SCALABLE AND RELIABLE VIDEO TRANSCODING IN HASKELL

Alfredo Di Napoli

Haskell Exchange 2015

ABOUT ME

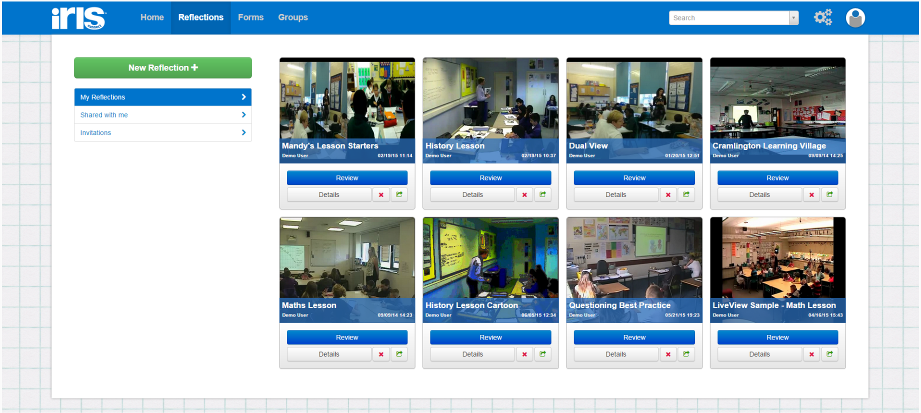
Full story at: **http://goo.gl/qkKwKm**

`launchMissile :: IO ()`

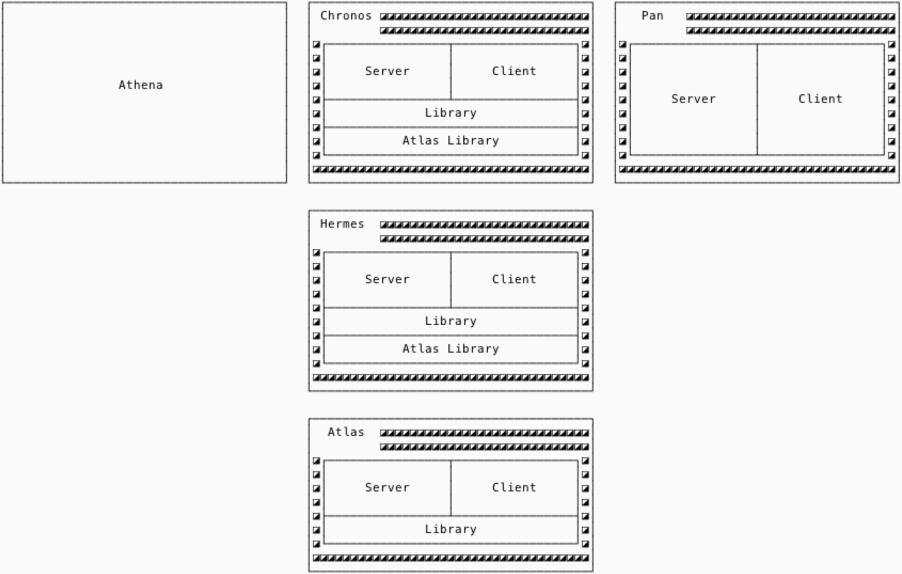
IRIS CONNECT

- Present in over 1800 schools Worldwide (mostly UK, Europe, US & Australia)
- Used by over 32000 teachers

IRIS CONNECT (CONTD.)



IRIS' GREEK ZOO



HERMES' EVOLUTION

October, 2013

```
hermes [74aeab2] ⚡cloc src scripts
       3 text files.
       3 unique files.
       0 files ignored.

http://cloc.sourceforge.net v 1.60  T=0.24 s (12.3 files/s, 762.9 lines/s)
-------------------------------------------------------------------------------
Language                     files          blank        comment           code
-------------------------------------------------------------------------------
Haskell                          1             22              7             80
Bourne Shell                     2             25              2             50
-------------------------------------------------------------------------------
SUM:                             3             47              9            130
-------------------------------------------------------------------------------
```

