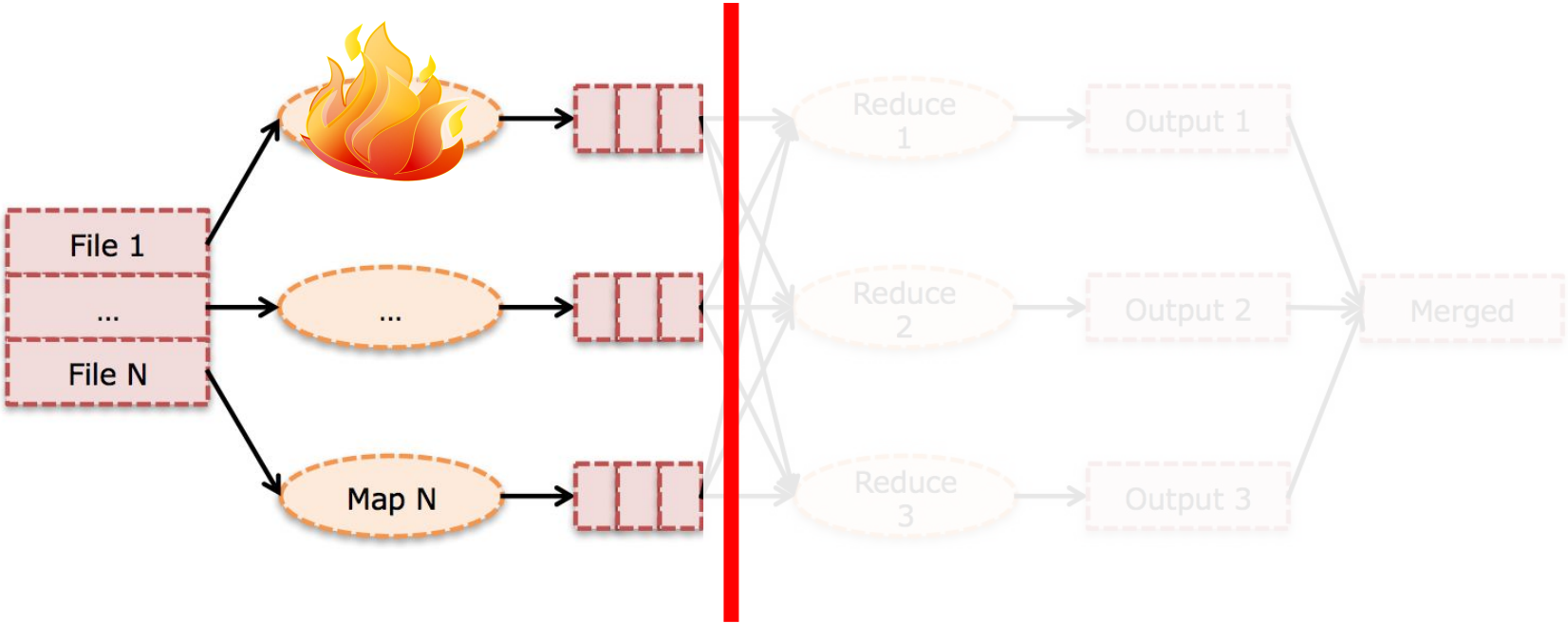
Synchronization barrier

MapReduce: Fault Tolerance

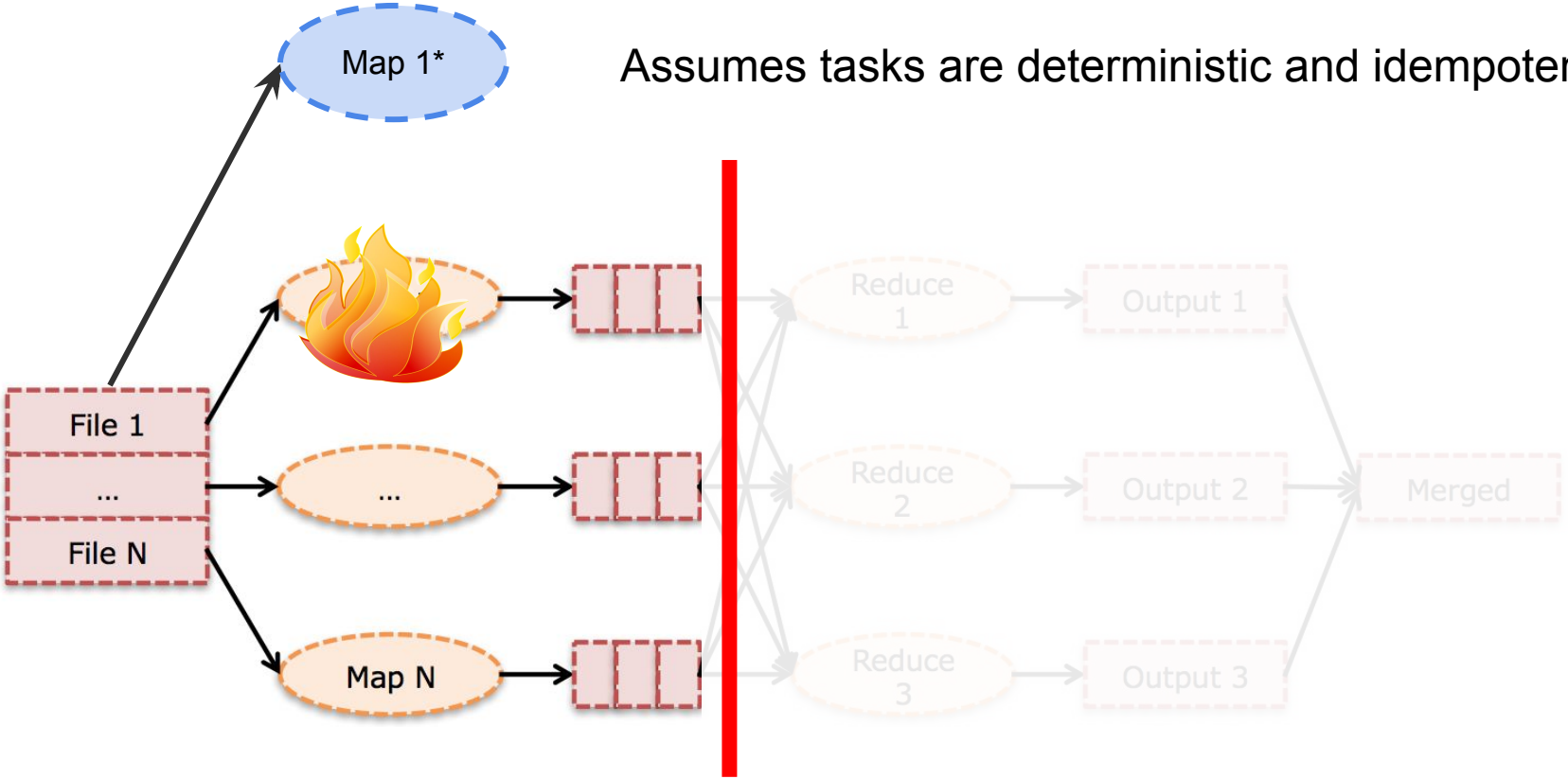


