Cardano.BM - benchmarking and logging

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Abstract

This is a framework that combines logging, benchmarking and monitoring. Complex evaluations of STM or monadic actions can be observed from outside while reading operating system counters before and after, and calculating their differences, thus relating resource usage to such actions. Through interactive configuration, the runtime behaviour of logging or the measurement of resource usage can be altered. Further reduction in logging can be achieved by redirecting log messages to an aggregation function which will output the running statistics with less frequency than the original message.

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Chapter 1

Logging, benchmarking and monitoring

1.1 Overview

In figure 1.1 we display the relationships among modules in *Cardano.BM*. The arrows indicate import of a module. The arrows with a triangle at one end would signify "inheritance" in object-oriented programming, but we use it to show that one module replaces the other in the namespace, thus refines its interface.

1.2 Introduction

1.2.1 Logging with Trace

1.2.2 Setup procedure

Hierarchy of Traces

1.2.3 Measuring *Observable*s

1.2.4 Information reduction in Aggregation

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1.3 Examples

1.3.1 Observing evaluation of a STM action

1.3.2 Observing evaluation of a monad action

1.3.3 Simple example showing plain logging

```
 {-# LANGUAGE OverloadedStrings #-}
module Main
  (main)
  where
import Control.Concurrent (threadDelay)
import Cardano.BM.Configuration.Static (defaultConfigStdout)
```

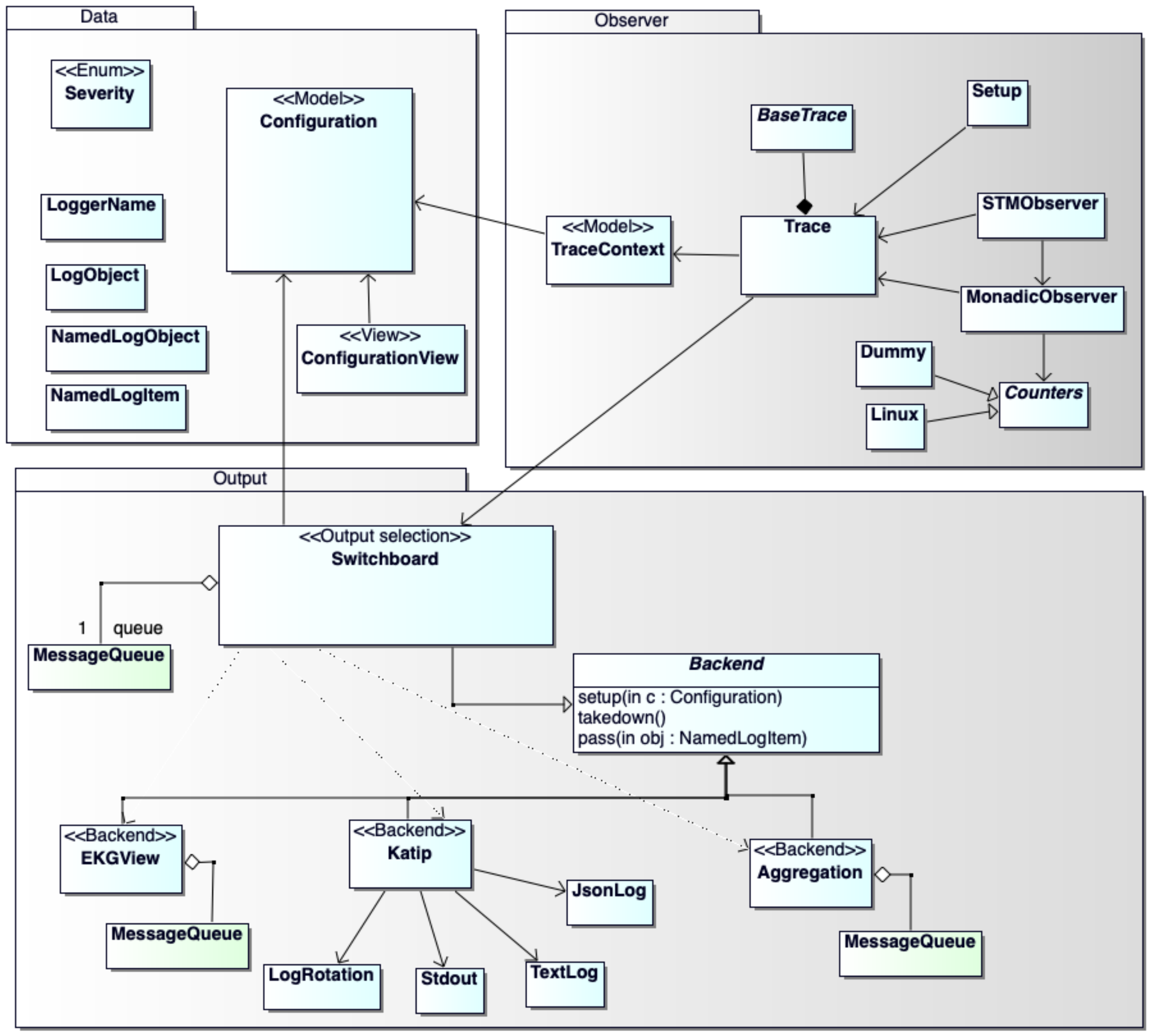


Figure 1.1: Overview of module relationships

```
import Cardano.BM.Setup (setupTrace)
import Cardano.BM.Trace (logDebug, logError, logInfo, logNotice,
           logWarning)
main :: IO ()
main = do
  c ← defaultConfigStdout
  tr ← setupTrace (Right c) "simple"
  logDebug tr "this is a debug message"
  logInfo   tr "this is an information."
  logNotice tr "this is a notice!"
  logWarning tr "this is a warning!"
  logError  tr "this is an error!"
  threadDelay 80000
```

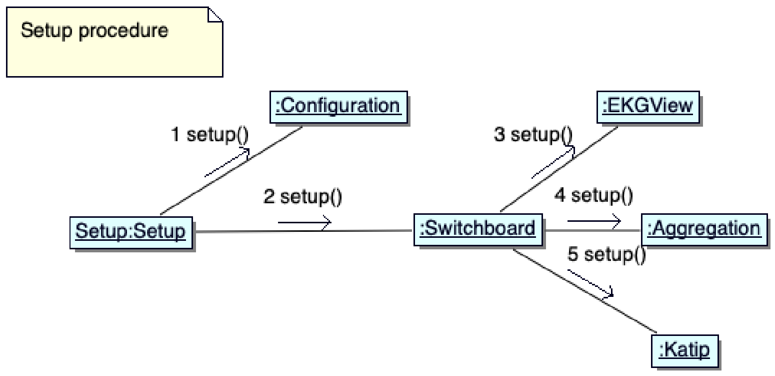


Figure 1.2: Setup procedure

```
    return ()
```

1.3.4 Complex example showing logging, aggregation of log items, and observing *IO* actions

Module header and import directives

```
 {-# LANGUAGE CPP #-}
 {-# LANGUAGE OverloadedStrings #-}
# if defined (linux_HOST_OS)
# define LINUX
# endif
module Main
  (main)
  where
import Control.Concurrent (threadDelay)
import qualified Control.Concurrent.Async as Async
import Control.Monad (forM, forM_)
import GHC.Conc.Sync (STM, TVar, atomically, newTVar, readTVar, writeTVar)
import Data.Text (pack)
# ifdef LINUX
import qualified Data.ByteString.Char8 as BS8
import Network.Download (openURI)
# endif
import System.Random
import qualified Cardano.BM.Configuration.Model as CM
import Cardano.BM.Data.Aggregated (Measurable (..))
import Cardano.BM.Data.AggregatedKind
import Cardano.BM.Data.BackendKind
import Cardano.BM.Data.LogItem
import Cardano.BM.Data.Observable
import Cardano.BM.Data.Output
import Cardano.BM.Data.Rotation
import Cardano.BM.Data.Severity
import Cardano.BM.Data.SubTrace
import Cardano.BM.Observer.Monadic (bracketObserveIO)
import qualified Cardano.BM.Observer.STM as STM
import Cardano.BM.Setup
import Cardano.BM.Trace
```

Define configuration

The output can be viewed in EKG on `http://localhost:12789`.

```
config :: IO CM.Configuration
config = do
  c ← CM.empty
  CM.setMinSeverity c Debug
  CM.setSetupBackends c [KatipBK, AggregationBK, EKGViewBK]
  CM.setDefaultBackends c [KatipBK]
  CM.setSetupScribes c [ScribeDefinition {
        scName = "stdout"
        , scKind = StdoutSK
        , scRotation = Nothing
        }
    , ScribeDefinition {
        scName = "logs/out.odd.json"
        , scKind = FileJsonSK
        , scRotation = Nothing
        }
    , ScribeDefinition {
        scName = "logs/out.even.json"
        , scKind = FileJsonSK
        , scRotation = Nothing
        }
    , ScribeDefinition {
        scName = "logs/out.txt"
        , scKind = FileTextSK
        , scRotation = Just $ RotationParameters
          {rpLogLimitBytes = 5000-- 5kB
          , rpMaxAgeHours  = 24
          , rpKeepFilesNum = 3
          }
        }
    ]
  CM.setDefaultScribes c ["StdoutSK::stdout"]
  CM.setScribes c "complex.random" (Just ["StdoutSK::stdout", "FileTextSK::logs/out.txt"])
  CM.setScribes c "#aggregated.complex.random" (Just ["StdoutSK::stdout"])
```

```
    forM_ [(1 :: Int)..10] $ λx →
      if odd x
      then
        CM.setScribes c ("#aggregation.complex.observeSTM." <> (pack $ show x)) $ Just ["FileJsonSK::lo
      else
        CM.setScribes c ("#aggregation.complex.observeSTM." <> (pack $ show x)) $ Just ["FileJsonSK::lo
  # ifdef LINUX
    CM.setSubTrace c "complex.observeDownload" (Just $ ObservableTrace [IOStats])
  # endif
    CM.setSubTrace c "complex.random" (Just $ TeeTrace "ewma")
    CM.setSubTrace c "#ekgview"
      (Just $ FilterTrace [(Drop (StartsWith "#ekgview.#aggregation.complex.random"),
              Unhide [(EndsWith ".count"),
                (EndsWith ".avg"),
                (EndsWith ".mean")]),
        (Drop (StartsWith "#ekgview.#aggregation.complex.observeIO"),
          Unhide [(Contains "diff.RTS.cpuNs.timed.")]),
        (Drop (StartsWith "#ekgview.#aggregation.complex.observeSTM"),
          Unhide [(Contains "diff.RTS.gcNum.timed.")]),
        (Drop (StartsWith "#ekgview.#aggregation.complex.message"),
          Unhide [(Contains ".timed.m")])
        ])
    CM.setSubTrace c "complex.observeIO" (Just $ ObservableTrace [GhcRtsStats, MemoryStats])
    forM_ [(1 :: Int)..10] $ λx →
      CM.setSubTrace
        c
        ("complex.observeSTM." <> (pack $ show x))
        (Just $ ObservableTrace [GhcRtsStats, MemoryStats])
    CM.setBackends c "complex.message" (Just [AggregationBK, KatipBK])
    CM.setBackends c "complex.random" (Just [AggregationBK, KatipBK])
    CM.setBackends c "complex.random.ewma" (Just [AggregationBK])
    CM.setBackends c "complex.observeIO" (Just [AggregationBK])
    forM_ [(1 :: Int)..10] $ λx → do
      CM.setBackends c
        ("complex.observeSTM." <> (pack $ show x))
        (Just [AggregationBK])
      CM.setBackends c
        ("#aggregation.complex.observeSTM." <> (pack $ show x))
        (Just [EKGViewBK, KatipBK])
    CM.setAggregatedKind c "complex.random.rr" (Just StatsAK)
    CM.setAggregatedKind c "complex.random.ewma.rr" (Just (EwmaAK 0.42))
    CM.setBackends c "#aggregation.complex.message" (Just [EKGViewBK])
    CM.setBackends c "#aggregation.complex.observeIO" (Just [EKGViewBK])
    CM.setBackends c "#aggregation.complex.random" (Just [EKGViewBK])
    CM.setBackends c "#aggregation.complex.random.ewma" (Just [EKGViewBK])
    CM.setEKGport c 12789
    return c
```

Thread that outputs a random number to a Trace

```
randomThr :: Trace IO → IO (Async.Async ())
randomThr trace = do
  logInfo trace "starting random generator"
  trace′ ← subTrace "random" trace
  proc ← Async.async (loop trace′)
  return proc
  where
    loop tr = do
      threadDelay 500000-- 0.5 second
      num ← randomRIO (42 − 42, 42 + 42) :: IO Double
      lo ← LogObject < $ > mkLOMeta < ∗ > pure (LogValue "rr" (PureD num))
      traceNamedObject tr lo
      loop tr
```

Thread that observes an *IO* action

```
observeIO :: Trace IO → IO (Async.Async ())
observeIO trace = do
  logInfo trace "starting observer"
  proc ← Async.async (loop trace)
  return proc
  where
    loop tr = do
      threadDelay 5000000-- 5 seconds
      _ ← bracketObserveIO tr "observeIO" $ do
        num ← randomRIO (100000, 200000) :: IO Int
        ls ← return $ reverse $ init $ reverse $ 42 : [1 . . num]
        pure $ const ls ()
      loop tr
```

Thread that observes an *IO* action which downloads a txt in order to observe the I/O statistics

disabled for now! on Mac OSX this function was blocking all IO.

```
observeDownload :: Trace IO → IO ()
observeDownload trace = loop trace
  where
    loop tr = do
      threadDelay 10000000-- 10 seconds
      tr′ ← appendName "observeDownload" tr
      bracketObserveIO tr′ "" $ do
```

```
        license ← openURI "http://www.gnu.org/licenses/gpl.txt"
        case license of
          Right bs → logNotice tr′ $ "downloaded " <> BS8.length bs <> " bytes"
          Left e → logError tr′ e
        threadDelay 500000-- .5 second
        pure ()
      loop tr
```

Threads that observe *STM* actions on the same TVar

```
observeSTM :: Trace IO → IO [Async.Async ()]
observeSTM trace = do
  logInfo trace "starting STM observer"
  tvar ← atomically $ newTVar ([1..1000] :: [Int])
  -- spawn 10 threads
  proc ← forM [(1 :: Int)..10] $ λx → Async.async (loop trace tvar (pack $ show x))
  return proc
  where
    loop tr tvarlist name = do
      threadDelay 10000000-- 10 seconds
      STM.bracketObserveIO tr ("observeSTM." <> name) (stmAction tvarlist)
      loop tr tvarlist name
stmAction :: TVar [Int] → STM ()
stmAction tvarlist = do
  list ← readTVar tvarlist
  writeTVar tvarlist $ reverse $ init $ reverse $ list
  pure ()
```

Thread that observes an *IO* action which downloads a txt in order to observe the I/O statistics

```
#ifdef LINUX
observeDownload :: Trace IO → IO (Async.Async ())
observeDownload trace = do
  proc ← Async.async (loop trace)
  return proc
  where
    loop tr = do
      threadDelay 1000000-- 1 second
      tr′ ← appendName "observeDownload" tr
      bracketObserveIO tr′ "" $ do
        license ← openURI "http://www.gnu.org/licenses/gpl.txt"
        case license of
          Right bs → logNotice tr′ $ pack $ BS8.unpack bs
          Left _ → return ()
        threadDelay 50000-- .05 second
        pure ()
      loop tr
# endif
```

Thread that periodically outputs a message

```
msgThr :: Trace IO → IO (Async.Async ())
msgThr trace = do
  logInfo trace "start messaging .."
  trace′ ← subTrace "message" trace
  Async.async (loop trace′)
  where
    loop tr = do
      threadDelay 3000000-- 3 seconds
      logNotice tr "N O T I F I C A T I O N ! ! !"
      logDebug tr "a detailed debug message."
      logError tr "Boooommm .."
      loop tr
```

Main entry point

```
main :: IO ()
main = do
  -- create configuration
  c ← config
  -- create initial top-level Trace
  tr ← setupTrace (Right c) "complex"
  logNotice tr "starting program; hit CTRL-C to terminate"
  logInfo tr "watch its progress on http://localhost:12789"
   {-start thread sending unbounded sequence of random numbers to a trace which aggregates them into a
  procRandom ← randomThr tr
  -- start thread endlessly reversing lists of random length
  procObsvIO ← observeIO tr
  -- start threads endlessly observing STM actions operating on the same TVar
  procObsvSTMs ← observeSTM tr
# ifdef LINUX
  -- start thread endlessly which downloads sth in order to check the I/O usage
  procObsvDownload ← observeDownload tr
# endif
  -- start a thread to output a text messages every n seconds
  procMsg ← msgThr tr
  -- wait for message thread to finish, ignoring any exception
  _ ← Async.waitCatch procMsg
```

```
# ifdef LINUX
  -- wait for download thread to finish, ignoring any exception
  _ ← Async.waitCatch procObsvDownload
# endif
  -- wait for observer thread to finish, ignoring any exception
  _ ← forM procObsvSTMs Async.waitCatch
  -- wait for observer thread to finish, ignoring any exception
  _ ← Async.waitCatch procObsvIO
  -- wait for random thread to finish, ignoring any exception
  _ ← Async.waitCatch procRandom
  return ()
```