October, 2015

```
hermes [master] cloc main server src test
     105 text files.
     105 unique files.
       0 files ignored.

http://cloc.sourceforge.net v 1.60  T=0.66 s (159.6 files/s, 26288.3 lines/s)
-------------------------------------------------------------------------------
Language                     files          blank        comment           code
-------------------------------------------------------------------------------
Haskell                        105           2332           2252          12712
-------------------------------------------------------------------------------
SUM:                           105           2332           2252          12712
-------------------------------------------------------------------------------
```

Upon taking the lead on Hermes, I was asked for a couple of requirements to be fullfilled, the most important one being that the system needed to be capable of scaling according to demand.

More specifically, we wanted a system with these desirable properties:

- Scalable
- Fault tolerant
- Distributed

ALL I WANT IS A CLUSTER

- It's easy to see that what we want is a **cluster**, which should ramp up during busiest times in the day and cooldown during night hours
- We need to transcode videos, which is a very stateful operation
- A cluster typically implies machines talking to each other, which is also very stateful
- **As good Haskell programmers**, we want to have components in our system to be **as stateless as possible**, and potentially treat videos as **persistent data structures**!

A shared nothing architecture (SN) is a distributed computing architecture in which each node is independent and self-sufficient, and there is no single point of contention across the system.

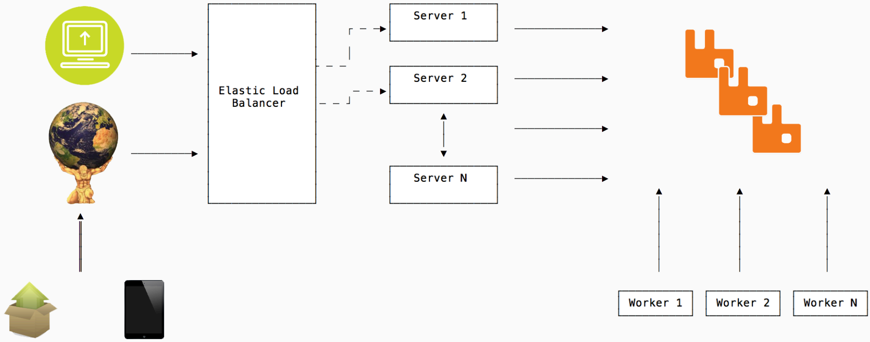
"All problems in computer science can be solved by another level of indirection." - Butler Lampson

1. RabbitMQ was just the right tool for the job at hand:
   - ∼ Easy to setup
   - ∼ Can be configured to operate in a federation of nodes
   - ∼ Extremely reliable
   - ∼ Good Haskell bindings for it (*AMQP*)
2. A question genuinely arise: it seems extremely costly to shuffle video as binary blobs over the queues. Can we avoid that?

```
root__m-stg-main-2014_10_29_13_27_26-videos-1-2333-vid-smc-oxz8dmdi1lx7fong
    ^    ^   ^        ^                 ^   ^   ^   ^   ^        ^
    |    |   |        |                 |   |   |   |   |        |
comment  |   |        |                 |   |   |   |   |        |
         |   |        |                 |   |   |   |   |        |
host ----+   |        |                 |   |   |   |   |        |
             |        |                 |   |   |   |   |        |
database --- +        |                 |   |   |   |   |        |
                      |                 |   |   |   |   |        |
dataset version ------+                 |   |   |   |   |        |
                                        |   |   |   |   |        |
resource (video or image) --------------+   |   |   |   |        |
                                            |   |   |   |        |
user ID ------------------------------------+   |   |   |        |
                                                |   |   |        |
video ID -------------------------------------- +   |   |        |
                                                    |   |        |
channel type ---------------------------------------+   |        |
                                                        |        |
video products -----------------------------------------+        |
                                                                 |
MAC (avoids submission of bogus keys) ---------------------------+
```

To be fair, the media key abstraction was already present in Atlas when I choose RabbitMQ, but it was the perfect fit for it!

THE ARCHITECTURE



WHAT ABOUT DATA STORAGE?

Fine, but RabbitMQ doesn't give you data storage...