Synchronization barrier

MapReduce: Fault Tolerance

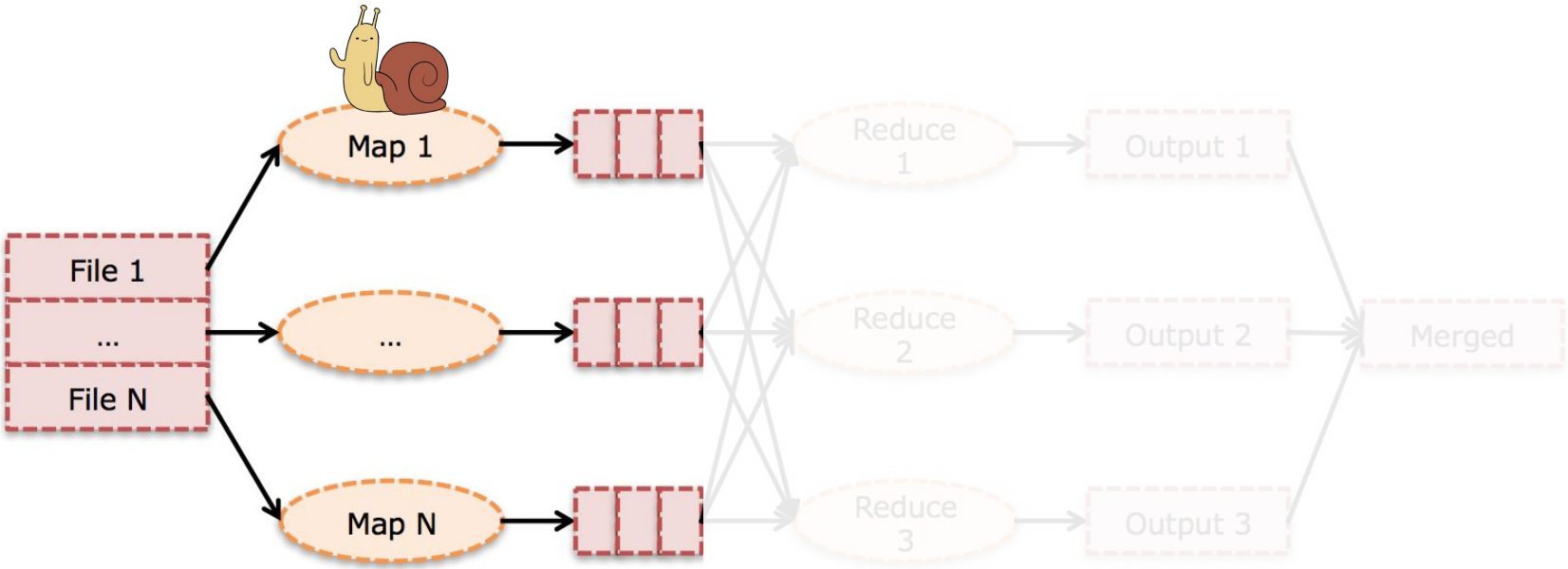


Launch same task on a different machine