1.4 Code listings

1.4.1 Cardano.BM.Observer.STM

```
stmWithLog :: STM.STM (t, [LogObject]) → STM.STM (t, [LogObject])
stmWithLog action = action
```

Observe *STM* action in a named context

With given name, create a SubTrace according to Configuration and run the passed *STM* action on it.

```
bracketObserveIO :: Trace IO → Text → STM.STM t → IO t
bracketObserveIO logTrace0 name action = do
    logTrace ← subTrace name logTrace0
    let subtrace = typeofTrace logTrace
    bracketObserveIO′ subtrace logTrace action
  where
    bracketObserveIO′ :: SubTrace → Trace IO → STM.STM t → IO t
    bracketObserveIO′ NoTrace _ act =
      STM.atomically act
    bracketObserveIO′ subtrace logTrace act = do
      mCountersid ← observeOpen subtrace logTrace
      -- run action; if an exception is caught will be logged and rethrown.
      t ← (STM.atomically act) ‘catch‘ (λ(e :: SomeException) → (logError logTrace (pack (show e)) ≫ throwM e)
      case mCountersid of
        Left openException →
          -- since observeOpen faced an exception there is no reason to call observeClose
          -- however the result of the action is returned
          logNotice logTrace ("ObserveOpen: " <> pack (show openException))
        Right countersid → do
          res ← observeClose subtrace logTrace countersid [ ]
          case res of
```

```
                    Left ex → logNotice logTrace ("ObserveClose: " <> pack (show ex))
                    _ → pure ()
            pure t
```

Observe *STM* action in a named context and output captured log items

The *STM* action might output messages, which after ”success” will be forwarded to the logging trace. Otherwise, this function behaves the same as Observe *STM* action in a named context.

```
bracketObserveLogIO :: Trace IO → Text → STM.STM (t, [LogObject]) → IO t
bracketObserveLogIO logTrace0 name action = do
    logTrace ← subTrace name logTrace0
    let subtrace = typeofTrace logTrace
    bracketObserveLogIO' subtrace logTrace action
  where
    bracketObserveLogIO' :: SubTrace → Trace IO → STM.STM (t, [LogObject]) → IO t
    bracketObserveLogIO' NoTrace _ act = do
      (t, _) ← STM.atomically $ stmWithLog act
      pure t
    bracketObserveLogIO' subtrace logTrace act = do
      mCountersid ← observeOpen subtrace logTrace
      -- run action, return result and log items; if an exception is
      -- caught will be logged and rethrown.
      (t, as) ← (STM.atomically $ stmWithLog act) ‘catch‘
          (λ(e :: SomeException) → (logError logTrace (pack (show e)) ≫ throwM e))
      case mCountersid of
        Left openException →
          -- since observeOpen faced an exception there is no reason to call observeClose
          -- however the result of the action is returned
          logNotice logTrace ("ObserveOpen: " <> pack (show openException))
        Right countersid → do
          res ← observeClose subtrace logTrace countersid as
          case res of
            Left ex → logNotice logTrace ("ObserveClose: " <> pack (show ex))
            _ → pure ()
      pure t
```

1.4.2 Cardano.BM.Observer.Monadic

Monadic.bracketObserverIO

Observes an *IO* action and adds a name to the logger name of the passed in Trace. An empty *Text* leaves the logger name untouched.

Microbenchmarking steps:

1. Create a *trace* which will have been configured to observe things besides logging.

```
import qualified Cardano.BM.Configuration.Model as CM
 ○ ○ ○
c ← config
trace@(ctx, _) ← setupTrace (Right c) "demo-playground"
  where
    config :: IO CM.Configuration
    config = do
      c ← CM.empty
      CM.setMinSeverity c Debug
      CM.setSetupBackends c [KatipBK, AggregationBK]
      CM.setDefaultBackends c [KatipBK, AggregationBK]
      CM.setSetupScribes c [ScribeDefinition {
        scName = "stdout"
        , scKind = StdoutSK
        , scRotation = Nothing
        }
        ]
      CM.setDefaultScribes c ["StdoutSK::stdout"]
      return c
```

2. *c* is the Configuration of *trace*. In order to enable the collection and processing of measurements (min, max, mean, std-dev) *AggregationBK* is needed.

```
CM.setDefaultBackends c [KatipBK, AggregationBK]
```

in a configuration file (YAML) means

```
defaultBackends:
  – KatipBK
  – AggregationBK
```

3. Set the measurements that you want to take by changing the configuration of the *trace* using *setSubTrace*, in order to declare the namespace where we want to enable the particular measurements and the list with the kind of measurements.

```
CM.setSubTrace
    (configuration ctx)
    "demo-playground.submit-tx"
    (Just $ ObservableTrace observablesSet)
  where
    observablesSet = [MonotonicClock, MemoryStats]
```

4. Find an action to measure. e.g.:

```
runProtocolWithPipe x hdl proto ‘catch‘ (λProtocolStopped → return ())
```

and use bracketObserveIO. e.g.:

```
bracketObserveIO trace "submit-tx" $
  runProtocolWithPipe x hdl proto ‘catch‘ (λProtocolStopped → return ())
```

```
bracketObserveIO :: Trace IO → Text → IO t → IO t
bracketObserveIO logTrace0 name action = do
    logTrace ← subTrace name logTrace0
    bracketObserveIO′ (typeofTrace logTrace) logTrace action
  where
    bracketObserveIO′ :: SubTrace → Trace IO → IO t → IO t
    bracketObserveIO′ NoTrace _ act = act
    bracketObserveIO′ subtrace logTrace act = do
      mCountersid ← observeOpen subtrace logTrace
      -- run action; if an exception is caught will be logged and rethrown.
      t ← act ‘catch‘ (λ(e :: SomeException) → (logError logTrace (pack (show e)) ≫ throwM e))
      case mCountersid of
        Left openException →
          -- since observeOpen faced an exception there is no reason to call observeClose
          -- however the result of the action is returned
          logNotice logTrace ("ObserveOpen: " <> pack (show openException))
        Right countersid → do
          res ← observeClose subtrace logTrace countersid [ ]
          case res of
            Left ex → logNotice logTrace ("ObserveClose: " <> pack (show ex))
            _ → pure ()
      pure t
```

Monadic.bracketObserverM

Observes a *MonadIO m* ⇒ *m* action and adds a name to the logger name of the passed in Trace. An empty *Text* leaves the logger name untouched.

```
bracketObserveM :: (MonadCatch m, MonadIO m) ⇒ Trace IO → Text → m t → m t
bracketObserveM logTrace0 name action = do
    logTrace ← liftIO $ subTrace name logTrace0
    bracketObserveM′ (typeofTrace logTrace) logTrace action
  where
    bracketObserveM′ :: (MonadCatch m, MonadIO m) ⇒ SubTrace → Trace IO → m t → m t
    bracketObserveM′ NoTrace _ act = act
    bracketObserveM′ subtrace logTrace act = do
      mCountersid ← liftIO $ observeOpen subtrace logTrace
      -- run action; if an exception is caught will be logged and rethrown.
      t ← act ‘catch‘
        (λ(e :: SomeException) → (liftIO (logError logTrace (pack (show e)) ≫ throwM e)))
      case mCountersid of
        Left openException →
          -- since observeOpen faced an exception there is no reason to call observeClose
          -- however the result of the action is returned
          liftIO $ logNotice logTrace ("ObserveOpen: " <> pack (show openException))
        Right countersid → do
          res ← liftIO $ observeClose subtrace logTrace countersid [ ]
          case res of
            Left ex → liftIO (logNotice logTrace ("ObserveClose: " <> pack (show ex)))
            _ → pure ()
      pure t
```

observerOpen

```
observeOpen :: SubTrace → Trace IO → IO (Either SomeException CounterState)
observeOpen subtrace logTrace = (do
  identifier ← newUnique
  -- take measurement
  counters ← readCounters subtrace
  let state = CounterState identifier counters
  if counters ≡ [ ]
  then return ()
  else do
    -- send opening message to Trace
    traceNamedObject logTrace =≪
      LogObject < $ > mkLOMeta < ∗ > pure (ObserveOpen state)
  return (Right state)) ‘catch‘ (return ∘ Left)
```

observeClose

```
observeClose :: SubTrace → Trace IO → CounterState → [LogObject] → IO (Either SomeException ())
observeClose subtrace logTrace initState logObjects = (do
  let identifier = csIdentifier initState
    initialCounters = csCounters initState
  -- take measurement
  counters ← readCounters subtrace
  if counters ≡ [ ]
  then return ()
  else do
    mle ← mkLOMeta
    -- send closing message to Trace
    traceNamedObject logTrace $
      LogObject mle (ObserveClose (CounterState identifier counters))
    -- send diff message to Trace
    traceNamedObject logTrace $
      LogObject mle (ObserveDiff (CounterState identifier (diffCounters initialCounters counters)))
  -- trace the messages gathered from inside the action
  forM_ logObjects $ traceNamedObject logTrace
  return (Right ())) ‘catch‘ (return ∘ Left)
```

1.4.3 BaseTrace

Contravariant

A covariant is a functor: F A → F B
A contravariant is a functor: F B → F A

Op a b implements the inverse to 'arrow' "$getOp :: b \to a$", which when applied to a BaseTrace of type "$Op\ (m\ ())\ s$", yields "$s \to m\ ()$". In our case, *Op* accepts an action in a monad *m* with input type LogNamed LogObject (see 'Trace').

```
newtype BaseTrace m s = BaseTrace {runTrace :: Op (m ()) s}
```

contramap

A covariant functor defines the function "$fmap :: (a \to b) \to f\ a \to f\ b$". In case of a contravariant functor, it is the dual function "$contramap :: (a \to b) \to f\ b \to f\ a$" which is defined.

In the following instance, *runTrace* extracts type "$Op\ (m\ ())\ s$" to which contramap applies *f*, thus "$f\ s \to m\ ()$". The constructor BaseTrace restores "$Op\ (m\ ())\ (f\ s)$".

```
instance Contravariant (BaseTrace m) where
  contramap f = BaseTrace ∘ contramap f ∘ runTrace
```

traceWith

Accepts a Trace and some payload *s*. First it gets the contravariant from the Trace as type "$Op\ (m\ ())\ s$" and, after "$getOp::b \to a$" which translates to "$s \to m\ ()$", calls the action on the LogNamed LogObject.

```
traceWith :: BaseTrace m s → s → m ()
traceWith = getOp ∘ runTrace
```

natTrace

Natural transformation from monad *m* to monad *n*.

```
natTrace :: (forall x ∘ m x → n x) → BaseTrace m s → BaseTrace n s
natTrace nat (BaseTrace (Op tr)) = BaseTrace $ Op $ nat ∘ tr
```

noTrace

A Trace that discards all inputs.

```
noTrace :: Applicative m ⇒ BaseTrace m a
noTrace = BaseTrace $ Op $ const (pure ())
```

1.4.4 Cardano.BM.Trace

Utilities

Natural transformation from monad *m* to monad *n*.

```
natTrace :: (forall x ∘ m x → n x) → Trace m → Trace n
natTrace nat (ctx, trace) = (ctx, BaseTrace.natTrace nat trace)
```

Access type of Trace.

```
typeofTrace :: Trace m → SubTrace
typeofTrace (ctx, _) = tracetype ctx
```

Update type of Trace.

```
updateTracetype :: SubTrace → Trace m → Trace m
updateTracetype subtr (ctx, tr) = (ctx {tracetype = subtr}, tr)
```

Enter new named context

The context name is created and checked that its size is below a limit (currently 80 chars). The minimum severity that a log message must be labelled with is looked up in the configuration and recalculated.

```
appendName :: MonadIO m ⇒ LoggerName → Trace m → m (Trace m)
appendName name (ctx, trace) = do
  let prevLoggerName = loggerName ctx
      prevMinSeverity = minSeverity ctx
      newLoggerName   = appendWithDot prevLoggerName name
  globMinSeverity ← liftIO $ Config.minSeverity (configuration ctx)
  namedSeverity ← liftIO $ Config.inspectSeverity (configuration ctx) newLoggerName
  case namedSeverity of
      Nothing → return (ctx {loggerName = newLoggerName}, trace)
      Just sev → return (ctx {loggerName = newLoggerName
         , minSeverity = max (max sev prevMinSeverity) globMinSeverity}
         , trace)
appendWithDot :: LoggerName → LoggerName → LoggerName
appendWithDot "" newName = T.take 80 newName
appendWithDot xs "" = xs
appendWithDot xs newName = T.take 80 $ xs <> "." <> newName
```

Contramap a trace and produce the naming context

```
named :: BaseTrace.BaseTrace m (LogNamed i) → LoggerName → BaseTrace.BaseTrace m i
named trace name = contramap (LogNamed name) trace
```

Trace a LogObject through

```
traceNamedObject
  :: MonadIO m
  ⇒ Trace m
  → LogObject
  → m ()
traceNamedObject trace@(ctx, logTrace) lo@(LogObject _ lc) = do
  let lname = loggerName ctx
  doOutput ← case (typeofTrace trace) of
    FilterTrace filters →
      case lc of
        LogValue loname _ →
          return $ evalFilters filters (lname <> "." <> loname)
        _ →
          return $ evalFilters filters lname
    TeeTrace secName → do
      -- create a newly named copy of the LogObject
      BaseTrace.traceWith (named logTrace (lname <> "." <> secName)) lo
      return True
    _ → return True
  if doOutput
  then BaseTrace.traceWith (named logTrace lname) lo
  else return ()
```

Evaluation of FilterTrace

A filter consists of a *DropName* and a list of *UnhideNames*. If the context name matches the *DropName* filter, then at least one of the *UnhideNames* must match the name to have the evaluation of the filters return *True*.

```
evalFilters :: [(DropName, UnhideNames)] → LoggerName → Bool
evalFilters fs nm =
    all (λ(no, yes) → if (dropFilter nm no) then (unhideFilter nm yes) else True) fs
  where
    dropFilter :: LoggerName → DropName → Bool
    dropFilter name (Drop sel) = {-not -} (matchName name sel)
    unhideFilter :: LoggerName → UnhideNames → Bool
    unhideFilter _ (Unhide [ ]) = False
    unhideFilter name (Unhide us) = any (λsel → matchName name sel) us
    matchName :: LoggerName → NameSelector → Bool
    matchName name (Exact name′) = name ≡ name′
    matchName name (StartsWith prefix) = T.isPrefixOf prefix name
    matchName name (EndsWith postfix) = T.isSuffixOf postfix name
    matchName name (Contains name′) = T.isInfixOf name′ name
```

Concrete Trace on stdout

This function returns a trace with an action of type "(LogNamed LogObject) → IO ()" which will output a text message as text and all others as JSON encoded representation to the console.

TODO remove *locallock*

```
locallock :: MVar ()
locallock = unsafePerformIO $ newMVar ()
```

```
stdoutTrace :: TraceNamed IO
stdoutTrace = BaseTrace.BaseTrace $ Op $ λ(LogNamed logname (LogObject _ lc)) →
    withMVar locallock $ \_ →
      case lc of
        (LogMessage logItem) →
          output logname $ liPayload logItem
        obj →
          output logname $ toStrict (encodeToLazyText obj)
  where
    output nm msg = TIO.putStrLn $ nm <> " :: " <> msg
```

Concrete Trace into a *TVar*

```
traceInTVar :: STM.TVar [a] → BaseTrace.BaseTrace STM.STM a
traceInTVar tvar = BaseTrace.BaseTrace $ Op $ λa → STM.modifyTVar tvar ((:) a)
traceInTVarIO :: STM.TVar [LogObject] → TraceNamed IO
traceInTVarIO tvar = BaseTrace.BaseTrace $ Op $ λln →
  STM.atomically $ STM.modifyTVar tvar ((:) (lnItem ln))
traceNamedInTVarIO :: STM.TVar [LogNamed LogObject] → TraceNamed IO
traceNamedInTVarIO tvar = BaseTrace.BaseTrace $ Op $ λln →
  STM.atomically $ STM.modifyTVar tvar ((:) ln)
```

Check a log item's severity against the Trace's minimum severity

do we need three different minSeverity defined?