1. We use AWS' S3 for our storing needs

   ∼ A media key **uniquely identifies** an S3 location (it's like an **IP address for videos**!)

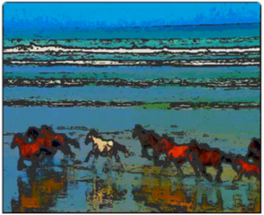
2. Upon upload the original file from the user is synced over S3 and we call this generation-0 file the **master file**
3. Such master file is **immutable**, and each product we transcode generates a brand new binary on S3

We are treating videos as immutable data structures!

Easy concurrency and parallelism!

root__m-inplc-main-2015_09_07_12_31_16-videos-1-4-vid-s-4s7byyc9pkbkfv1v

root__m-inplc-main-2015_09_07_12_31_16-videos-1-4-vid-c-4mpvvngvajarzx0n



Fine, but RabbitMQ doesn't give you scalability...

1. We stood once again on the shoulder of giants - namely AWS' Auto Scaling Groups
2. Our very first naive scaling algorithm used AWS' builtin alarms and looked like:
    - ~ Scaling up: Based on CPU% over time
    - ~ Scaling down: Based on CPU% over time

It kept us going for a while...

REVIEWING THE SCALING EXPERIENCE

1. Scaling up was too conservative and slow
   - ~ It could take up to 15 mins to spawn a new worker
2. Scaling down suffered similar problems
3. The result was unoptimal for customers (due to the slow turnaround time) and unoptimal for us (due to the additional costs incurring from poor scaling down)

SCALING UP, REVISITED

- Scaling up is easy: all we care about is the total number of jobs in RabbitMQ's **Ready** state;
  - ∼ In RMQ jargon those are jobs waiting for a "transcoding slot"

Ready	Unacked	Total
0	0	0

- We periodically monitor those figures and kick off a "ScaleUP" action whenever `ready_jobs >= 0`
  - ∼ AWS's ASG allows us to put an upper bound to the total number of spawnable machines, to keep costs at bay.

1. More interesting is the scaling down. Ideally we want to kill a worker if the following is true:
   - ∼ That worker didn't receive any new jobs within a `starvation_time` period (say, 5 minutes)
2. At the same time, we would like to optimise the time it stays around
3. Last but not least, it needs to commit suicide alone (I know it sounds sad..), taking a local decision, as it doesn't know its peers (SN architecture - remember?)

SCALING DOWN - THE REAPER

```haskell
type HeartBeat = TBQueue ()
type Toggle = TMVar ()
type PoisonFlask = TMVar ()

data Reaper = Reaper {
    _rr_timeout :: Maybe Int
  -- ^ The timeout to use for this `Reaper`. Setting this to
  -- Nothing means no timeout at all. This is useful for those transcoders
  -- not associated with jobs (e.g. dual-view, discovery-kit, notifications,..)
  , _rr_reapCondition :: IO Bool
  -- ^ If True, will trigger the reaping. If False, the Reaper will be
  -- permissive.
  , _rr_reapAction :: IO ()
  , _rr_heartbeat :: HeartBeat
  , _rr_toggle :: Toggle
  -- ^ When filled, inform the listeners they can carry on with their
  -- activities (i.e. fetch another job from the queue)
  , _rr_poisonFlask :: PoisonFlask
  }
```

SCALING DOWN - REAPER TIMEOUT

```haskell
data ReaperPoisoned = ReaperPoisoned ()
type ReaperResponse = Either ReaperPoisoned (Maybe ())

-- | peek the next value from a TBQueue or timeout
peekTBQueueTimeout :: Maybe Int
                   -> HeartBeat
                   -> PoisonFlask
                   -> IO ReaperResponse
peekTBQueueTimeout Nothing heartbeat fsk =
    atomically $ Right . Just <$> peekTBQueue heartbeat <|>
                 Left  . ReaperPoisoned <$> takeTMVar fsk
peekTBQueueTimeout (Just timeoutAfter) heartbeat fsk = do
  delay <- registerDelay timeoutAfter
  atomically $ (Right . Just <$> peekTBQueue heartbeat) <|>
               (pure (Right Nothing) <* untilTimeout delay) <|>
               (Left . ReaperPoisoned <$> takeTMVar fsk)
```