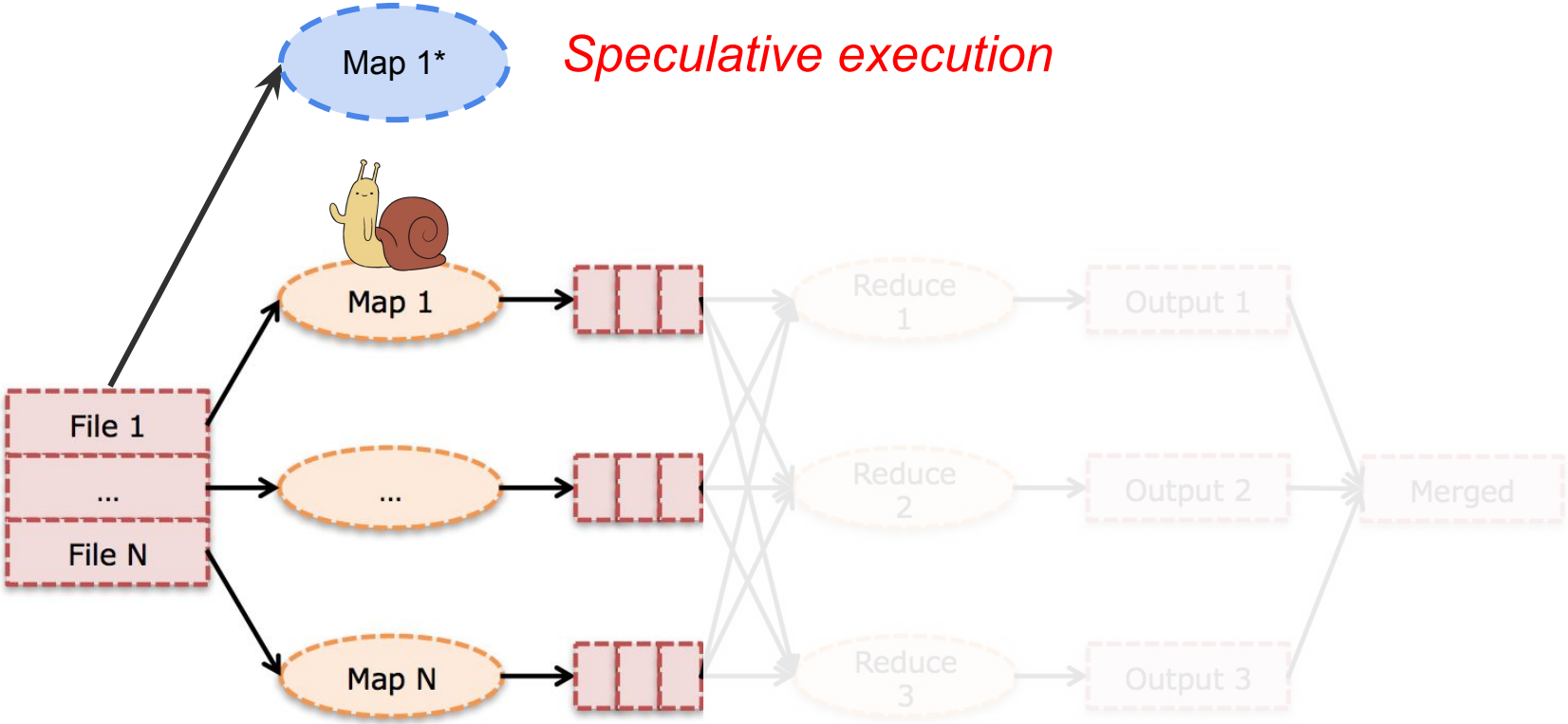
Assumes tasks are deterministic and idempotent

What if server 1 is just *REALLY* slow?