We do a lookup of the global minSeverity in the configuration. And, a lookup of the minSeverity for the current named context. These values might have changed in the meanwhile.
A third filter is the minSeverity defined in the current context.

```
traceConditionally
  :: MonadIO m
  ⇒ Trace m
  → LogObject
  → m ()
traceConditionally logTrace@(ctx, _) msg@(LogObject _ (LogMessage item)) = do
  globminsev ← liftIO $ Config.minSeverity (configuration ctx)
```

```
    globnamesev ← liftIO $ Config.inspectSeverity (configuration ctx) (loggerName ctx)
    let minsev = max (minSeverity ctx) $ max globminsev (fromMaybe Debug globnamesev)
        flag = (liSeverity item) ⩾ minsev
    when flag $ traceNamedObject logTrace msg
traceConditionally logTrace logObject =
    traceNamedObject logTrace logObject
```

Enter message into a trace

The function traceNamedItem creates a LogObject and threads this through the action defined in the Trace.

```
traceNamedItem
    :: MonadIO m
    ⇒ Trace m
    → LogSelection
    → Severity
    → T.Text
    → m ()
traceNamedItem trace p s m =
    traceConditionally trace =≪
        LogObject < $ > liftIO mkLOMeta
            < ∗ > pure (LogMessage LogItem {liSelection = p
                ,liSeverity = s
                ,liPayload  = m
                })
```

Logging functions

```
logDebug, logInfo, logNotice, logWarning, logError, logCritical, logAlert, logEmergency
    :: MonadIO m ⇒ Trace m → T.Text → m ()
logDebug     logTrace = traceNamedItem logTrace Both Debug
logInfo      logTrace = traceNamedItem logTrace Both Info
logNotice    logTrace = traceNamedItem logTrace Both Notice
logWarning   logTrace = traceNamedItem logTrace Both Warning
logError     logTrace = traceNamedItem logTrace Both Error
logCritical  logTrace = traceNamedItem logTrace Both Critical
logAlert     logTrace = traceNamedItem logTrace Both Alert
logEmergency logTrace = traceNamedItem logTrace Both Emergency
logDebugS, logInfoS, logNoticeS, logWarningS, logErrorS, logCriticalS, logAlertS, logEmergencyS
    :: MonadIO m ⇒ Trace m → T.Text → m ()
logDebugS    logTrace = traceNamedItem logTrace Private Debug
logInfoS     logTrace = traceNamedItem logTrace Private Info
logNoticeS   logTrace = traceNamedItem logTrace Private Notice
logWarningS  logTrace = traceNamedItem logTrace Private Warning
logErrorS    logTrace = traceNamedItem logTrace Private Error
```

```
logCriticalS  logTrace = traceNamedItem logTrace Private Critical
logAlertS     logTrace = traceNamedItem logTrace Private Alert
logEmergencyS logTrace = traceNamedItem logTrace Private Emergency

logDebugP, logInfoP, logNoticeP, logWarningP, logErrorP, logCriticalP, logAlertP, logEmergencyP
  :: MonadIO m ⇒ Trace m → T.Text → m ()
logDebugP     logTrace = traceNamedItem logTrace Public Debug
logInfoP      logTrace = traceNamedItem logTrace Public Info
logNoticeP    logTrace = traceNamedItem logTrace Public Notice
logWarningP   logTrace = traceNamedItem logTrace Public Warning
logErrorP     logTrace = traceNamedItem logTrace Public Error
logCriticalP  logTrace = traceNamedItem logTrace Public Critical
logAlertP     logTrace = traceNamedItem logTrace Public Alert
logEmergencyP logTrace = traceNamedItem logTrace Public Emergency

logDebugUnsafeP, logInfoUnsafeP, logNoticeUnsafeP, logWarningUnsafeP, logErrorUnsafeP,
  logCriticalUnsafeP, logAlertUnsafeP, logEmergencyUnsafeP
  :: MonadIO m ⇒ Trace m → T.Text → m ()
logDebugUnsafeP     logTrace = traceNamedItem logTrace PublicUnsafe Debug
logInfoUnsafeP      logTrace = traceNamedItem logTrace PublicUnsafe Info
logNoticeUnsafeP    logTrace = traceNamedItem logTrace PublicUnsafe Notice
logWarningUnsafeP   logTrace = traceNamedItem logTrace PublicUnsafe Warning
logErrorUnsafeP     logTrace = traceNamedItem logTrace PublicUnsafe Error
logCriticalUnsafeP  logTrace = traceNamedItem logTrace PublicUnsafe Critical
logAlertUnsafeP     logTrace = traceNamedItem logTrace PublicUnsafe Alert
logEmergencyUnsafeP logTrace = traceNamedItem logTrace PublicUnsafe Emergency
```

subTrace

Transforms the input Trace according to the Configuration using the logger name of the current Trace appended with the new name. If the empty *Text* is passed, then the logger name remains untouched.

```
subTrace :: MonadIO m ⇒ T.Text → Trace m → m (Trace m)
subTrace name tr@(ctx, _) = do
  let newName = appendWithDot (loggerName ctx) name
  subtrace0 ← liftIO $ Config.findSubTrace (configuration ctx) newName
  let subtrace = case subtrace0 of Nothing → Neutral; Just str → str
  case subtrace of
    Neutral      → do
                     tr' ← appendName name tr
                     return $ updateTracetype subtrace tr'
    UntimedTrace → do
                     tr' ← appendName name tr
                     return $ updateTracetype subtrace tr'
    TeeTrace _   → do
                     tr' ← appendName name tr
                     return $ updateTracetype subtrace tr'
    FilterTrace _ → do
```

```
                    tr′ ← appendName name tr
                    return $ updateTracetype subtrace tr′
    NoTrace        → return $ updateTracetype subtrace (ctx, BaseTrace.BaseTrace $ Op $ \_ → pure ())
    DropOpening    → return $ updateTracetype subtrace (ctx, BaseTrace.BaseTrace $ Op $
                    λ(LogNamed _ lo@(LogObject _ lc)) → do
                        case lc of
                            ObserveOpen _ → return ()
                            _ → traceNamedObject tr lo)
    ObservableTrace _ → do
                    tr′ ← appendName name tr
                    return $ updateTracetype subtrace tr′
```

1.4.5 Cardano.BM.Setup

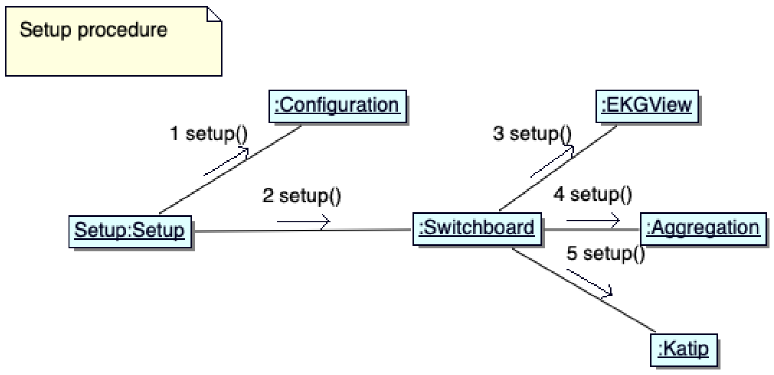


Figure 1.3: Setup procedure

setupTrace

Setup a new Trace (Trace) with either a given Configuration (Configuration.Model) or a *FilePath* to a configuration file. After all tracing operations have ended; shutdownTrace must be called.

```
setupTrace :: MonadIO m ⇒ Either FilePath Config.Configuration → Text → m (Trace m)
setupTrace (Left cfgFile) name = do
    c ← liftIO $ Config.setup cfgFile
    setupTrace_ c name
setupTrace (Right c) name = setupTrace_ c name
setupTrace_ :: MonadIO m ⇒ Config.Configuration → Text → m (Trace m)
setupTrace_ c name = do
    sb ← liftIO $ Switchboard.realize c
    sev ← liftIO $ Config.minSeverity c
    ctx ← liftIO $ newContext "" c sev sb
    tr ← subTrace name $ natTrace liftIO (ctx, Switchboard.mainTrace sb)
    liftIO $ addFinalizer tr $ shutdownTrace tr
    return tr
```

shutdownTrace

Shut down a Trace and all the Traces related to it.

```
shutdownTrace :: MonadIO m ⇒ Trace m → IO ()
shutdownTrace (ctx, _) = shutdown ctx
```

withTrace

```
withTrace :: (MonadIO m, MonadMask m) ⇒ Config.Configuration → Text → (Trace m → m t) → m t
withTrace cfg name action =
    bracket (setupTrace (Right cfg) name) (liftIO < $ > shutdownTrace) action
```

newContext

```
newContext :: LoggerName
    → Config.Configuration
    → Severity
    → Switchboard.Switchboard
    → IO TraceContext
newContext name cfg sev sb = do
    return $ TraceContext {
        loggerName = name
        , configuration = cfg
        , minSeverity = sev
        , tracetype = Neutral
        , shutdown = unrealize sb
        }
```

1.4.6 Cardano.BM.Counters

Here the platform is chosen on which we compile this program.
Currently, we mainly support *Linux* with its 'proc' filesystem.

```
 {-# LANGUAGE CPP #-}
# if defined (linux_HOST_OS)
# define LINUX
# endif
module Cardano.BM.Counters
    (
        Platform.readCounters
    , diffTimeObserved
    , getMonoClock
    ) where
 # ifdef LINUX
import qualified Cardano.BM.Counters.Linux as Platform
 # else
import qualified Cardano.BM.Counters.Dummy as Platform
 # endif
import Cardano.BM.Counters.Common (getMonoClock)
import Cardano.BM.Data.Aggregated (Measurable (..))
import Cardano.BM.Data.Counter
```

Calculate difference between clocks

```
diffTimeObserved :: CounterState → CounterState → Measurable
diffTimeObserved (CounterState id0 startCounters) (CounterState id1 endCounters) =
    let
      startTime = getMonotonicTime startCounters
      endTime = getMonotonicTime endCounters
    in
    if (id0 ≡ id1)
      then endTime − startTime
      else error "these clocks are not from the same experiment"
  where
    getMonotonicTime counters = case (filter isMonotonicClockCounter counters) of
      [(Counter MonotonicClockTime _ mus)] → mus
      _ → error "A time measurement is missing!"
    isMonotonicClockCounter :: Counter → Bool
    isMonotonicClockCounter = (MonotonicClockTime ≡) ∘ cType
```

1.4.7 Cardano.BM.Counters.Common

Common functions that serve *readCounters* on all platforms.

```
nominalTimeToMicroseconds :: Word64 → Microsecond
nominalTimeToMicroseconds = fromMicroseconds ∘ toInteger ∘ (‘div‘1000)
```

Read monotonic clock

```
getMonoClock :: IO [Counter]
getMonoClock = do
  t ← getMonotonicTimeNSec
  return [Counter MonotonicClockTime "monoclock" $ Microseconds (t ‘div‘ 1000)]
```

Read GHC RTS statistics

Read counters from GHC's *RTS* (runtime system). The values returned are as per the last GC (garbage collection) run.

```
readRTSStats :: IO [Counter]
readRTSStats = do
    iscollected ← GhcStats.getRTSStatsEnabled
    if iscollected
      then ghcstats
      else return [ ]
  where
    ghcstats :: IO [Counter]
    ghcstats = do
      -- need to run GC?
      rts ← GhcStats.getRTSStats
      let getrts = ghcval rts
      return [getrts (Bytes ∘ fromIntegral ∘ GhcStats.allocated_bytes, "bytesAllocated")
        ,getrts (Bytes ∘ fromIntegral ∘ GhcStats.max_live_bytes, "liveBytes")
        ,getrts (Bytes ∘ fromIntegral ∘ GhcStats.max_large_objects_bytes, "largeBytes")
        ,getrts (Bytes ∘ fromIntegral ∘ GhcStats.max_compact_bytes, "compactBytes")
        ,getrts (Bytes ∘ fromIntegral ∘ GhcStats.max_slop_bytes, "slopBytes")
        ,getrts (Bytes ∘ fromIntegral ∘ GhcStats.max_mem_in_use_bytes, "usedMemBytes")
        ,getrts (Nanoseconds ∘ fromIntegral ∘ GhcStats.gc_cpu_ns, "gcCpuNs")
        ,getrts (Nanoseconds ∘ fromIntegral ∘ GhcStats.gc_elapsed_ns, "gcElapsedNs")
        ,getrts (Nanoseconds ∘ fromIntegral ∘ GhcStats.cpu_ns, "cpuNs")
        ,getrts (Nanoseconds ∘ fromIntegral ∘ GhcStats.elapsed_ns, "elapsedNs")
        ,getrts (PureI ∘ toInteger ∘ GhcStats.gcs, "gcNum")
        ,getrts (PureI ∘ toInteger ∘ GhcStats.major_gcs, "gcMajorNum")
        ]
    ghcval :: GhcStats.RTSStats → ((GhcStats.RTSStats → Measurable), Text) → Counter
    ghcval s (f, n) = Counter RTSStats n $ (f s)
```

1.4.8 Cardano.BM.Counters.Dummy

This is a dummy definition of *readCounters* on platforms that do not support the 'proc' filesystem from which we would read the counters.

The only supported measurements are monotonic clock time and RTS statistics for now.

```
readCounters :: SubTrace → IO [Counter]
readCounters NoTrace         = return [ ]
readCounters Neutral         = return [ ]
readCounters (TeeTrace _)    = return [ ]
readCounters (FilterTrace _) = return [ ]
readCounters UntimedTrace    = return [ ]
readCounters DropOpening     = return [ ]
readCounters (ObservableTrace tts) = foldrM (λ(sel, fun) a →
    if any (≡ sel) tts
```

```
        then (fun ≫= λxs → return $ a ++ xs)
        else return a)[ ] selectors
    where
        selectors = [(MonotonicClock, getMonoClock)
            -- , (MemoryStats, readProcStatM)
           -- , (ProcessStats, readProcStats)
                -- , (IOStats, readProcIO)
             , (GhcRtsStats, readRTSStats)
                                    ]
```

1.4.9 Cardano.BM.Counters.Linux

we have to expand the *readMemStats* function
to read full data from *proc*

```
readCounters :: SubTrace → IO [Counter]
readCounters NoTrace           = return [ ]
readCounters Neutral           = return [ ]
readCounters (TeeTrace _)      = return [ ]
readCounters (FilterTrace _)   = return [ ]
readCounters UntimedTrace      = return [ ]
readCounters DropOpening       = return [ ]
readCounters (ObservableTrace tts) = foldrM (λ(sel, fun) a →
        if any (≡ sel) tts
        then (fun ≫= λxs → return $ a ++ xs)
        else return a)[ ] selectors
    where
        selectors = [(MonotonicClock, getMonoClock)
            , (MemoryStats, readProcStatM)
            , (ProcessStats, readProcStats)
            , (IOStats, readProcIO)
            , (GhcRtsStats, readRTSStats)
            ]

pathProc :: FilePath
pathProc = "/proc/"
pathProcStat :: ProcessID → FilePath
pathProcStat pid = pathProc </> (show pid) </> "stat"
pathProcStatM :: ProcessID → FilePath
pathProcStatM pid = pathProc </> (show pid) </> "statm"
pathProcIO :: ProcessID → FilePath
pathProcIO pid = pathProc </> (show pid) </> "io"
```

Reading from a file in /proc/<pid >

```
readProcList :: FilePath → IO [Integer]
readProcList fp = do
```

```
    cs ← readFile fp
    return $ map (λs → maybe 0 id $ (readMaybe s :: Maybe Integer)) (words cs)
```

readProcStatM - /proc/<pid >/statm

```
/proc/[pid]/statm
       Provides information about memory usage, measured in pages.  The columns are:
              size       (1) total program size
                            (same as VmSize in /proc/[pid]/status)
              resident   (2) resident set size
                            (same as VmRSS in /proc/[pid]/status)
              shared     (3) number of resident shared pages (i.e., backed by a file)
                            (same as RssFile+RssShmem in /proc/[pid]/status)
              text       (4) text (code)
              lib        (5) library (unused since Linux 2.6; always 0)
              data       (6) data + stack
              dt         (7) dirty pages (unused since Linux 2.6; always 0)
```

```
readProcStatM :: IO [Counter]
readProcStatM = do
    pid ← getProcessID
    ps0 ← readProcList (pathProcStatM pid)
    let ps = zip colnames ps0
      psUseful = filter (("unused" ≢) ∘ fst) ps
    return $ map (λ(n, i) → Counter MemoryCounter n (PureI i)) psUseful
  where
    colnames :: [Text]
    colnames = ["size", "resident", "shared", "text", "unused", "data", "unused"]
```