SCALING DOWN, STM TO THE RESCUE

```haskell
reap :: Reaper -> IO ReaperResponse
reap (Reaper t cond _ hb tgl pp) = do
  r <- peekTBQueueTimeout t hb pp
  case r of
    Left _ -> return r -- If we have been poisoned, honour the poisoning and die.
    v@(Right Nothing) -> do
      condT <- cond
      -- If the reaping condition is True, we need to die.
      -- If not, we simulate a state toggle to induce listeners to unlock
      -- and wait for the next batch of events.
      if condT then return v else toggle tgl >> return (Right $ Just ())
    Right s -> return . Right $ s
```

```haskell
instance Alternative STM where
  empty = retry
  (<|>) = orElse

-- orElse: Compose two alternative STM actions. If the first action completes
-- without retrying then it forms the result of the orElse.
-- Otherwise, if the first action retries, then the second action is tried
-- in its place. If both actions retry then the orElse as a whole retries.
```

SCALING DOWN, A TYPICAL TRANSCODER

```haskell
newtype Transcoder a = Transcoder { transcode :: StateT TranscoderState IO a }
  deriving (MonadState TranscoderState, Monad, Functor, Applicative, MonadIO)
```

```haskell
transcoder :: Transcoder ()
transcoder = do
  ctx@TranscoderCtx{..} <- getContext
  newTranscoder $ \_ hb tgl -> NewRabbitConsumer <$> do
    consumeTranscodingJobsIO _tr_channelConfig $ \(msg, env) -> void $ forkIO $
      withIncomingPacket msg $
      \job@(PendingJob key HermesOptions{..} _ (RetryWindow _ _)) -> do
        sendHeartBeat hb -- puts a 'token' into the heartbeat queue
        -- Do here transcoding stuff...
        signalDone hb -- reads from the heartbeat queue
        toggle tgl    -- puts a token (unit) inside the toggle
```

```haskell
newTranscoder :: (PoisonFlask -> HeartBeat -> Toggle -> IO NonBlockingAction)
              -> Transcoder ()
```

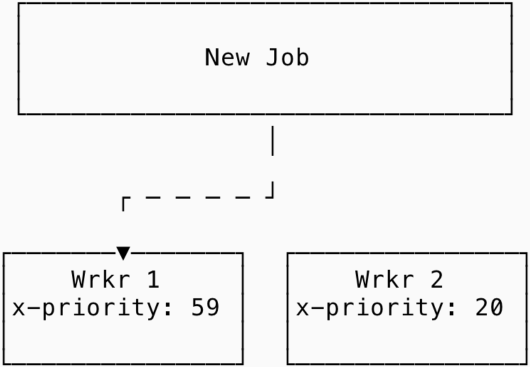
The purpose of that `NonBlockingAction` type will be clear soon.

SCALING DOWN, FIRST RESULTS

- When we deployed the code, we didn't find a sensible difference in costs...
- ... reason being Amazon doesn't bill you for fractional hours
  - ~ Even if you spawn a machine 5 mins, you are billed the full hour!
- We needed workers to stay around as much as possible, maximising their billing hour, without crossing the next-hour mark, if possible!

"Consumer priorities allow you to ensure that high priority consumers receive messages while they are active, with messages only going to lower priority consumers when the high priority consumers block."

RABBITMQ CONSUMER PRIORITIES (CNTD.)



- Each worker can transcode 1 job at time, before "blocking"
- The priority is set to be `60 - (uptime % 60)`
- A newly spawned machine gets max priority
- A machine close enough to the next billing hours (e.g. priority $<=$ 10) **if starving**, gets evicted!

RABBITMQ CONSUMER PRIORITIES (CNTD.)