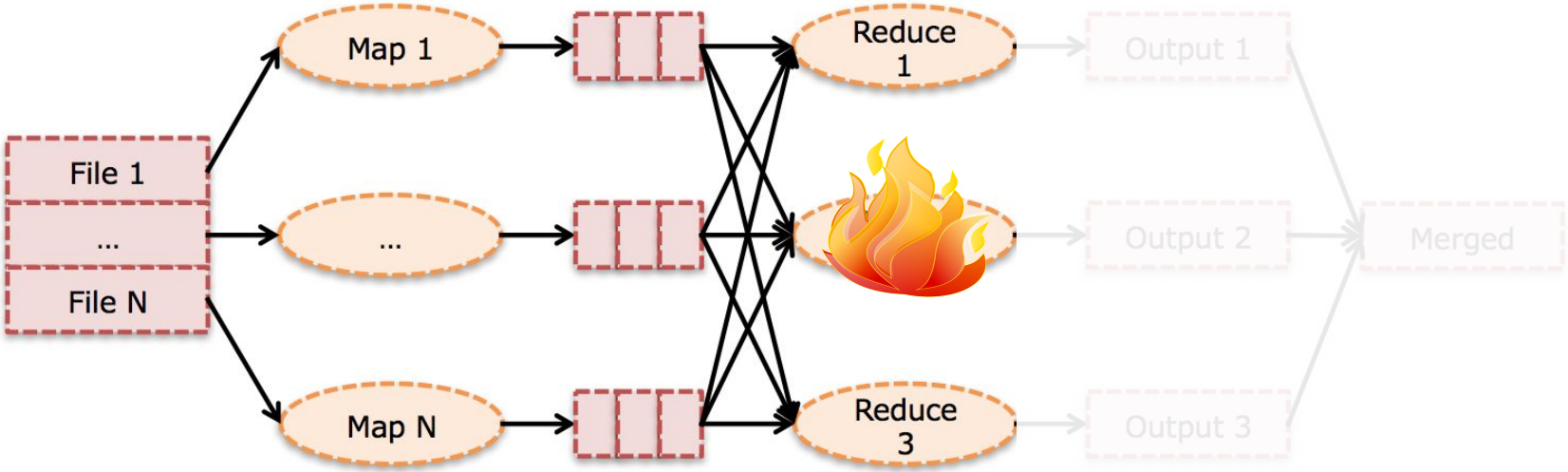


Server 1 is a *straggler*

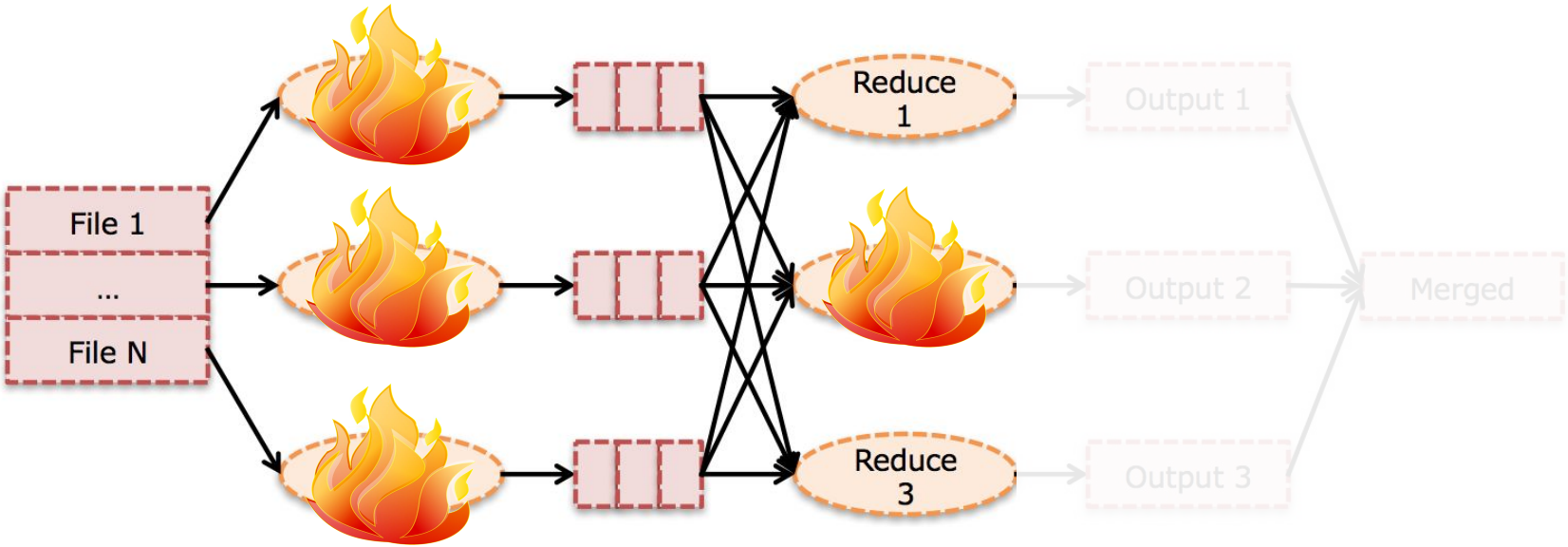
Use the same idea!