readProcStats - //proc//<pid >//stat

```
/proc/[pid]/stat
       Status  information about the process.  This is used by ps(1).  It is defined in the kernel source file
       fs/proc/array.c.

       The fields, in order, with their proper scanf(3) format specifiers, are listed below.  Whether  or  not
       certain   of   these   fields   display   valid   information   is   governed   by   a   ptrace   access   mode
       PTRACE_MODE_READ_FSCREDS | PTRACE_MODE_NOAUDIT check (refer to ptrace(2)).  If the check denies access,
       then the field value is displayed as 0.  The affected fields are indicated with the marking [PT].

       (1) pid  %d
                     The process ID.

       (2) comm  %s
                     The  filename  of  the  executable,  in parentheses.  This is visible whether or not the exe-
                     cutable is swapped out.

       (3) state  %c
                     One of the following characters, indicating process state:

                     R  Running

                     S  Sleeping in an interruptible wait

                     D  Waiting in uninterruptible disk sleep

                     Z  Zombie
```

```
              T  Stopped (on a signal) or (before Linux 2.6.33) trace stopped

              t  Tracing stop (Linux 2.6.33 onward)

              W  Paging (only before Linux 2.6.0)

              X  Dead (from Linux 2.6.0 onward)

              x  Dead (Linux 2.6.33 to 3.13 only)

              K  Wakekill (Linux 2.6.33 to 3.13 only)

              W  Waking (Linux 2.6.33 to 3.13 only)

              P  Parked (Linux 3.9 to 3.13 only)

(4) ppid  %d
              The PID of the parent of this process.

(5) pgrp  %d
              The process group ID of the process.

(6) session  %d
              The session ID of the process.

(7) tty_nr  %d
              The controlling terminal of the process.  (The minor device number is contained in the combi-
              nation of bits 31 to 20 and 7 to 0; the major device number is in bits 15 to 8.)

(8) tpgid  %d
              The ID of the foreground process group of the controlling terminal of the process.

(9) flags  %u
              The  kernel  flags  word of the process.  For bit meanings, see the PF_* defines in the Linux
              kernel source file include/linux/sched.h.  Details depend on the kernel version.

              The format for this field was %lu before Linux 2.6.

(10) minflt  %lu
              The number of minor faults the process has made which have not required loading a memory page
              from disk.

(11) cminflt  %lu
              The number of minor faults that the process's waited-for children have made.

(12) majflt  %lu
              The  number  of  major  faults the process has made which have required loading a memory page
              from disk.

(13) cmajflt  %lu
              The number of major faults that the process's waited-for children have made.

(14) utime  %lu
              Amount of time that this process has been scheduled in user mode,  measured  in  clock  ticks
              (divide by sysconf(_SC_CLK_TCK)).  This includes guest time, guest_time (time spent running a
              virtual CPU, see below), so that applications that are not aware of the guest time  field  do
              not lose that time from their calculations.

(15) stime  %lu
              Amount  of  time that this process has been scheduled in kernel mode, measured in clock ticks
              (divide by sysconf(_SC_CLK_TCK)).

(16) cutime  %ld
              Amount of time that this process's waited-for children have been scheduled in user mode, mea-
              sured  in  clock ticks (divide by sysconf(_SC_CLK_TCK)).  (See also times(2).)  This includes
              guest time, cguest_time (time spent running a virtual CPU, see below).

(17) cstime  %ld
```

```
              Amount of time that this process's waited-for children have been scheduled  in  kernel  mode,
              measured in clock ticks (divide by sysconf(_SC_CLK_TCK)).

       (18) priority  %ld
              (Explanation  for  Linux  2.6)  For  processes  running a real-time scheduling policy (policy
              below; see sched_setscheduler(2)), this is the negated scheduling priority, minus  one;  that
              is,  a  number  in  the range -2 to -100, corresponding to real-time priorities 1 to 99.  For
              processes running under a non-real-time scheduling policy, this is the raw nice  value  (set‐
              priority(2))  as  represented in the kernel.  The kernel stores nice values as numbers in the
              range 0 (high) to 39 (low), corresponding to the user-visible nice range of -20 to 19.

       (19) nice  %ld
              The nice value (see setpriority(2)), a value in the range 19 (low priority) to -20 (high pri‐
              ority).

       (20) num_threads  %ld
              Number of threads in this process (since Linux 2.6).  Before kernel 2.6, this field was  hard
              coded to 0 as a placeholder for an earlier removed field.

       (21) itrealvalue  %ld
              The  time in jiffies before the next SIGALRM is sent to the process due to an interval timer.
              Since kernel 2.6.17, this field is no longer maintained, and is hard coded as 0.

       (22) starttime  %llu
              The time the process started after system boot.  In kernels before Linux 2.6, this value  was
              expressed  in  jiffies.   Since  Linux  2.6, the value is expressed in clock ticks (divide by
              sysconf(_SC_CLK_TCK)).

              The format for this field was %lu before Linux 2.6.

       (23) vsize  %lu
              Virtual memory size in bytes.

       (24) rss  %ld
              Resident Set Size: number of pages the process has in real memory.  This is  just  the  pages
              which  count  toward  text, data, or stack space.  This does not include pages which have not
              been demand-loaded in, or which are swapped out.

       (25) rsslim  %lu
              Current soft limit in bytes on the rss of the process; see the description of  RLIMIT_RSS  in
              getrlimit(2).

       (26) startcode  %lu  [PT]
              The address above which program text can run.

       (27) endcode  %lu  [PT]
              The address below which program text can run.

       (28) startstack  %lu  [PT]
              The address of the start (i.e., bottom) of the stack.

       (29) kstkesp  %lu  [PT]
              The current value of ESP (stack pointer), as found in the kernel stack page for the process.

       (30) kstkeip  %lu  [PT]
              The current EIP (instruction pointer).

       (31) signal  %lu
              The  bitmap of pending signals, displayed as a decimal number.  Obsolete, because it does not
              provide information on real-time signals; use /proc/[pid]/status instead.

       (32) blocked  %lu
              The bitmap of blocked signals, displayed as a decimal number.  Obsolete, because it does  not
              provide information on real-time signals; use /proc/[pid]/status instead.

       (33) sigignore  %lu
              The  bitmap of ignored signals, displayed as a decimal number.  Obsolete, because it does not
              provide information on real-time signals; use /proc/[pid]/status instead.
```

```
(34) sigcatch  %lu
          The bitmap of caught signals, displayed as a decimal number.  Obsolete, because it  does  not
          provide information on real-time signals; use /proc/[pid]/status instead.

(35) wchan  %lu  [PT]
          This  is  the  "channel" in which the process is waiting.  It is the address of a location in
          the kernel where the process is sleeping.  The corresponding symbolic name can  be  found  in
          /proc/[pid]/wchan.

(36) nswap  %lu
          Number of pages swapped (not maintained).

(37) cnswap  %lu
          Cumulative nswap for child processes (not maintained).

(38) exit_signal  %d  (since Linux 2.1.22)
          Signal to be sent to parent when we die.

(39) processor  %d  (since Linux 2.2.8)
          CPU number last executed on.

(40) rt_priority  %u  (since Linux 2.5.19)
          Real-time  scheduling priority, a number in the range 1 to 99 for processes scheduled under a
          real-time policy, or 0, for non-real-time processes (see sched_setscheduler(2)).

(41) policy  %u  (since Linux 2.5.19)
          Scheduling policy  (see  sched_setscheduler(2)).  Decode  using  the  SCHED_*  constants  in
          linux/sched.h.

          The format for this field was %lu before Linux 2.6.22.

(42) delayacct_blkio_ticks  %llu  (since Linux 2.6.18)
          Aggregated block I/O delays, measured in clock ticks (centiseconds).

(43) guest_time  %lu  (since Linux 2.6.24)
          Guest  time  of  the process (time spent running a virtual CPU for a guest operating system),
          measured in clock ticks (divide by sysconf(_SC_CLK_TCK)).

(44) cguest_time  %ld  (since Linux 2.6.24)
          Guest  time   of   the   process's   children,   measured   in   clock   ticks   (divide   by
          sysconf(_SC_CLK_TCK)).

(45) start_data  %lu  (since Linux 3.3)  [PT]
          Address above which program initialized and uninitialized (BSS) data are placed.

(46) end_data  %lu  (since Linux 3.3)  [PT]
          Address below which program initialized and uninitialized (BSS) data are placed.

(47) start_brk  %lu  (since Linux 3.3)  [PT]
          Address above which program heap can be expanded with brk(2).

(48) arg_start  %lu  (since Linux 3.5)  [PT]
          Address above which program command-line arguments (argv) are placed.

(49) arg_end  %lu  (since Linux 3.5)  [PT]
          Address below program command-line arguments (argv) are placed.

(50) env_start  %lu  (since Linux 3.5)  [PT]
          Address above which program environment is placed.

(51) env_end  %lu  (since Linux 3.5)  [PT]
          Address below which program environment is placed.

(52) exit_code  %d  (since Linux 3.5)  [PT]
          The thread's exit status in the form reported by waitpid(2).
```

```
readProcStats :: IO [Counter]
readProcStats = do
      pid ← getProcessID
      ps0 ← readProcList (pathProcStat pid)
      let ps = zip colnames ps0
         psUseful = filter (("unused" ≢) ∘ fst) ps
      return $ map (λ(n,i) → Counter StatInfo n (PureI i)) psUseful
   where
      colnames :: [Text]
      colnames = ["pid","unused","unused","ppid","pgrp","session","ttynr","tpgid","flags","minfl
         ,"cminflt","majflt","cmajflt","utime","stime","cutime","cstime","priority","nice","num
         ,"itrealvalue","starttime","vsize","rss","rsslim","startcode","endcode","startstack","
         ,"signal","blocked","sigignore","sigcatch","wchan","nswap","cnswap","exitsignal","proc
         ,"policy","blkio","guesttime","cguesttime","startdata","enddata","startbrk","argstart"
         ,"envend","exitcode"
         ]
```

readProcIO - //proc//<pid >//io

```
 /proc/[pid]/io (since kernel 2.6.20)
        This file contains I/O statistics for the process, for example:

               # cat /proc/3828/io
               rchar: 323934931
               wchar: 323929600
               syscr: 632687
               syscw: 632675
               read_bytes: 0
               write_bytes: 323932160
               cancelled_write_bytes: 0

        The fields are as follows:

        rchar: characters read
               The number of bytes which this task has caused to be read from storage.  This is simply the  sum
               of bytes which this process passed to read(2) and similar system calls.  It includes things such
               as terminal I/O and is unaffected by whether or not actual physical disk I/O was  required  (the
               read might have been satisfied from pagecache).

        wchar: characters written
               The  number  of bytes which this task has caused, or shall cause to be written to disk.  Similar
               caveats apply here as with rchar.

        syscr: read syscalls
               Attempt to count the number of read I/O operations-that is, system calls  such  as  read(2)  and
               pread(2).

        syscw: write syscalls
               Attempt  to  count the number of write I/O operations-that is, system calls such as write(2) and
               pwrite(2).

        read_bytes: bytes read
               Attempt to count the number of bytes which this process really did cause to be fetched from  the
               storage layer.  This is accurate for block-backed filesystems.

        write_bytes: bytes written
               Attempt to count the number of bytes which this process caused to be sent to the storage layer.

        cancelled_write_bytes:
               The  big  inaccuracy  here  is truncate.  If a process writes 1MB to a file and then deletes the
```

```
          file, it will in fact perform no writeout.  But it will have been accounted as having caused 1MB
          of  write.   In other words: this field represents the number of bytes which this process caused
          to not happen, by truncating pagecache.  A task can cause "negative"  I/O  too.   If  this  task
          truncates  some  dirty  pagecache,  some  I/O  which another task has been accounted for (in its
          write\_bytes) will not be happening.

    Note: In the current implementation, things are a bit racy  on  32-bit  systems:  if  process  A  reads
    process  B's  /proc/[pid]/io  while process B is updating one of these 64-bit counters, process A could
    see an intermediate result.

    Permission to access this file is governed by a ptrace access mode PTRACE\_MODE\_READ\_FSCREDS check;  see
    ptrace(2).
```

```
readProcIO :: IO [Counter]
readProcIO = do
    pid ← getProcessID
    ps0 ← readProcList (pathProcIO pid)
    let ps = zip3 colnames ps0 units
    return $ map (λ(n,i,u) → Counter IOCounter n (u i)) ps
  where
    colnames :: [Text]
    colnames = ["rchar","wchar","syscr","syscw","rbytes","wbytes","cxwbytes"]
    units = [Bytes ∘ fromInteger, Bytes ∘ fromInteger, PureI, PureI, Bytes ∘ fromInteger, Bytes ∘ fromInteger, Bytes
```

1.4.10 Cardano.BM.Data.Aggregated

Measurable

A Measurable may consist of different types of values. Time measurements are strict, so are *Bytes* which are externally measured. The real or integral numeric values are lazily linked, so we can decide later to drop them.

```
data Measurable = Microseconds {-# UNPACK #-} !Word64
    | Nanoseconds  {-# UNPACK #-} !Word64
    | Seconds      {-# UNPACK #-} !Word64
    | Bytes        {-# UNPACK #-} !Word64
    | PureD        Double
    | PureI        Integer
    | Severity     S.Severity
  deriving (Eq, Read, Generic, ToJSON)
```

Measurable can be transformed to an integral value.

```
instance Ord Measurable where
  compare (Seconds a) (Seconds b)              = compare a b
  compare (Microseconds a) (Microseconds b)    = compare a b
  compare (Nanoseconds a) (Nanoseconds b)      = compare a b
  compare (Seconds a) (Microseconds b)         = compare (a ∗ 1000000) b
  compare (Nanoseconds a) (Microseconds b)     = compare a (b ∗ 1000)
  compare (Seconds a) (Nanoseconds b)          = compare (a ∗ 1000000000) b
  compare a@(Microseconds _) b@(Nanoseconds _) = compare b a
```

```
    compare a@(Microseconds _) b@(Seconds _) = compare b a
    compare a@(Nanoseconds _) b@(Seconds _)  = compare b a
    compare (Bytes a) (Bytes b)               = compare a b
    compare (PureD a) (PureD b)               = compare a b
    compare (PureI a) (PureI b)               = compare a b
    compare (Severity a) (Severity b)         = compare a b
    compare (PureI a) (Seconds b)      | a ⩾ 0 = compare a (toInteger b)
    compare (PureI a) (Microseconds b) | a ⩾ 0 = compare a (toInteger b)
    compare (PureI a) (Nanoseconds b)  | a ⩾ 0 = compare a (toInteger b)
    compare (PureI a) (Bytes b)        | a ⩾ 0 = compare a (toInteger b)
    compare a@(Seconds _) b@(PureI _)         = compare b a
    compare a@(Microseconds _) b@(PureI _)    = compare b a
    compare a@(Nanoseconds _) b@(PureI _)     = compare b a
    compare a@(Bytes _) b@(PureI _)           = compare b a
    compare a@(PureD _) (PureI b)             = compare (getInteger a) b
    compare a@(PureI _) b@(PureD _)           = compare b a
    compare a b                               = error $ "cannot compare " ++ (showType a) ++ " " ++ (show a) +
```

Measurable can be transformed to an integral value.

```
  getInteger :: Measurable → Integer
  getInteger (Microseconds a) = toInteger a
  getInteger (Nanoseconds a)  = toInteger a
  getInteger (Seconds a)      = toInteger a
  getInteger (Bytes a)        = toInteger a
  getInteger (PureI a)        = a
  getInteger (PureD a)        = round a
  getInteger (Severity a)     = toInteger (fromEnum a)
```

Measurable can be transformed to a rational value.

```
  getDouble :: Measurable → Double
  getDouble (Microseconds a) = fromIntegral a
  getDouble (Nanoseconds a)  = fromIntegral a
  getDouble (Seconds a)      = fromIntegral a
  getDouble (Bytes a)        = fromIntegral a
  getDouble (PureI a)        = fromInteger a
  getDouble (PureD a)        = a
  getDouble (Severity a)     = fromIntegral (fromEnum a)
```

It is a numerical value, thus supports functions to operate on numbers.

```
  instance Num Measurable where
    (+) (Microseconds a) (Microseconds b) = Microseconds (a + b)
    (+) (Nanoseconds a) (Nanoseconds b)   = Nanoseconds (a + b)
    (+) (Seconds a)     (Seconds b)       = Seconds     (a + b)
    (+) (Bytes a)       (Bytes b)         = Bytes       (a + b)
    (+) (PureI a)       (PureI b)         = PureI       (a + b)
    (+) (PureD a)       (PureD b)         = PureD       (a + b)
    (+) _ _                                    = error "Trying to add values with different units"
    (*) (Microseconds a) (Microseconds b) = Microseconds (a * b)
    (*) (Nanoseconds a)  (Nanoseconds b)  = Nanoseconds (a * b)
    (*) (Seconds a)      (Seconds b)      = Seconds      (a * b)
    (*) (Bytes a)        (Bytes b)        = Bytes        (a * b)
    (*) (PureI a)        (PureI b)        = PureI        (a * b)
    (*) (PureD a)        (PureD b)        = PureD        (a * b)
    (*) _ _                                    = error "Trying to multiply values with different units"
    abs (Microseconds a) = Microseconds (abs a)
    abs (Nanoseconds a)  = Nanoseconds (abs a)
    abs (Seconds a)      = Seconds      (abs a)
    abs (Bytes a)        = Bytes        (abs a)
    abs (PureI a)        = PureI        (abs a)
    abs (PureD a)        = PureD        (abs a)
    abs (Severity _)     = error "cannot compute absolute value for Severity"
    signum (Microseconds a) = Microseconds (signum a)
    signum (Nanoseconds a)  = Nanoseconds (signum a)
    signum (Seconds a)      = Seconds      (signum a)
    signum (Bytes a)        = Bytes        (signum a)
    signum (PureI a)        = PureI        (signum a)
    signum (PureD a)        = PureD        (signum a)
    signum (Severity _)     = error "cannot compute sign of Severity"
    negate (Microseconds a) = Microseconds (negate a)
    negate (Nanoseconds a)  = Nanoseconds (negate a)
    negate (Seconds a)      = Seconds      (negate a)
    negate (Bytes a)        = Bytes        (negate a)
    negate (PureI a)        = PureI        (negate a)
    negate (PureD a)        = PureD        (negate a)
    negate (Severity _)     = error "cannot negate Severity"
    fromInteger = PureI
```

Pretty printing of Measurable.

```
instance Show Measurable where
    show (Microseconds a) = show a
    show (Nanoseconds a)  = show a
    show (Seconds a)      = show a
    show (Bytes a)        = show a
    show (PureI a)        = show a
    show (PureD a)        = show a
    show (Severity a)     = show a
showUnits :: Measurable → String
showUnits (Microseconds _) = " µs"
showUnits (Nanoseconds _)  = " ns"
showUnits (Seconds _)      = " s"
showUnits (Bytes _)        = " B"
showUnits (PureI _)        = ""
showUnits (PureD _)        = ""
showUnits (Severity _)     = ""

showType :: Measurable → String
showType (Microseconds _) = "Microseconds"
showType (Nanoseconds _) = "Nanoseconds"
showType (Seconds _)      = "Seconds"
showType (Bytes _)        = "Bytes"
showType (PureI _)        = "PureI"
showType (PureD _)        = "PureD"
showType (Severity _)     = "Severity"

-- show in S.I. units
showSI :: Measurable → String
showSI (Microseconds a) = show (fromFloatDigits ((fromIntegral a) / (1000000 :: Float))) ++
                            showUnits (Seconds a)
showSI (Nanoseconds a) = show (fromFloatDigits ((fromIntegral a) / (1000000000 :: Float))) ++
                            showUnits (Seconds a)
showSI v@(Seconds a)   = show a ++ showUnits v
showSI v@(Bytes a)     = show a ++ showUnits v
showSI v@(PureI a)     = show a ++ showUnits v
showSI v@(PureD a)     = show a ++ showUnits v
showSI v@(Severity a)  = show a ++ showUnits v
```

Stats

A Stats statistics is strictly computed.

```
data BaseStats = BaseStats {
  fmin :: !Measurable,
  fmax :: !Measurable,
  fcount ::  {-# UNPACK #-}  ! Int,
  fsum_A ::  {-# UNPACK #-}  ! Double,
  fsum_B ::  {-# UNPACK #-}  ! Double
  } deriving (Generic, ToJSON, Show)

instance Eq BaseStats where
  (BaseStats mina maxa counta sumAa sumBa) ≡ (BaseStats minb maxb countb sumAb sumBb) =
    mina ≡ minb ∧ maxa ≡ maxb ∧ counta ≡ countb ∧
    abs (sumAa − sumAb) < 1.0e−4 ∧
    abs (sumBa − sumBb) < 1.0e−4

data Stats = Stats {
  flast  :: !Measurable,
  fold   :: !Measurable,
  fbasic :: !BaseStats,
  fdelta :: !BaseStats,
  ftimed :: !BaseStats
  } deriving (Eq, Generic, ToJSON, Show)

meanOfStats :: BaseStats → Double
meanOfStats = fsum_A
```

```
stdevOfStats :: BaseStats → Double
stdevOfStats s =
  if fcount s < 2
  then 0
  else sqrt $ (fsum_B s) / (fromInteger $ fromIntegral (fcount s) − 1)
```

instance *Semigroup* Stats disabled for the moment, because not needed.