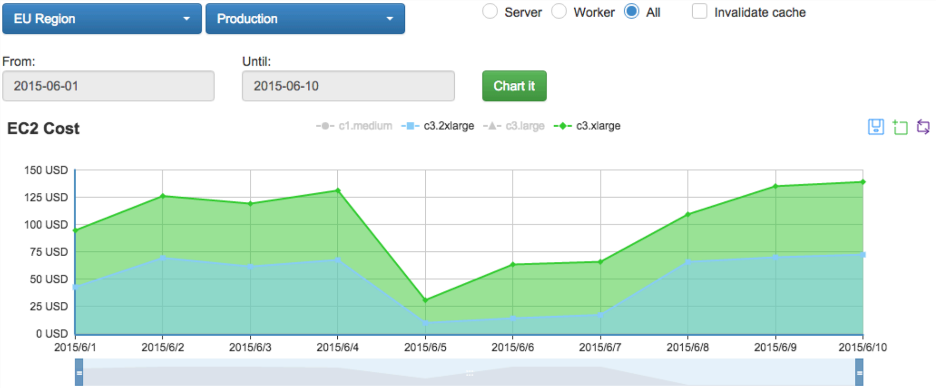
- A consumer priority cannot be updated dynamically
- The easiest way we found was - after a successful heartbeat - to simply cancel the old consumer and create a new one, with updated priority

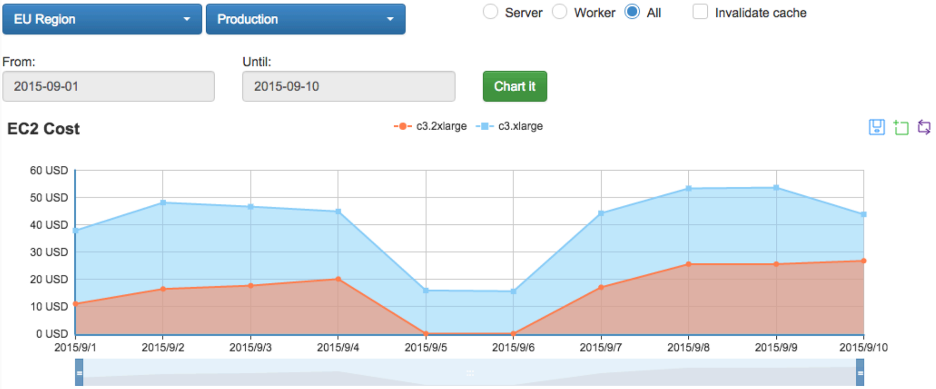
```
data NonBlockingAction = VoidAction ()
                       | NewRabbitConsumer ConsumerTag
```

- We used the `ConsumerTag` returned by `NewRabbitConsumer` to cancel the old one, compute the updated priority and start a new transcoder

```haskell
newTranscoderState :: HeartBeat
                   -> TranscoderType
                   -> TranscoderCtx
                   -> IO TranscoderState
newTranscoderState hb ttype tctx = do
  let config = tctx ^. tr_config
  pp <- newPoisonFlask
  rpr <- case ttype of
    JobTranscoder (Production _) ->
      newReaper pp hb (Just twoMinutes) closeToNextBillingHour (reapFromAWS config)
    JobTranscoder Devel ->
      newReaper pp hb (Just oneMinute) (return True) reapLocally
    JobTranscoder _     ->
      newReaper pp hb Nothing (return True) (return ())
    AuxiliaryTranscoder ->
      newReaper pp hb Nothing (return True) (return ())
  return TranscoderState {
           _ts_transitions = singleton 50 WaitingForJob
         , _ts_poisonFlask = pp
         , _ts_reaper = rpr
         , _ts_ctx    = tctx
         }
```

THE NEW SCALING ALGORITHM: RESULTS





We shaved almost 50% of the costs!

What's the elephant in the room?

Why not use Cloud Haskell?

WHY NOT CLOUD HASKELL

1. CH encourages Erlang-style (i.e. actor based) communication, so nodes should know each other

   We do not want that!

2. Peer discovery would have been tricky in a dynamic environment where new machines born and die frequently
3. It wasn't mature enough in 2013, if not for a handful of companies using it

Thank you!

Questions?

My road to Haskell

http://www.alfredodinapoli.com/posts/2014-04-27-my-road-to-haskell.html