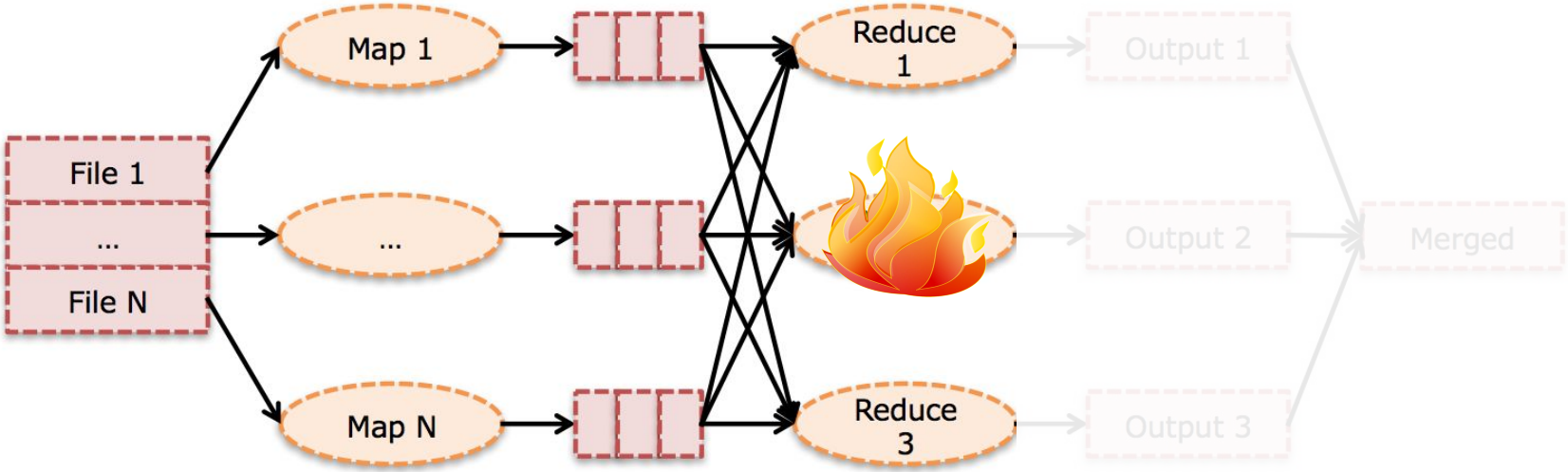
What should we re-execute?



All mappers might provide inputs to Reduce 2



Can we be smarter?