We use a parallel algorithm to update the estimation of mean and variance from two sample statistics. (see https://en.wikipedia.org/wiki/Algorithms_for_calculating_variance#Parallel_algorit

```
instance Semigroup Stats where
  (<>) a b = let countа = fcount a
    countb = fcount b
    newcount = counta + countb
    delta = fsum_A b − fsum_A a
    in
    Stats {flast = flast b-- right associative
      ,fmin    = min (fmin a) (fmin b)
      ,fmax    = max (fmax a) (fmax b)
      ,fcount = newcount
      ,fsum_A = fsum_A a + (delta / fromInteger newcount)
      ,fsum_B = fsum_B a + fsum_B b + (delta ∗ delta) ∗ (fromInteger (counta ∗ countb) / fromInteger newcount)
      }
```

```
stats2Text :: Stats → Text
stats2Text (Stats slast _ sbasic sdelta stimed) =
    pack $
      "{ last=" ++ show slast ++
      ", basic-stats=" ++ showStats' (sbasic) ++
      ", delta-stats=" ++ showStats' (sdelta) ++
      ", timed-stats=" ++ showStats' (stimed) ++
      " }"
  where
    showStats' :: BaseStats → String
    showStats' s =
      ", { min=" ++ show (fmin s) ++
      ", max=" ++ show (fmax s) ++
      ", mean=" ++ show (meanOfStats s) ++ showUnits (fmin s) ++
      ", std-dev=" ++ show (stdevOfStats s) ++
      ", count=" ++ show (fcount s) ++
      " }"
```

Exponentially Weighted Moving Average (EWMA)

Following https://en.wikipedia.org/wiki/Moving_average#Exponential_moving_average we calculate the exponential moving average for a series of values Y_t according to:

$$S_t = \begin{cases} Y_1, & t = 1 \\ \alpha \cdot Y_t + (1-\alpha) \cdot S_{t-1}, & t > 1 \end{cases}$$

```
data EWMA = EmptyEWMA {alpha :: Double}
   | EWMA {alpha :: Double
     ,avg :: Measurable
     } deriving (Show, Eq, Generic, ToJSON)
```

Aggregated

```
data Aggregated = AggregatedStats Stats
   | AggregatedEWMA EWMA
   deriving (Eq, Generic, ToJSON)
```

instance *Semigroup* Aggregated disabled for the moment, because not needed.

```
instance Semigroup Aggregated where
   (<>) (AggregatedStats a) (AggregatedStats b) =
     AggregatedStats (a <> b)
   (<>) _ _ = error "Cannot combine different objects"
```

```
singletonStats :: Measurable → Aggregated
singletonStats a =
   let stats = Stats {flast = a
     ,fold              = Nanoseconds 0
     ,fbasic = BaseStats
       {fmin = a
       ,fmax = a
       ,fcount = 1
       ,fsum_A = getDouble a
       ,fsum_B = 0}
     ,fdelta = BaseStats
       {fmin = 0
       ,fmax = 0
       ,fcount = 0
       ,fsum_A = 0
       ,fsum_B = 0}
     ,ftimed = BaseStats
       {fmin = Nanoseconds 999999999999
       ,fmax = Nanoseconds 0
       ,fcount = (−1)
       ,fsum_A = 0
       ,fsum_B = 0}
     }
```

```
    in
      AggregatedStats stats

instance Show Aggregated where
    show (AggregatedStats astats) =
        "{ stats = " ++ show astats ++ " }"
    show (AggregatedEWMA a) = show a
```

1.4.11 Cardano.BM.Data.AggregatedKind

AggregatedKind

This identifies the type of Aggregated.

```
data AggregatedKind = StatsAK
    | EwmaAK {alpha :: Double}
        deriving (Generic, Eq, Show, FromJSON, ToJSON, Read)
```

1.4.12 Cardano.BM.Data.Backend

Accepts a NamedLogItem

Instances of this type class accept a NamedLogItem and deal with it.

```
class IsEffectuator t where
    effectuate :: t → NamedLogItem → IO ()
    effectuatefrom :: forall s ∘ (IsEffectuator s) ⇒ t → NamedLogItem → s → IO ()
    default effectuatefrom :: forall s ∘ (IsEffectuator s) ⇒ t → NamedLogItem → s → IO ()
    effectuatefrom t nli _ = effectuate t nli
    handleOverflow :: t → IO ()
```

Declaration of a Backend

A backend is life-cycle managed, thus can be *realize*d and *unrealize*d.

```
class (IsEffectuator t) ⇒ IsBackend t where
    typeof      :: t → BackendKind
    realize     :: Configuration → IO t
    realizefrom :: forall s ∘ (IsEffectuator s) ⇒ Trace IO → s → IO t
    default realizefrom :: forall s ∘ (IsEffectuator s) ⇒ Trace IO → s → IO t
    realizefrom (ctx, _) _ = realize (configuration ctx)
    unrealize :: t → IO ()
```

Backend

This data structure for a backend defines its behaviour as an IsEffectuator when processing an incoming message, and as an IsBackend for unrealizing the backend.

```
data Backend = MkBackend
  {bEffectuate :: NamedLogItem → IO ()
  ,bUnrealize :: IO ()
  }
```

1.4.13 Cardano.BM.Data.BackendKind

BackendKind

This identifies the backends that can be attached to the Switchboard.

```
data BackendKind = AggregationBK
  | EKGViewBK
  | KatipBK
  | MonitoringBK
  | SwitchboardBK
  deriving (Generic, Eq, Ord, Show, ToJSON, FromJSON, Read)
```

1.4.14 Cardano.BM.Data.Configuration

Data structure to help parsing configuration files.

Representation

```
type Port = Int
data Representation = Representation
  {minSeverity    :: Severity
  ,rotation       :: Maybe RotationParameters
  ,setupScribes   :: [ScribeDefinition]
  ,defaultScribes :: [(ScribeKind, Text)]
  ,setupBackends  :: [BackendKind]
  ,defaultBackends :: [BackendKind]
  ,hasEKG         :: Maybe Port
  ,hasGUI         :: Maybe Port
  ,options        :: HM.HashMap Text Object
  }
  deriving (Generic, Show, ToJSON, FromJSON)
```

parseRepresentation

```
parseRepresentation :: FilePath → IO Representation
parseRepresentation fp = do
  repr :: Representation ← decodeFileThrow fp
  return $ implicit_fill_representation repr
```

after parsing the configuration representation we implicitly correct it.

```
implicit_fill_representation :: Representation → Representation
implicit_fill_representation =
    remove_ekgview_if_not_defined ∘
    filter_duplicates_from_backends ∘
    filter_duplicates_from_scribes ∘
    union_setup_and_usage_backends ∘
    add_ekgview_if_port_defined ∘
    add_katip_if_any_scribes
  where
    filter_duplicates_from_backends r =
      r {setupBackends = mkUniq $ setupBackends r}
    filter_duplicates_from_scribes r =
      r {setupScribes = mkUniq $ setupScribes r}
    union_setup_and_usage_backends r =
      r {setupBackends = setupBackends r <> defaultBackends r}
    remove_ekgview_if_not_defined r =
      case hasEKG r of
      Nothing → r {defaultBackends = filter (λbk → bk ≢ EKGViewBK) (defaultBackends r)
        ,setupBackends = filter (λbk → bk ≢ EKGViewBK) (setupBackends r)
        }
      Just _ → r
    add_ekgview_if_port_defined r =
      case hasEKG r of
      Nothing → r
      Just _ → r {setupBackends = setupBackends r <> [EKGViewBK]}
    add_katip_if_any_scribes r =
      if (any ¬ [null $ setupScribes r, null $ defaultScribes r])
      then r {setupBackends = setupBackends r <> [KatipBK]}
      else r
    mkUniq :: Ord a ⇒ [a] → [a]
    mkUniq = Set.toList ∘ Set.fromList
```

1.4.15 Cardano.BM.Data.Counter

Counter

```
data Counter = Counter
        {cType  :: CounterType
```

```
                 ,cName :: Text
                 ,cValue :: Measurable
                 }
                 deriving (Eq, Show, Generic, ToJSON)
data CounterType = MonotonicClockTime
    | MemoryCounter
    | StatInfo
    | IOCounter
    | CpuCounter
    | RTSStats
       deriving (Eq, Show, Generic, ToJSON)
instance ToJSON Microsecond where
    toJSON = toJSON ∘ toMicroseconds
    toEncoding = toEncoding ∘ toMicroseconds
```

Names of counters

```
nameCounter :: Counter → Text
nameCounter (Counter MonotonicClockTime _ _) = "Time-interval"
nameCounter (Counter MemoryCounter _ _) = "Mem"
nameCounter (Counter StatInfo          _ _) = "Stat"
nameCounter (Counter IOCounter         _ _) = "IO"
nameCounter (Counter CpuCounter        _ _) = "Cpu"
nameCounter (Counter RTSStats          _ _) = "RTS"
```

CounterState

```
data CounterState = CounterState {
    csIdentifier :: Unique
    ,csCounters :: [Counter]
    }
    deriving (Generic, ToJSON)
instance ToJSON Unique where
    toJSON = toJSON ∘ hashUnique
    toEncoding = toEncoding ∘ hashUnique
instance Show CounterState where
    show cs = (show ∘ hashUnique) (csIdentifier cs)
        <> " => " <> (show $ csCounters cs)
```

Difference between counters

```
diffCounters :: [Counter] → [Counter] → [Counter]
diffCounters openings closings =
    getCountersDiff openings closings
  where
    getCountersDiff :: [Counter]
                    → [Counter]
                    → [Counter]
    getCountersDiff as bs =
      let
        getName counter = nameCounter counter <> cName counter

        asNames = map getName as
        aPairs = zip asNames as

        bsNames = map getName bs
        bs′ = zip bsNames bs
        bPairs = HM.fromList bs′
      in
        catMaybes $ (flip map) aPairs $ λ(name, Counter _ _ startValue) →
          case HM.lookup name bPairs of
            Nothing      → Nothing
            Just counter → let endValue = cValue counter
                           in Just counter {cValue = endValue − startValue}
```

1.4.16 Cardano.BM.Data.LogItem

LoggerName

A LoggerName has currently type *Text*.

```
type LoggerName = Text
```

NamedLogItem

```
type NamedLogItem = LogNamed LogObject
```

LogNamed

A LogNamed contains of a context name and some log item.

```
data LogNamed item = LogNamed
  {lnName :: LoggerName
  ,lnItem :: item
  } deriving (Show)
deriving instance Generic item ⇒ Generic (LogNamed item)
deriving instance (ToJSON item, Generic item) ⇒ ToJSON (LogNamed item)
```

Logging of outcomes with LogObject

```
data LogObject = LogObject LOMeta LOContent
  deriving (Generic, Show, ToJSON)
```

Meta data for a LogObject:

```
data LOMeta = LOMeta {
  tstamp :: {-# UNPACK #-} ! UTCTime
  , tid :: {-# UNPACK #-} ! ThreadId
  }
  deriving (Show)
instance ToJSON LOMeta where
  toJSON (LOMeta _tstamp _tid) =
    object ["tstamp" .= _tstamp, "tid" .= show _tid]
mkLOMeta :: IO LOMeta
mkLOMeta =
  LOMeta <$> getCurrentTime
    <*> myThreadId
```

Payload of a LogObject:

```
data LOContent = LogMessage LogItem
   | LogValue Text Measurable
   | ObserveOpen CounterState
   | ObserveDiff CounterState
   | ObserveClose CounterState
   | AggregatedMessage [(Text, Aggregated)]
   | MonitoringEffect LogObject
   | KillPill
     deriving (Generic, Show, ToJSON)
```

LogItem

TODO liPayload :: ToObject

```
data LogItem = LogItem
  {liSelection :: LogSelection
  , liSeverity :: Severity
  , liPayload :: Text-- TODO should become ToObject
  } deriving (Show, Generic, ToJSON)

data LogSelection =
  Public   -- only to public logs.
  | PublicUnsafe-- only to public logs, not console.
  | Private-- only to private logs.
  | Both   -- to public and private logs.
  deriving (Show, Generic, ToJSON, FromJSON)
```

1.4.17 Cardano.BM.Data.Observable

ObservableInstance

```
data ObservableInstance = MonotonicClock
    | MemoryStats
    | ProcessStats
    | IOStats
    | GhcRtsStats
      deriving (Generic, Eq, Show, FromJSON, ToJSON, Read)
```

1.4.18 Cardano.BM.Data.Output

OutputKind

```
data OutputKind = TVarList (STM.TVar [LogObject])
    | TVarListNamed (STM.TVar [LogNamed LogObject])
    deriving (Eq)
```

ScribeKind

This identifies katip's scribes by type.

```
data ScribeKind = FileTextSK
    | FileJsonSK
    | StdoutSK
    | StderrSK
    deriving (Generic, Eq, Ord, Show, FromJSON, ToJSON)
```

ScribeId

A scribe is identified by ScribeKind *x Filename*

```
type ScribeId = Text-- (ScribeKind :: Filename)
```

ScribeDefinition

This identifies katip's scribes by type.

```
data ScribeDefinition = ScribeDefinition
    {scKind  :: ScribeKind
    ,scName :: Text
    ,scRotation :: Maybe RotationParameters
    }
    deriving (Generic, Eq, Ord, Show, FromJSON, ToJSON)
```

1.4.19 Cardano.BM.Data.Rotation

RotationParameters

```
data RotationParameters = RotationParameters
  {rpLogLimitBytes :: !Word64-- max size of file in bytes
  ,rpMaxAgeHours :: !Word   -- hours
  ,rpKeepFilesNum :: !Word  -- number of files to keep
  } deriving (Generic, Show, Eq, Ord, FromJSON, ToJSON)
```

1.4.20 Cardano.BM.Data.Severity

Severity

The intended meaning of severity codes:

Debug *detailled information about values and decision flow* Info general information of events; progressing properly Notice *needs attention;something ¬ progressing properly* Warning may continue into an error condition if continued Error *unexpected set* **of** *event or condition occured* Critical error condition causing degrade of operation Alert *a subsystem is no longer operating correctly,likely requires manual*
at this point, the system can never progress without additional intervention

We were informed by the *Syslog* taxonomy: https://en.wikipedia.org/wiki/Syslog#Severity_level

```
data Severity = Debug
   | Info
   | Notice
   | Warning
   | Error
   | Critical
   | Alert
   | Emergency
     deriving (Show, Eq, Ord, Enum, Generic, ToJSON, Read)
instance FromJSON Severity where
  parseJSON = withText "severity" $ λcase
    "Debug"     → pure Debug
    "Info"      → pure Info
    "Notice"    → pure Notice
    "Warning"   → pure Warning
    "Error"     → pure Error
    "Critical"  → pure Critical
    "Alert"     → pure Alert
    "Emergency" → pure Emergency
    _           → pure Info-- catch all
```