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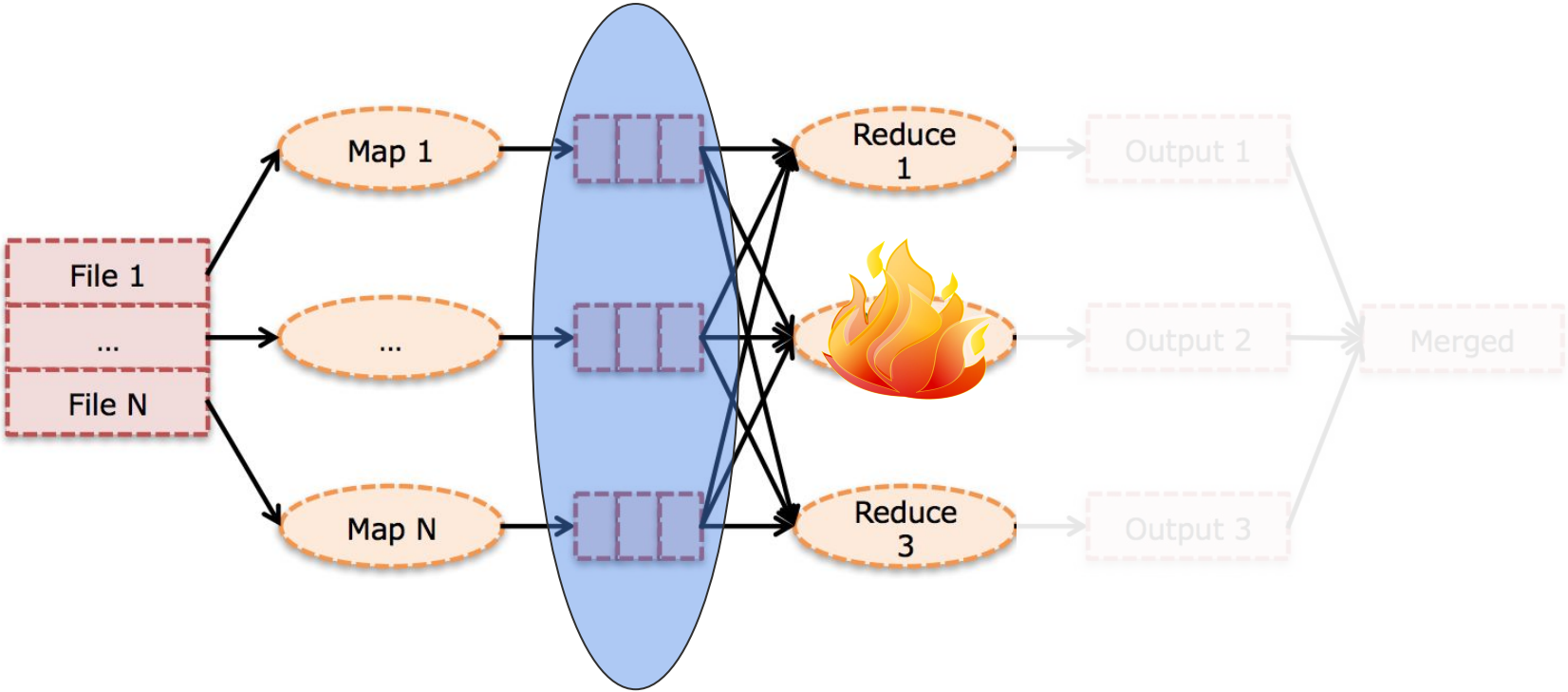
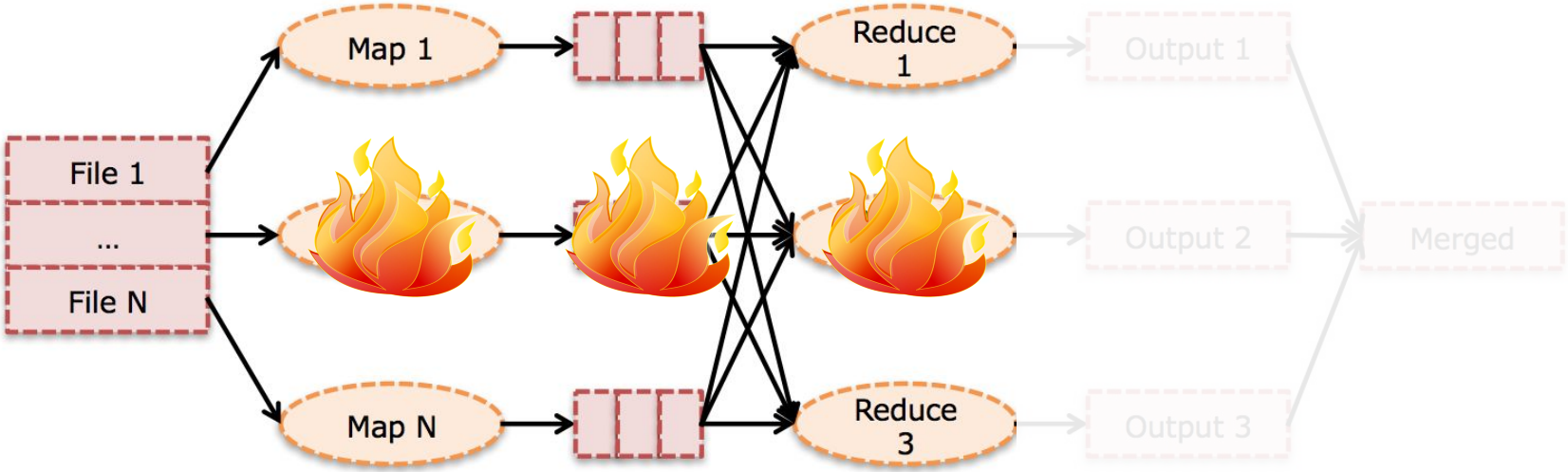
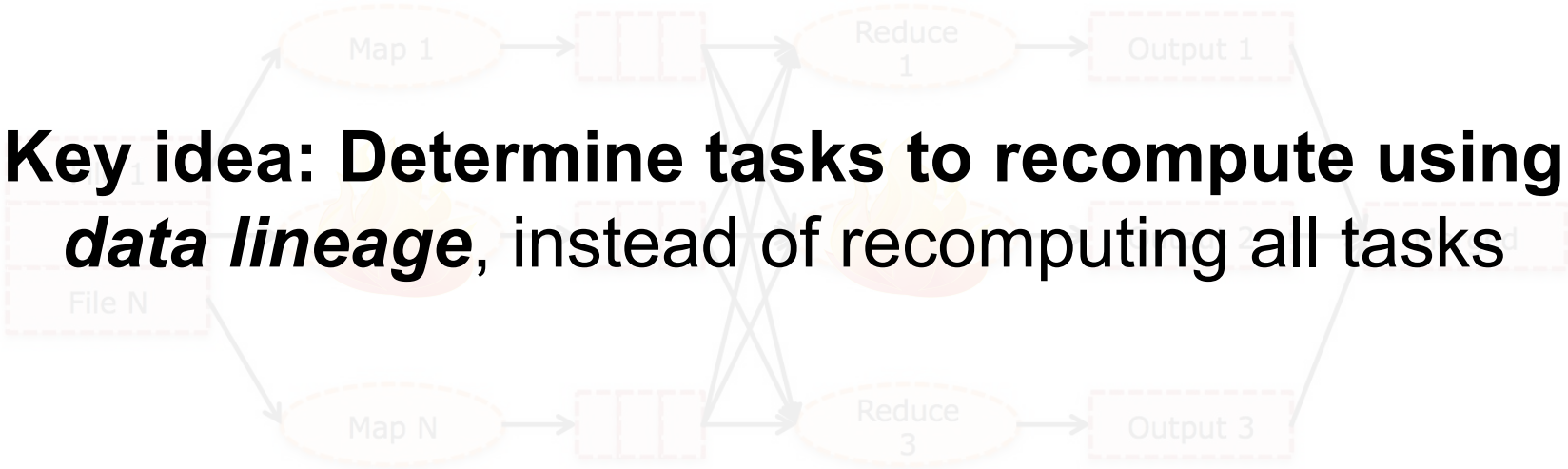


Write intermediate output to stable storage

What could go wrong?