1.4.21 Cardano.BM.Data.SubTrace

SubTrace

```
data NameSelector = Exact Text | StartsWith Text | EndsWith Text | Contains Text
                    deriving (Generic, Show, FromJSON, ToJSON, Read, Eq)
```

```
data DropName    = Drop NameSelector
                   deriving (Generic, Show, FromJSON, ToJSON, Read, Eq)
data UnhideNames = Unhide [NameSelector]
                   deriving (Generic, Show, FromJSON, ToJSON, Read, Eq)
data SubTrace = Neutral
  | UntimedTrace
  | NoTrace
  | TeeTrace LoggerName
  | FilterTrace [(DropName, UnhideNames)]
  | DropOpening
  | ObservableTrace [ObservableInstance]
    deriving (Generic, Show, FromJSON, ToJSON, Read, Eq)
```

1.4.22 Cardano.BM.Data.Trace

Trace

A Trace consists of a TraceContext and a TraceNamed in *m*.

```
type Trace m = (TraceContext, TraceNamed m)
```

TraceNamed

A TraceNamed is a specialized Contravariant of type NamedLogItem, a LogNamed with payload LogObject.

```
type TraceNamed m = BaseTrace m (NamedLogItem)
```

TraceContext

We keep the context's name and a reference to the Configuration in the TraceContext.

```
data TraceContext = TraceContext
  {loggerName :: LoggerName
  ,configuration :: Configuration
  ,tracetype     :: SubTrace
  ,minSeverity :: Severity
  ,shutdown      :: IO ()
  }
```

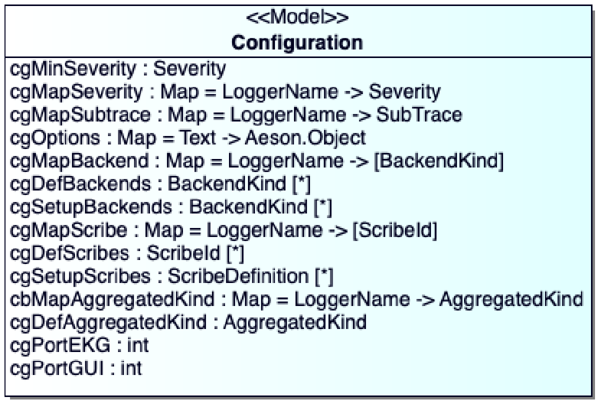
1.4.23 Cardano.BM.Configuration

see Cardano.BM.Configuration.Model for the implementation.

```
getOptionOrDefault :: CM.Configuration → Text → Text → IO (Text)
getOptionOrDefault cg name def = do
  opt ← CM.getOption cg name
  case opt of
    Nothing → return def
    Just o → return o
```

1.4.24 Cardano.BM.Configuration.Model

Configuration.Model



<<Model>>
Configuration
cgMinSeverity : Severity
cgMapSeverity : Map = LoggerName -> Severity
cgMapSubtrace : Map = LoggerName -> SubTrace
cgOptions : Map = Text -> Aeson.Object
cgMapBackend : Map = LoggerName -> [BackendKind]
cgDefBackends : BackendKind [*]
cgSetupBackends : BackendKind [*]
cgMapScribe : Map = LoggerName -> [ScribeId]
cgDefScribes : ScribeId [*]
cgSetupScribes : ScribeDefinition [*]
cbMapAggregatedKind : Map = LoggerName -> AggregatedKind
cgDefAggregatedKind : AggregatedKind
cgPortEKG : int
cgPortGUI : int

Figure 1.4: Configuration model

```
type ConfigurationMVar = MVar ConfigurationInternal
newtype Configuration = Configuration
  {getCG :: ConfigurationMVar}
-- Our internal state; see -"Configuration model"-
data ConfigurationInternal = ConfigurationInternal
  {cgMinSeverity      :: Severity
  -- minimum severity level of every object that will be output
  ,cgMapSeverity      :: HM.HashMap LoggerName Severity
  -- severity filter per loggername
  ,cgMapSubtrace      :: HM.HashMap LoggerName SubTrace
  -- type of trace per loggername
  ,cgOptions          :: HM.HashMap Text Object
  -- options needed for tracing, logging and monitoring
  ,cgMapBackend       :: HM.HashMap LoggerName [BackendKind]
  -- backends that will be used for the specific loggername
  ,cgDefBackendKs     :: [BackendKind]
  -- backends that will be used if a set of backends for the
  -- specific loggername is not set
  ,cgSetupBackends    :: [BackendKind]
  -- backends to setup; every backend to be used must have
  -- been declared here
  ,cgMapScribe        :: HM.HashMap LoggerName [ScribeId]
  -- katip scribes that will be used for the specific loggername
  ,cgMapScribeCache   :: HM.HashMap LoggerName [ScribeId]
  -- map to cache info of the cgMapScribe
  ,cgDefScribes       :: [ScribeId]
  -- katip scribes that will be used if a set of scribes for the
```

```
    -- specific loggername is not set
    ,cgSetupScribes     :: [ScribeDefinition]
    -- katip scribes to setup; every scribe to be used must have
    -- been declared here
    ,cgMapAggregatedKind :: HM.HashMap LoggerName AggregatedKind
    -- kind of Aggregated that will be used for the specific loggername
    ,cgDefAggregatedKind :: AggregatedKind
    -- kind of Aggregated that will be used if a set of scribes for the
    -- specific loggername is not set
    ,cgMonitors         :: HM.HashMap LoggerName (MEvExpr, [MEvAction])
    ,cgPortEKG          :: Int
    -- port for EKG server
    ,cgPortGUI          :: Int
    -- port for changes at runtime (NOT IMPLEMENTED YET)
    } deriving (Show, Eq)
```

Backends configured in the Switchboard

For a given context name return the list of backends configured, or, in case no such configuration exists, return the default backends.

```
  getBackends :: Configuration → LoggerName → IO [BackendKind]
  getBackends configuration name = do
    cg ← readMVar $ getCG configuration
    let outs = HM.lookup name (cgMapBackend cg)
    case outs of
      Nothing → return (cgDefBackendKs cg)
      Just os → return os
  getDefaultBackends :: Configuration → IO [BackendKind]
  getDefaultBackends configuration =
    cgDefBackendKs < $ > (readMVar $ getCG configuration)
  setDefaultBackends :: Configuration → [BackendKind] → IO ()
  setDefaultBackends configuration bes =
    modifyMVar_ (getCG configuration) $ λcg →
      return cg {cgDefBackendKs = bes}
  setBackends :: Configuration → LoggerName → Maybe [BackendKind] → IO ()
  setBackends configuration name be =
    modifyMVar_ (getCG configuration) $ λcg →
      return cg {cgMapBackend = HM.alter (\_ → be) name (cgMapBackend cg)}
```

Backends to be setup by the Switchboard

Defines the list of Backends that need to be setup by the Switchboard.

```
  setSetupBackends :: Configuration → [BackendKind] → IO ()
  setSetupBackends configuration bes =
    modifyMVar_ (getCG configuration) $ λcg →
```

```
        return cg {cgSetupBackends = bes}
    getSetupBackends :: Configuration → IO [BackendKind]
    getSetupBackends configuration =
      cgSetupBackends <$> (readMVar $ getCG configuration)
```

Scribes configured in the Log backend

For a given context name return the list of scribes to output to, or, in case no such configuration exists, return the default scribes to use.

```
    getScribes :: Configuration → LoggerName → IO [ScribeId]
    getScribes configuration name = do
        cg ← readMVar (getCG configuration)
        (updateCache, scribes) ← do
          let defs = cgDefScribes cg
          let mapScribe = cgMapScribe cg
          let find_s lname = case HM.lookup lname mapScribe of
            Nothing →
              case dropToDot lname of
                Nothing → defs
                Just lname' → find_s lname'
            Just os → os
          let outs = HM.lookup name (cgMapScribeCache cg)
          -- look if scribes are already cached
          return $ case outs of
            -- if no cached scribes found; search the appropriate scribes that
            -- they must inherit and update the cached map
            Nothing → (True, find_s name)
            Just os → (False, os)
        when updateCache $ setCachedScribes configuration name $ Just scribes
        return scribes
      where
        dropToDot :: Text → Maybe Text
        dropToDot ts = dropToDot' (breakOnEnd "." ts)
        dropToDot' (_, "") = Nothing
        dropToDot' (name', _) = Just $ dropWhileEnd (≡ '.') name'
    getCachedScribes :: Configuration → LoggerName → IO (Maybe [ScribeId])
    getCachedScribes configuration name = do
        cg ← readMVar $ getCG configuration
        return $ HM.lookup name $ cgMapScribeCache cg
    setScribes :: Configuration → LoggerName → Maybe [ScribeId] → IO ()
    setScribes configuration name scribes =
        modifyMVar_ (getCG configuration) $ λcg →
          return cg {cgMapScribe = HM.alter (\_ → scribes) name (cgMapScribe cg)}
    setCachedScribes :: Configuration → LoggerName → Maybe [ScribeId] → IO ()
    setCachedScribes configuration name scribes =
        modifyMVar_ (getCG configuration) $ λcg →
```

```
            return cg {cgMapScribeCache = HM.alter (\_ → scribes) name (cgMapScribeCache cg)}
    setDefaultScribes :: Configuration → [ScribeId] → IO ()
    setDefaultScribes configuration scs =
        modifyMVar_ (getCG configuration) $ λcg →
            return cg {cgDefScribes = scs}
```

Scribes to be setup in the Log backend

Defines the list of *Scribe*s that need to be setup in the Log backend.

```
    setSetupScribes :: Configuration → [ScribeDefinition] → IO ()
    setSetupScribes configuration sds =
        modifyMVar_ (getCG configuration) $ λcg →
            return cg {cgSetupScribes = sds}
    getSetupScribes :: Configuration → IO [ScribeDefinition]
    getSetupScribes configuration =
        cgSetupScribes < $ > readMVar (getCG configuration)
```

AggregatedKind to define the type of measurement

For a given context name return its AggregatedKind or in case no such configuration exists, return the default AggregatedKind to use.

```
    getAggregatedKind :: Configuration → LoggerName → IO AggregatedKind
    getAggregatedKind configuration name = do
        cg ← readMVar $ getCG configuration
        let outs = HM.lookup name (cgMapAggregatedKind cg)
        case outs of
            Nothing → return $ cgDefAggregatedKind cg
            Just os → return $ os
    setDefaultAggregatedKind :: Configuration → AggregatedKind → IO ()
    setDefaultAggregatedKind configuration defAK =
        modifyMVar_ (getCG configuration) $ λcg →
            return cg {cgDefAggregatedKind = defAK}
    setAggregatedKind :: Configuration → LoggerName → Maybe AggregatedKind → IO ()
    setAggregatedKind configuration name ak =
        modifyMVar_ (getCG configuration) $ λcg →
            return cg {cgMapAggregatedKind = HM.alter (\_ → ak) name (cgMapAggregatedKind cg)}
```

Access port numbers of EKG, GUI

```
    getEKGport :: Configuration → IO Int
    getEKGport configuration =
        cgPortEKG < $ > (readMVar $ getCG configuration)
    setEKGport :: Configuration → Int → IO ()
```

```
setEKGport configuration port =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgPortEKG = port}
getGUIport :: Configuration → IO Int
getGUIport configuration =
  cgPortGUI < $ > (readMVar $ getCG configuration)
setGUIport :: Configuration → Int → IO ()
setGUIport configuration port =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgPortGUI = port}
```

Options

```
getOption :: Configuration → Text → IO (Maybe Text)
getOption configuration name = do
  cg ← readMVar $ getCG configuration
  case HM.lookup name (cgOptions cg) of
    Nothing → return Nothing
    Just o → return $ Just $ pack $ show o
```

Global setting of minimum severity

```
minSeverity :: Configuration → IO Severity
minSeverity configuration =
  cgMinSeverity < $ > (readMVar $ getCG configuration)
setMinSeverity :: Configuration → Severity → IO ()
setMinSeverity configuration sev =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgMinSeverity = sev}
```

Relation of context name to minimum severity

```
inspectSeverity :: Configuration → Text → IO (Maybe Severity)
inspectSeverity configuration name = do
  cg ← readMVar $ getCG configuration
  return $ HM.lookup name (cgMapSeverity cg)
setSeverity :: Configuration → Text → Maybe Severity → IO ()
setSeverity configuration name sev =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgMapSeverity = HM.alter (\_ → sev) name (cgMapSeverity cg)}
```

Relation of context name to SubTrace

A new context may contain a different type of Trace. The function appendName (Enter new named context) will look up the SubTrace for the context's name.

```
findSubTrace :: Configuration → Text → IO (Maybe SubTrace)
findSubTrace configuration name = do
  cg ← readMVar $ getCG configuration
  return $ HM.lookup name (cgMapSubtrace cg)
setSubTrace :: Configuration → Text → Maybe SubTrace → IO ()
setSubTrace configuration name trafo =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgMapSubtrace = HM.alter (\_ → trafo) name (cgMapSubtrace cg)}
```

Monitors

```
Just (
  fromList [
    ("chain.creation.block",Array [
      Object (fromList [("monitor",String "((time > 23 s) Or (time < 17 s))")]),
      Object (fromList [("actions",Array [
        String "AlterMinSeverity \"chain.creation\" Debug"])])])
  ,("#aggregation.critproc.observable",Array [
      Object (fromList [("monitor",String "(mean >= 42)")]),
      Object (fromList [("actions",Array [
        String "CreateMessage \"exceeded\" \"the observable has been too long too high!\"",
        String "AlterGlobalMinSeverity Info"])])])])
```

```
getMonitors :: Configuration → IO (HM.HashMap LoggerName (MEvExpr, [MEvAction]))
getMonitors configuration = do
  cg ← readMVar $ getCG configuration
  return (cgMonitors cg)
```

Parse configuration from file

Parse the configuration into an internal representation first. Then, fill in Configuration after refinement.

```
setup :: FilePath → IO Configuration
setup fp = do
    r ← R.parseRepresentation fp
    setupFromRepresentation r
parseMonitors :: Maybe (HM.HashMap Text Value) → HM.HashMap LoggerName (MEvExpr, [MEvAction])
parseMonitors Nothing = HM.empty
parseMonitors (Just hmv) = HM.mapMaybe mkMonitor hmv
    where
    mkMonitor (Array a) =
        if Vector.length a ≡ 2
        then do
          e ← mkExpression $ a Vector.! 0
          as ← mkActions $ a Vector.! 1
          return (e, as)
        else Nothing
    mkMonitor _ = Nothing
    mkExpression :: Value → Maybe MEvExpr
    mkExpression (Object o1) =
        case HM.lookup "monitor" o1 of
          Nothing → Nothing
          Just (String expr) → MEv.parseMaybe expr
          Just _      → Nothing
    mkExpression _ = Nothing
    mkActions :: Value → Maybe [MEvAction]
    mkActions (Object o2) =
        case HM.lookup "actions" o2 of
          Nothing → Nothing
          Just (Array as) → Just $ map (λ(String s) → s) $ Vector.toList as
          Just _      → Nothing
    mkActions _ = Nothing
setupFromRepresentation :: R.Representation → IO Configuration
setupFromRepresentation r = do
    let mapseverity     = HM.lookup "mapSeverity" (R.options r)
        mapbackends = HM.lookup "mapBackends" (R.options r)
        mapsubtrace  = HM.lookup "mapSubtrace" (R.options r)
        mapscribes     = HM.lookup "mapScribes"  (R.options r)
        mapaggregatedkinds = HM.lookup "mapAggregatedkinds" (R.options r)
        mapmonitors = HM.lookup "mapMonitors" (R.options r)
        mapScribe      = parseScribeMap mapscribes
    cgref ← newMVar $ ConfigurationInternal
        {cgMinSeverity = R.minSeverity r
        ,cgMapSeverity = parseSeverityMap mapseverity
        ,cgMapSubtrace = parseSubtraceMap mapsubtrace
        ,cgOptions = R.options r
        ,cgMapBackend = parseBackendMap mapbackends
        ,cgDefBackendKs = R.defaultBackends r
        ,cgSetupBackends = R.setupBackends r
        ,cgMapScribe = mapScribe
        ,cgMapScribeCache = mapScribe
        ,cgDefScribes = r_defaultScribes r
        ,cgSetupScribes = fillRotationParams (R.rotation r) (R.setupScribes r)
        ,cgMapAggregatedKind = parseAggregatedKindMap mapaggregatedkinds
        ,cgDefAggregatedKind = StatsAK
        ,cgMonitors = parseMonitors mapmonitors
        ,cgPortEKG = r_hasEKG r
        ,cgPortGUI = r_hasGUI r
        }
    return $ Configuration cgref
  where
    parseSeverityMap :: Maybe (HM.HashMap Text Value) → HM.HashMap Text Severity
    parseSeverityMap Nothing = HM.empty
    parseSeverityMap (Just hmv) = HM.mapMaybe mkSeverity hmv
      where
        mkSeverity (String s) = Just (read (unpack s) :: Severity)
        mkSeverity _ = Nothing
    fillRotationParams :: Maybe RotationParameters → [ScribeDefinition] → [ScribeDefinition]
    fillRotationParams defaultRotation = map $ λsd →
        if (scKind sd ≢ StdoutSK) ∧ (scKind sd ≢ StderrSK)
        then
          sd {scRotation = maybe defaultRotation Just (scRotation sd)}
        else
          -- stdout and stderr cannot be rotated
          sd {scRotation = Nothing}
    parseBackendMap Nothing = HM.empty
    parseBackendMap (Just hmv) = HM.map mkBackends hmv
      where
        mkBackends (Array bes) = catMaybes $ map mkBackend $ Vector.toList bes
        mkBackends _ = [ ]
        mkBackend (String s) = Just (read (unpack s) :: BackendKind)
        mkBackend _ = Nothing
    parseScribeMap Nothing = HM.empty
    parseScribeMap (Just hmv) = HM.map mkScribes hmv
      where
        mkScribes (Array scs) = catMaybes $ map mkScribe $ Vector.toList scs
        mkScribes (String s) = [(s :: ScribeId)]
        mkScribes _ = [ ]
        mkScribe (String s) = Just (s :: ScribeId)
        mkScribe _ = Nothing
    parseSubtraceMap :: Maybe (HM.HashMap Text Value) → HM.HashMap Text SubTrace
    parseSubtraceMap Nothing = HM.empty
    parseSubtraceMap (Just hmv) = HM.mapMaybe mkSubtrace hmv
      where
        mkSubtrace (String s) = Just (read (unpack s) :: SubTrace)
        mkSubtrace (Object hm) = mkSubtrace′ (HM.lookup "tag" hm) (HM.lookup "contents" hm)
        mkSubtrace _ = Nothing
        mkSubtrace′ Nothing _ = Nothing
        mkSubtrace′ _ Nothing = Nothing
        mkSubtrace′ (Just (String tag)) (Just (Array cs)) =
          if tag ≡ "ObservableTrace"
          then Just $ ObservableTrace $ map (λ(String s) → (read (unpack s) :: ObservableInstance)) $ Vector.
          else Nothing
        mkSubtrace′ _ _ = Nothing
    r_hasEKG repr = case (R.hasEKG repr) of
      Nothing → 0
      Just p        → p
    r_hasGUI repr = case (R.hasGUI repr) of
      Nothing → 0
      Just p        → p
    r_defaultScribes repr = map (λ(k, n) → pack (show k) <> "::" <> n) (R.defaultScribes repr)
    parseAggregatedKindMap Nothing = HM.empty
    parseAggregatedKindMap (Just hmv) =
        let
          listv = HM.toList hmv
          mapAggregatedKind = HM.fromList $ catMaybes $ map mkAggregatedKind listv
        in
        mapAggregatedKind
      where
        mkAggregatedKind (name, String s) = Just (name, read (unpack s) :: AggregatedKind)
        mkAggregatedKind _ = Nothing
```

Setup empty configuration

```
empty :: IO Configuration
empty = do
  cgref ← newMVar $ ConfigurationInternal
    {cgMinSeverity       = Debug
    , cgMapSeverity      = HM.empty
    , cgMapSubtrace      = HM.empty
    , cgOptions          = HM.empty
    , cgMapBackend       = HM.empty
    , cgDefBackendKs     = [ ]
    , cgSetupBackends    = [ ]
    , cgMapScribe        = HM.empty
    , cgMapScribeCache   = HM.empty
    , cgDefScribes       = [ ]
    , cgSetupScribes     = [ ]
    , cgMapAggregatedKind = HM.empty
    , cgDefAggregatedKind = StatsAK
    , cgMonitors         = HM.empty
    , cgPortEKG          = 0
    , cgPortGUI          = 0
    }
  return $ Configuration cgref
```

1.4.25 Cardano.BM.Configuration.Static

Default configuration outputting on *stdout*

```
defaultConfigStdout :: IO CM.Configuration
defaultConfigStdout = do
  c ← CM.empty
  CM.setMinSeverity c Debug
  CM.setSetupBackends c [KatipBK]
  CM.setDefaultBackends c [KatipBK]
  CM.setSetupScribes c [ScribeDefinition {
    scName = "stdout"
    ,scKind = StdoutSK
    ,scRotation = Nothing
    }
    ]
  CM.setDefaultScribes c ["StdoutSK::stdout"]
  return c
```

Default configuration for testing

```
defaultConfigTesting :: IO CM.Configuration
defaultConfigTesting = do
  c ← CM.empty
  CM.setMinSeverity c Debug
  CM.setSetupBackends c [KatipBK, AggregationBK]
  CM.setDefaultBackends c [KatipBK, AggregationBK]
  CM.setSetupScribes c [ScribeDefinition {
    scName = "stdout"
    ,scKind = StdoutSK
    ,scRotation = Nothing
    }
    ]
  CM.setDefaultScribes c ["StdoutSK::stdout"]
  return c
```

1.4.26 Cardano.BM.Output.Switchboard

Switchboard

We are using an *MVar* because we spawn a set of backends that may try to send messages to the switchboard before it is completely setup.

```
type SwitchboardMVar = MVar SwitchboardInternal
newtype Switchboard = Switchboard
  {getSB :: SwitchboardMVar}
data SwitchboardInternal = SwitchboardInternal
```

```
    {sbQueue :: TBQ.TBQueue NamedLogItem
    ,sbDispatch :: Async.Async ()
    }
```

Trace that forwards to the Switchboard

Every Trace ends in the Switchboard which then takes care of dispatching the messages to outputs

```
mainTrace :: Switchboard → TraceNamed IO
mainTrace sb = BaseTrace.BaseTrace $ Op $ λlognamed → do
    effectuate sb lognamed
```

Process incoming messages

Incoming messages are put into the queue, and then processed by the dispatcher.
The queue is initialized and the message dispatcher launched.

```
instance IsEffectuator Switchboard where
    effectuate switchboard item = do
        let writequeue :: TBQ.TBQueue NamedLogItem → NamedLogItem → IO ()
            writequeue q i = do
                nocapacity ← atomically $ TBQ.isFullTBQueue q
                if nocapacity
                then handleOverflow switchboard
                else atomically $ TBQ.writeTBQueue q i
        sb ← readMVar (getSB switchboard)
        writequeue (sbQueue sb) item
    handleOverflow _ = putStrLn "Error: Switchboard's queue full, dropping log items!"

instead of 'writequeue ...':
    evalMonitoringAction config item ≫=
        mapM_ (writequeue (sbQueue sb))
evalMonitoringAction :: Configuration → NamedLogItem → m [NamedLogItem]
evalMonitoringAction c item = return [item]
    -- let action = LogNamed  lnName=(lnName item) <> ".action", lnItem=LogMessage ...
    -- return (action :  item)
```

Switchboard implements Backend functions

Switchboard is an Declaration of a Backend

```
instance IsBackend Switchboard where
    typeof _ = SwitchboardBK
    realize cfg =
        let spawnDispatcher
                :: Configuration
        → [(BackendKind, Backend)]
        → TBQ.TBQueue NamedLogItem
        → IO (Async.Async ())
    spawnDispatcher config backends queue =
      let sendMessage nli befilter = do
            selectedBackends ← getBackends config (lnName nli)
            let selBEs = befilter selectedBackends
            forM_ backends $ λ(bek, be) →
              when (bek ∈ selBEs) (bEffectuate be $ nli)
          qProc = do
            nli ← atomically $ TBQ.readTBQueue queue
            case lnItem nli of
              LogObject _ KillPill →
                forM_ backends (λ(_, be) → bUnrealize be)
              LogObject _ (AggregatedMessage _) → do
                sendMessage nli (filter (≢ AggregationBK))
                qProc
              LogObject _ (MonitoringEffect inner) → do
                sendMessage (nli {lnItem = inner}) (filter (≢ MonitoringBK))
                qProc
              _ → sendMessage nli id ≫ qProc
      in
        Async.async qProc
  in do
  q ← atomically $ TBQ.newTBQueue 2048
  sbref ← newEmptyMVar
  let sb :: Switchboard = Switchboard sbref
  backends ← getSetupBackends cfg
  bs ← setupBackends backends cfg sb [ ]
  dispatcher ← spawnDispatcher cfg bs q
  -- link the given Async to the current thread, such that if the Async
  -- raises an exception, that exception will be re-thrown in the current
  -- thread, wrapped in ExceptionInLinkedThread.
  Async.link dispatcher
  putMVar sbref $ SwitchboardInternal {sbQueue = q, sbDispatch = dispatcher}
  return sb
unrealize switchboard = do
  let clearMVar :: MVar a → IO ()
      clearMVar = void ∘ tryTakeMVar
  (dispatcher, queue) ← withMVar (getSB switchboard) (λsb → return (sbDispatch sb, sbQueue sb))
  -- send terminating item to the queue
  lo ← LogObject <$> mkLOMeta <*> pure KillPill
  atomically $ TBQ.writeTBQueue queue $ LogNamed "kill.switchboard" lo
  -- wait for the dispatcher to exit
  res ← Async.waitCatch dispatcher
  either throwM return res
```

```
    (clearMVar ∘ getSB) switchboard
```

Realizing the backends according to configuration

```
setupBackends :: [BackendKind]
            → Configuration
            → Switchboard
            → [(BackendKind, Backend)]
            → IO [(BackendKind, Backend)]
setupBackends [ ] _ _ acc = return acc
setupBackends (bk : bes) c sb acc = do
  be′ ← setupBackend′ bk c sb
  setupBackends bes c sb ((bk, be′) : acc)
setupBackend′ :: BackendKind → Configuration → Switchboard → IO Backend
setupBackend′ SwitchboardBK _ _ = error "cannot instantiate a further Switchboard"
setupBackend′ MonitoringBK c _ = do
  be :: Cardano.BM.Output ∘ Monitoring.Monitor ← Cardano.BM.Output ∘ Monitoring.realize c
  return MkBackend
    {bEffectuate = Cardano.BM.Output ∘ Monitoring.effectuate be
    , bUnrealize = Cardano.BM.Output ∘ Monitoring.unrealize be
    }
setupBackend′ EKGViewBK c _ = do
  be :: Cardano.BM.Output ∘ EKGView.EKGView ← Cardano.BM.Output ∘ EKGView.realize c
  return MkBackend
    {bEffectuate = Cardano.BM.Output ∘ EKGView.effectuate be
    , bUnrealize = Cardano.BM.Output ∘ EKGView.unrealize be
    }
setupBackend′ AggregationBK c sb = do
  let trace = mainTrace sb
    ctx = TraceContext {loggerName = ""
          , configuration = c
          , minSeverity = Debug
          , tracetype = Neutral
          , shutdown = pure ()
          }
  be :: Cardano.BM.Output ∘ Aggregation.Aggregation ← Cardano.BM.Output ∘ Aggregation.realizefrom (ctx,
  return MkBackend
    {bEffectuate = Cardano.BM.Output ∘ Aggregation.effectuate be
    , bUnrealize = Cardano.BM.Output ∘ Aggregation.unrealize be
    }
setupBackend′ KatipBK c _ = do
  be :: Cardano.BM.Output ∘ Log.Log ← Cardano.BM.Output ∘ Log.realize c
  return MkBackend
    {bEffectuate = Cardano.BM.Output ∘ Log.effectuate be
    , bUnrealize = Cardano.BM.Output ∘ Log.unrealize be
    }
```

1.4.27 Cardano.BM.Output.Log

Internal representation

```
type LogMVar = MVar LogInternal
newtype Log = Log
  {getK :: LogMVar}
data LogInternal = LogInternal
  {kLogEnv :: K.LogEnv
  ,configuration :: Config.Configuration}
```

Log implements *effectuate*

```
instance IsEffectuator Log where
  effectuate katip item = do
    c ← configuration < $ > readMVar (getK katip)
    selscribes ← getScribes c (lnName item)
    forM_ selscribes $ λsc → passN sc katip item
  handleOverflow _ = putStrLn "Notice: Katip's queue full, dropping log items!"
```

Log implements backend functions

```
instance IsBackend Log where
  typeof _ = KatipBK
  realize config = do
    let updateEnv :: K.LogEnv → IO UTCTime → K.LogEnv
        updateEnv le timer =
          le {K._logEnvTimer = timer, K._logEnvHost = "hostname"}
        register :: [ScribeDefinition] → K.LogEnv → IO K.LogEnv
        register [ ] le = return le
        register (defsc : dscs) le = do
          let kind  = scKind   defsc
              name  = scName defsc
              rotParams = scRotation defsc
              name' = pack (show kind) <> "::" <> name
          scr ← createScribe kind name rotParams
          register dscs =≪ K.registerScribe name' scr scribeSettings le
        mockVersion :: Version
        mockVersion = Version [0, 1, 0, 0] [ ]
        scribeSettings :: KC.ScribeSettings
        scribeSettings =
          let bufferSize = 5000-- size of the queue (in log items)
          in
          KC.ScribeSettings bufferSize
        createScribe FileTextSK name rotParams = mkTextFileScribe
```

```
          rotParams
          (FileDescription $ unpack name)
          False
        createScribe FileJsonSK name rotParams = mkJsonFileScribe
          rotParams
          (FileDescription $ unpack name)
          False
        createScribe StdoutSK _ _ = mkStdoutScribe
        createScribe StderrSK _ _ = mkStderrScribe
      cfoKey ← Config.getOptionOrDefault config (pack "cfokey") (pack "<unknown>")
      le0 ← K.initLogEnv
              (K.Namespace ["iohk"])
              (fromString $ (unpack cfoKey) <> ":" <> showVersion mockVersion)
      -- request a new time 'getCurrentTime' at most 100 times a second
      timer ← mkAutoUpdate defaultUpdateSettings {updateAction = getCurrentTime, updateFreq = 10000}
      let le1 = updateEnv le0 timer
      scribes ← getSetupScribes config
      le ← register scribes le1
      kref ← newMVar $ LogInternal le config
      return $ Log kref
    unrealize katip = do
      le ← withMVar (getK katip) $ λk → return (kLogEnv k)
      void $ K.closeScribes le

  example :: IO ()
  example = do
    config ← Config.setup "from_some_path.yaml"
    k ← setup config
    passN (pack (show StdoutSK)) k $ LogNamed
      {lnName = "test"
      ,lnItem = LogMessage $ LogItem
        {liSelection = Both
        ,liSeverity = Info
        ,liPayload  = "Hello!"
        }
      }
    passN (pack (show StdoutSK)) k $ LogNamed
      {lnName = "test"
      ,lnItem = LogValue "cpu-no" 1
      }
```

Needed instances for *katip*:

```
  deriving instance K.ToObject LogObject
  deriving instance K.ToObject LogItem
  deriving instance K.ToObject (Maybe LOContent)
  instance KC.LogItem LogObject where
```

```
    payloadKeys _ _ = KC.AllKeys
instance KC.LogItem LogItem where
    payloadKeys _ _ = KC.AllKeys
instance KC.LogItem (Maybe LOContent) where
    payloadKeys _ _ = KC.AllKeys
```

Log.passN

The following function copies the NamedLogItem to the queues of all scribes that match on their name. Compare start of name of scribe to (*show backend* <> "::"). This function is non-blocking.

```
passN :: Text → Log → NamedLogItem → IO ()
passN backend katip namedLogItem = do
    env ← kLogEnv < $ > readMVar (getK katip)
    forM_ (Map.toList $ K._logEnvScribes env) $
        λ(scName, (KC.ScribeHandle _ shChan)) →
            -- check start of name to match ScribeKind
                if backend ‘isPrefixOf‘ scName
                then do
                    let (LogObject lometa loitem) = lnItem namedLogItem
                    let (sev, msg, payload) = case loitem of
                            (LogMessage logItem) →
                                (liSeverity logItem, liPayload logItem, Nothing)
                            (ObserveDiff _) →
                                let text = TL.toStrict (encodeToLazyText loitem)
                                in
                                (Info, text, Just loitem)
                            (ObserveOpen _) →
                                let text = TL.toStrict (encodeToLazyText loitem)
                                in
                                (Info, text, Just loitem)
                            (ObserveClose _) →
                                let text = TL.toStrict (encodeToLazyText loitem)
                                in
                                (Info, text, Just loitem)
                            (AggregatedMessage aggregated) →
                                let text = T.concat $ (flip map) aggregated $ λ(name, agg) →
                                    "\n" <> name <> ":  " <> pack (show agg)
                                in
                                (Info, text, Nothing)
                            (LogValue name value) →
                                (Debug, name <> " = " <> pack (showSI value), Nothing)
                            (MonitoringEffect logitem) →
                                let text = TL.toStrict (encodeToLazyText logitem)
                                in
                                (Info, text, Just loitem)
                            KillPill →
                                (Info, "Kill pill received!", Nothing)
```

```
          if (msg ≡ "") ∧ (isNothing payload)
          then return ()
          else do
            let threadIdText = KC.mkThreadIdText (tid lometa)
            let ns = lnName namedLogItem
            let itemTime = tstamp lometa
            let itemKatip = K.Item {
              _itemApp       = env ^. KC.logEnvApp
              , _itemEnv       = env ^. KC.logEnvEnv
              , _itemSeverity  = sev2klog sev
              , _itemThread    = threadIdText
              , _itemHost      = env ^. KC.logEnvHost
              , _itemProcess   = env ^. KC.logEnvPid
              , _itemPayload   = payload
              , _itemMessage   = K.logStr msg
              , _itemTime      = itemTime
              , _itemNamespace = (env ^. KC.logEnvApp) <> (K.Namespace [ns])
              , _itemLoc       = Nothing
              }
            void $ atomically $ KC.tryWriteTBQueue shChan (KC.NewItem itemKatip)
        else return ()
```