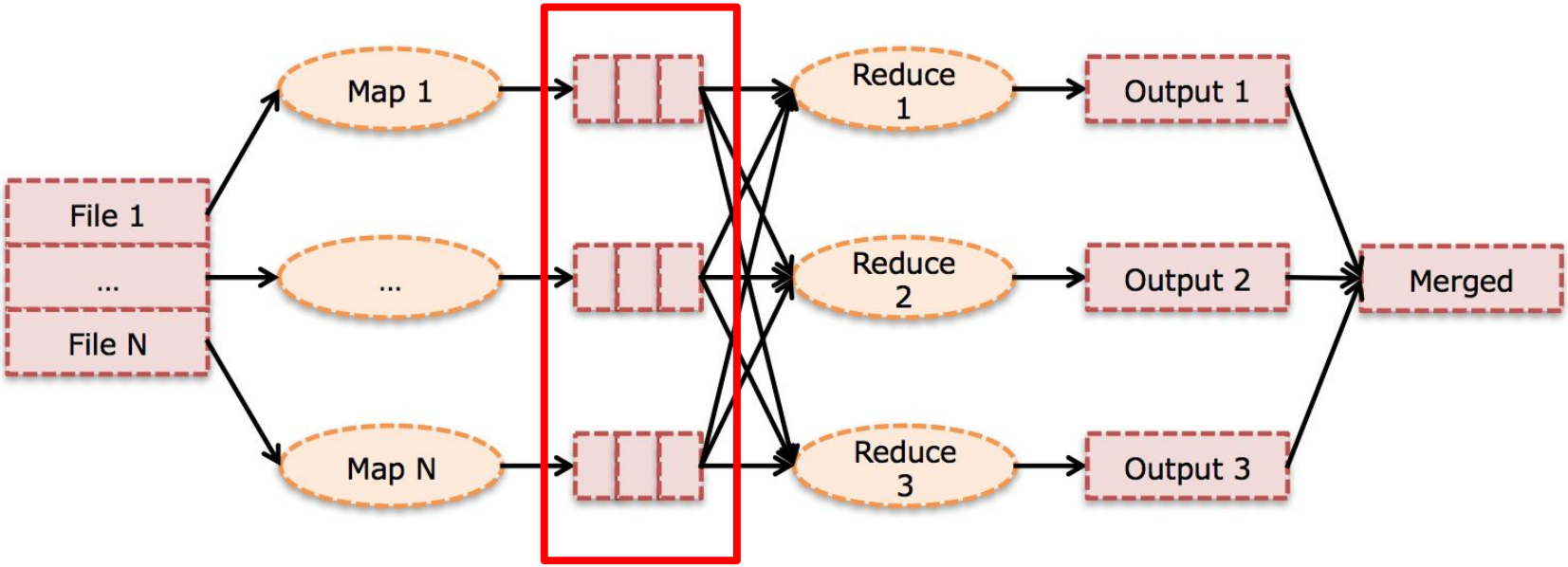


Mapreduce: What could go wrong?



Key idea: Determine tasks to recompute using *data lineage*, instead of recomputing all tasks

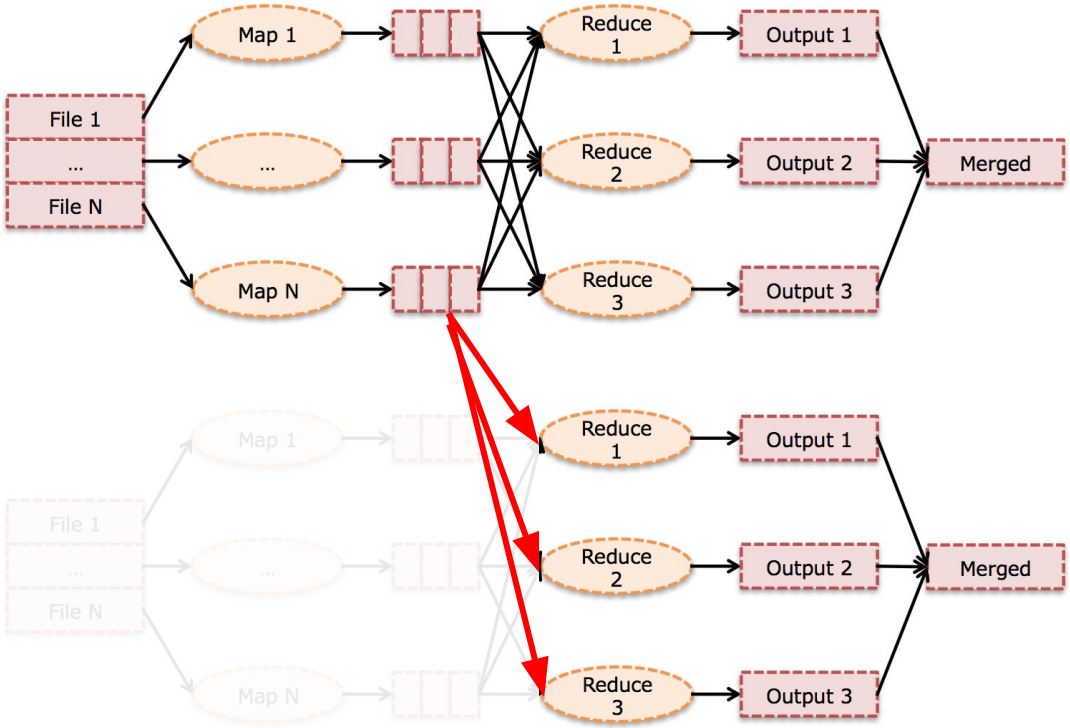
Lineage is useful for optimizations too



Reusing map outputs

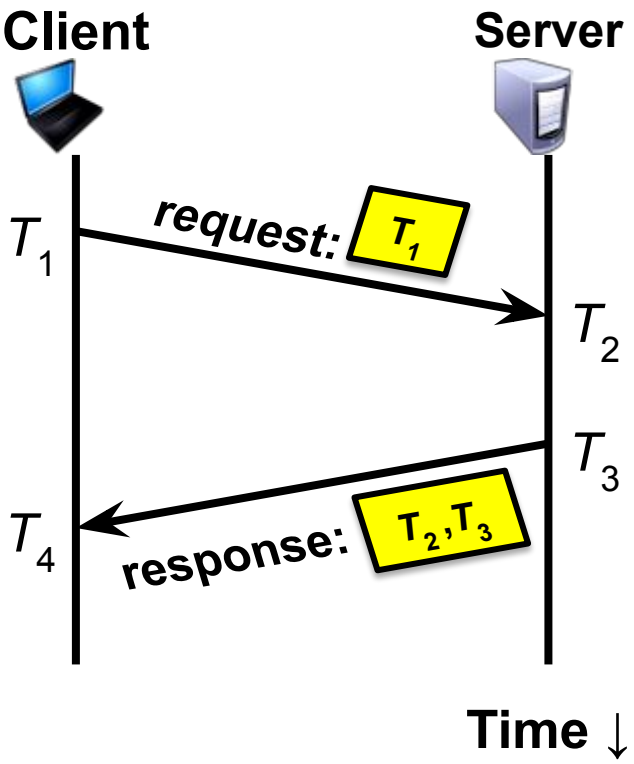
Job 1:

Job 2:



Cristian's algorithm: Outline

1. Client sends a ***request*** packet, timestamped with its local clock T_1
2. Server timestamps its receipt of the request T_2 with its local clock
3. Server sends a ***response*** packet with its local clock T_3 and T_2
4. Client locally timestamps its receipt of the server's response T_4



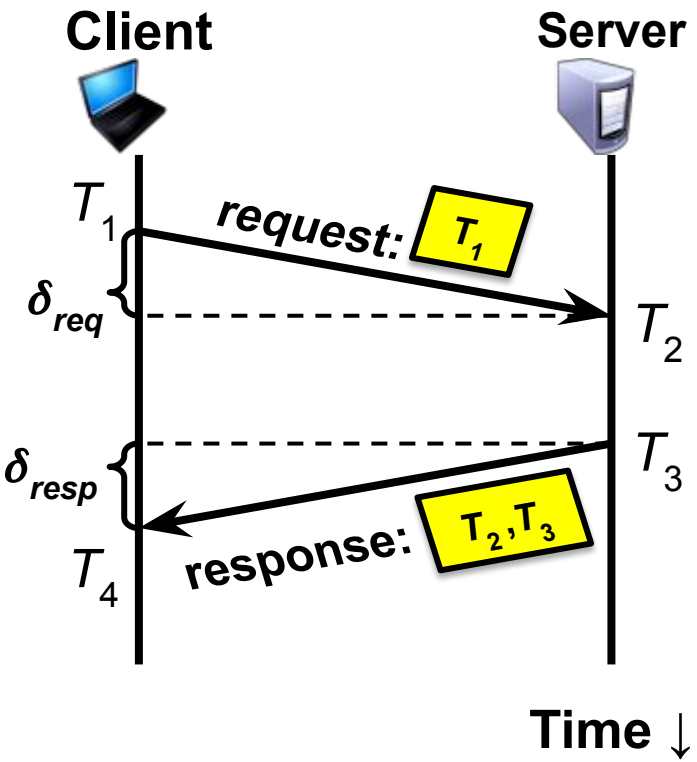
Cristian's algorithm: Offset sample calculation

Goal: Client sets clock ← $T_3 + \delta_{resp}$

- Client samples ***round trip time*** $\delta = \delta_{req} + \delta_{resp} = (T_4 - T_1) - (T_3 - T_2)$
- **But client knows δ, not δ_{resp}**

Assume: $\delta_{req} \approx \delta_{resp}$

Client sets clock ← $T_3 + \frac{1}{2}\delta$



Exercise: Cristian's algorithm

Implement a `CristianServer` that other machines sync their local time to

```
func SyncTime(serverAddr string) (time.Time, error)
```

Set *local time* = T_3 + *RTT/2*, where RTT = (T_4 - T_1) - (T_3 - T_2)

Note: You can just build a simplified version where $T_2 = T_3$

Hint: use `time.Time`'s `Sub` and `Add` methods, `time.Now()`