Scribes

```
mkStdoutScribe :: IO K.Scribe
mkStdoutScribe = do
    -- duplicate stdout so that Katip's closing
    -- action will not close the real stdout
    stdout' ← hDuplicate stdout
    mkTextFileScribeH stdout' True

mkStderrScribe :: IO K.Scribe
mkStderrScribe = do
    -- duplicate stderr so that Katip's closing
    -- action will not close the real stderr
    stderr' ← hDuplicate stderr
    mkTextFileScribeH stderr' True

mkTextFileScribeH :: Handle → Bool → IO K.Scribe
mkTextFileScribeH handler color = do
    mkFileScribeH handler formatter color
  where
    formatter h colorize verbosity item =
      TIO.hPutStrLn h $! toLazyText $ formatItem colorize verbosity item

mkFileScribeH
    :: Handle
    → (forall a ∘ K.LogItem a ⇒ Handle → Bool → K.Verbosity → K.Item a → IO ())
    → Bool
```

```
        → IO K.Scribe
mkFileScribeH h formatter colorize = do
    hSetBuffering h LineBuffering
    locklocal ← newMVar ()
    let logger :: forall a ∘ K.LogItem a ⇒ K.Item a → IO ()
        logger item = withMVar locklocal $ \_ →
                formatter h colorize K.V0 item
    pure $ K.Scribe logger (hClose h)
mkTextFileScribe :: Maybe RotationParameters → FileDescription → Bool → IO K.Scribe
mkTextFileScribe rotParams fdesc colorize = do
    mkFileScribe rotParams fdesc formatter colorize
  where
    formatter :: Handle → Bool → K.Verbosity → K.Item a → IO Int
    formatter hdl colorize′ v′ item =
      case KC._itemMessage item of
          K.LogStr "" →
            -- if message is empty do not output it
            return 0
          _ → do
            let tmsg = toLazyText $ formatItem colorize′ v′ item
            TIO.hPutStrLn hdl tmsg
            return $ fromIntegral $ TL.length tmsg
mkJsonFileScribe :: Maybe RotationParameters → FileDescription → Bool → IO K.Scribe
mkJsonFileScribe rotParams fdesc colorize = do
    mkFileScribe rotParams fdesc formatter colorize
  where
    formatter :: (K.LogItem a) ⇒ Handle → Bool → K.Verbosity → K.Item a → IO Int
    formatter h _ verbosity item = do
      let jmsg = case KC._itemMessage item of
          -- if a message is contained in item then only the
          -- message is printed and not the data
          K.LogStr "" → K.itemJson verbosity item
          K.LogStr msg → K.itemJson verbosity $
            item {KC._itemMessage = K.logStr ("" :: Text)
              ,KC._itemPayload = LogItem Both Info $ TL.toStrict $ toLazyText msg
              }
        tmsg = encodeToLazyText jmsg
      TIO.hPutStrLn h tmsg
      return $ fromIntegral $ TL.length tmsg
mkFileScribe
    :: Maybe RotationParameters
    → FileDescription
    → (forall a ∘ K.LogItem a ⇒ Handle → Bool → K.Verbosity → K.Item a → IO Int)
    → Bool
    → IO K.Scribe
mkFileScribe (Just rotParams) fdesc formatter colorize = do
    let prefixDir = prefixPath fdesc
    (createDirectoryIfMissing True prefixDir)
      `catchIO` (prtoutException ("cannot log prefix directory: " ++ prefixDir))
    let fpath = filePath fdesc
    trp ← initializeRotator rotParams fpath
    scribestate ← newMVar trp-- triple of (handle), (bytes remaining), (rotate time)
    -- sporadically remove old log files - every 10 seconds
    cleanup ← mkAutoUpdate defaultUpdateSettings {
                                  updateAction = cleanupRotator rotParams fpath
                       , updateFreq = 10000000
                       }
    let finalizer :: IO ()
      finalizer = withMVar scribestate $
                                  λ(h, _, _) → hClose h
    let logger :: forall a ∘ K.LogItem a ⇒ K.Item a → IO ()
      logger item =
        modifyMVar_ scribestate $ λ(h, bytes, rottime) → do
          byteswritten ← formatter h colorize K.V0 item
          -- remove old files
          cleanup
          -- detect log file rotation
          let bytes' = bytes − (toInteger $ byteswritten)
          let tdiff' = round $ diffUTCTime rottime (K._itemTime item)
          if bytes' < 0 ∨ tdiff' < (0 :: Integer)
            then do -- log file rotation
              hClose h
              (h2, bytes2, rottime2) ← evalRotator rotParams fpath
              return (h2, bytes2, rottime2)
            else
              return (h, bytes', rottime)
    return $ K.Scribe logger finalizer
-- log rotation disabled.
mkFileScribe Nothing fdesc formatter colorize = do
    let prefixDir = prefixPath fdesc
    (createDirectoryIfMissing True prefixDir)
      `catchIO` (prtoutException ("cannot log prefix directory: " ++ prefixDir))
    let fpath = filePath fdesc
    h ← catchIO (openFile fpath WriteMode) $
              λe → do
                prtoutException ("error while opening log: " ++ fpath) e
                -- fallback to standard output in case of exception
                return stdout
    hSetBuffering h LineBuffering
    scribestate ← newMVar h
    let finalizer :: IO ()
      finalizer = withMVar scribestate hClose
    let logger :: forall a ∘ K.LogItem a ⇒ K.Item a → IO ()
      logger item =
        withMVar scribestate $ λhandler →
```

```
            void $ formatter handler colorize K.V0 item
      return $ K.Scribe logger finalizer



formatItem :: Bool → K.Verbosity → K.Item a → Builder
formatItem withColor _verb K.Item {..} =
      fromText header <>
      fromText "  " <>
      brackets (fromText timestamp) <>
      fromText "  " <>
      KC.unLogStr _itemMessage
   where
      header = colorBySeverity _itemSeverity $
         "[" <> mconcat namedcontext <> ":" <> severity <> ":" <> threadid <> "]"
      namedcontext = KC.intercalateNs _itemNamespace
      severity = KC.renderSeverity _itemSeverity
      threadid = KC.getThreadIdText _itemThread
      timestamp = pack $ formatTime defaultTimeLocale tsformat _itemTime
      tsformat :: String
      tsformat = "%F %T%2Q %Z"
      colorBySeverity s m = case s of
         K.EmergencyS → red m
         K.AlertS     → red m
         K.CriticalS  → red m
         K.ErrorS     → red m
         K.NoticeS    → magenta m
         K.WarningS   → yellow m
         K.InfoS      → blue m
         _ → m
      red = colorize "31"
      yellow = colorize "33"
      magenta = colorize "35"
      blue = colorize "34"
      colorize c m
         | withColor = "\ESC[" <> c <> "m" <> m <> "\ESC[0m"
         | otherwise = m
-- translate Severity to Log.Severity
sev2klog :: Severity → K.Severity
sev2klog = λcase
      Debug     → K.DebugS
      Info      → K.InfoS
      Notice    → K.NoticeS
      Warning   → K.WarningS
      Error     → K.ErrorS
      Critical  → K.CriticalS
      Alert     → K.AlertS
      Emergency → K.EmergencyS
```

```
data FileDescription = FileDescription {
   filePath :: !FilePath}
   deriving (Show)
prefixPath :: FileDescription → FilePath
prefixPath = takeDirectory ∘ filePath
```

1.4.28 Cardano.BM.Output.EKGView

Structure of EKGView

```
type EKGViewMVar = MVar EKGViewInternal
newtype EKGView = EKGView
   {getEV :: EKGViewMVar}
data EKGViewInternal = EKGViewInternal
   {evQueue :: TBQ.TBQueue (Maybe NamedLogItem)
   ,evLabels :: EKGViewMap
   ,evServer :: Server
   }
```

Relation from variable name to label handler

We keep the label handlers for later update in a *HashMap*.

```
type EKGViewMap = HM.HashMap Text Label.Label
```

Internal Trace

This is an internal Trace, named "#ekgview", which can be used to control the messages that are being displayed by EKG.

```
ekgTrace :: EKGView → Configuration → IO (Trace IO)
ekgTrace ekg c = do
      let trace = ekgTrace' ekg
         ctx = TraceContext {loggerName = ""
                  ,configuration = c
                  ,minSeverity = Debug
                  ,tracetype = Neutral
                  ,shutdown = pure ()
                  }
      Trace.subTrace "#ekgview" (ctx, trace)
   where
      ekgTrace' :: EKGView → TraceNamed IO
      ekgTrace' ekgview = BaseTrace.BaseTrace $ Op $ λ(LogNamed lognamed lo) → do
         let setlabel :: Text → Text → EKGViewInternal → IO (Maybe EKGViewInternal)
            setlabel name label ekg_i@(EKGViewInternal _ labels server) =
               case HM.lookup name labels of
```

```
                Nothing → do
                    ekghdl ← getLabel name server
                    Label.set ekghdl label
                    return $ Just $ ekg_i {evLabels = HM.insert name ekghdl labels}
                Just ekghdl → do
                    Label.set ekghdl label
                    return Nothing
        update :: LogObject → LoggerName → EKGViewInternal → IO (Maybe EKGViewInternal)
        update (LogObject _ (LogMessage logitem)) logname ekg_i =
            setlabel logname (liPayload logitem) ekg_i
        update (LogObject _ (LogValue iname value)) logname ekg_i =
            let logname' = logname <> "." <> iname
            in
            setlabel logname' (pack $ show value) ekg_i
        update _ _ _ = return Nothing
    modifyMVar_ (getEV ekgview) $ λekgup → do
        let -- strip off some prefixes not necessary for display
            lognam1 = case stripPrefix "#ekgview.#aggregation." lognamed of
                    Nothing → lognamed
                    Just ln' → ln'
            logname = case stripPrefix "#ekgview." lognam1 of
                    Nothing → lognam1
                    Just ln' → ln'
        upd ← update lo logname ekgup
        case upd of
            Nothing → return ekgup
            Just ekgup' → return ekgup'
```

EKG view is an effectuator

Function *effectuate* is called to pass in a NamedLogItem for display in EKG. If the log item is an *AggregatedStats* message, then all its constituents are put into the queue. In case the queue is full, all new items are dropped.

```
instance IsEffectuator EKGView where
    effectuate ekgview item = do
        ekg ← readMVar (getEV ekgview)
        let enqueue a = do
                nocapacity ← atomically $ TBQ.isFullTBQueue (evQueue ekg)
                if nocapacity
                then handleOverflow ekgview
                else atomically $ TBQ.writeTBQueue (evQueue ekg) (Just a)
        case (lnItem item) of
            (LogObject lometa (AggregatedMessage ags)) → liftIO $ do
                let logname = lnName item
                    traceAgg :: [(Text, Aggregated)] → IO ()
                    traceAgg [ ] = return ()
```

```
              traceAgg ((n, AggregatedEWMA ewma) : r) = do
                 enqueue $ LogNamed (logname <> "." <> n) $ LogObject lometa (LogValue "avg" $ avg ewma)
                 traceAgg r
              traceAgg ((n, AggregatedStats stats) : r) = do
                 let statsname = logname <> "." <> n
                     qbasestats s′ nm = do
                        enqueue $ LogNamed nm $ LogObject lometa (LogValue "mean" (PureD $ meanOfStats s′))
                        enqueue $ LogNamed nm $ LogObject lometa (LogValue "min" $ fmin s′)
                        enqueue $ LogNamed nm $ LogObject lometa (LogValue "max" $ fmax s′)
                        enqueue $ LogNamed nm $ LogObject lometa (LogValue "count" $ PureI $ fromIntegral $ fco
                        enqueue $ LogNamed nm $ LogObject lometa (LogValue "stdev" (PureD $ stdevOfStats s′))
                 enqueue $ LogNamed statsname $ LogObject lometa (LogValue "last" $ flast stats)
                 qbasestats (fbasic stats) $ statsname <> ".basic"
                 qbasestats (fdelta stats) $ statsname <> ".delta"
                 qbasestats (ftimed stats) $ statsname <> ".timed"
                 traceAgg r
           traceAgg ags
        (LogObject _ (LogMessage _)) → enqueue item
        (LogObject _ (LogValue _ _)) → enqueue item
        _ → return ()
    handleOverflow _ = putStrLn "Notice: EKGViews′s queue full, dropping log items!"
```

EKGView implements Backend functions

EKGView is an IsBackend

```
instance IsBackend EKGView where
    typeof _ = EKGViewBK
    realize config = do
        evref ← newEmptyMVar
        let ekgview = EKGView evref
        evport ← getEKGport config
        ehdl ← forkServer "127.0.0.1" evport
        ekghdl ← getLabel "iohk-monitoring version" ehdl
        Label.set ekghdl $ pack (showVersion version)
        ekgtrace ← ekgTrace ekgview config
        queue ← atomically $ TBQ.newTBQueue 512
        dispatcher ← spawnDispatcher queue ekgtrace
        -- link the given Async to the current thread, such that if the Async
        -- raises an exception, that exception will be re-thrown in the current
        -- thread, wrapped in ExceptionInLinkedThread.
        Async.link dispatcher
        putMVar evref $ EKGViewInternal
            {evLabels = HM.empty
            ,evServer = ehdl
            ,evQueue = queue
            }
    return ekgview
  unrealize ekgview =
    withMVar (getEV ekgview) $ λekg →
      killThread $ serverThreadId $ evServer ekg
```

Asynchrouniously reading log items from the queue and their processing

```
spawnDispatcher :: TBQ.TBQueue (Maybe NamedLogItem)
            → Trace.Trace IO
            → IO (Async.Async ())
spawnDispatcher evqueue trace =
    Async.async $ qProc
  where
    qProc = do
      maybeItem ← atomically $ TBQ.readTBQueue evqueue
      case maybeItem of
        Just (LogNamed logname logvalue) → do
          trace' ← Trace.appendName logname trace
          Trace.traceNamedObject trace' logvalue
          qProc
        Nothing → return ()-- stop here
```

Interactive testing EKGView

```
test :: IO ()
test = do
  c ← Cardano.BM.Setup.setupTrace (Left "test/config.yaml") "ekg"
  ev ← Cardano.BM.Output ∘ EKGView.realize c
  effectuate ev $ LogNamed "test.questions" (LogValue "answer" 42)
  effectuate ev $ LogNamed "test.monitor023" (LogMessage (LogItem Public Warning "!!!! ALARM !!!!"
```

1.4.29 Cardano.BM.Output.Aggregation

Internal representation

```
type AggregationMVar = MVar AggregationInternal
newtype Aggregation = Aggregation
  {getAg :: AggregationMVar}
data AggregationInternal = AggregationInternal
  {agQueue :: TBQ.TBQueue (Maybe NamedLogItem)
  ,agDispatch :: Async.Async ()
  }
```

Relation from context name to aggregated statistics

We keep the aggregated values (Aggregated) for a named context in a *HashMap*.

```
type AggregationMap = HM.HashMap Text AggregatedExpanded
```

Info for Aggregated operations

Apart from the Aggregated we keep some valuable info regarding to them; such as when was the last time it was sent.

```
type Timestamp = Word64
data AggregatedExpanded = AggregatedExpanded
  {aeAggregated :: !Aggregated
  ,aeResetAfter :: !(Maybe Int)
  ,aeLastSent ::  {-# UNPACK #-}  ! Timestamp
  }
```

Aggregation implements *effectuate*

Aggregation is an IsEffectuator Enter the log item into the Aggregation queue.

```
instance IsEffectuator Aggregation where
  effectuate agg item = do
    ag ← readMVar (getAg agg)
    nocapacity ← atomically $ TBQ.isFullTBQueue (agQueue ag)
    if nocapacity
    then handleOverflow agg
    else atomically $ TBQ.writeTBQueue (agQueue ag) $! Just item
  handleOverflow _ = putStrLn "Notice: Aggregation's queue full, dropping log items!"
```

Aggregation implements Backend functions

Aggregation is an IsBackend

```
instance IsBackend Aggregation where
  typeof _ = AggregationBK
  realize _ = error "Aggregation cannot be instantiated by 'realize'"
  realizefrom trace0@(ctx, _) _ = do
    trace ← Trace.subTrace "#aggregation" trace0
    aggref ← newEmptyMVar
    aggregationQueue ← atomically $ TBQ.newTBQueue 2048
    dispatcher ← spawnDispatcher (configuration ctx) HM.empty aggregationQueue trace
    -- link the given Async to the current thread, such that if the Async
    -- raises an exception, that exception will be re-thrown in the current
    -- thread, wrapped in ExceptionInLinkedThread.
    Async.link dispatcher
    putMVar aggref $ AggregationInternal aggregationQueue dispatcher
    return $ Aggregation aggref
  unrealize aggregation = do
    let clearMVar :: MVar a → IO ()
      clearMVar = void ∘ tryTakeMVar
    (dispatcher, queue) ← withMVar (getAg aggregation) (λag →
      return (agDispatch ag, agQueue ag))
    -- send terminating item to the queue
    atomically $ TBQ.writeTBQueue queue Nothing
    -- wait for the dispatcher to exit
    -- TODO add a timeout to waitCatch in order
    -- to be sure that it will finish
    res ← Async.waitCatch dispatcher
    either throwM return res
    (clearMVar ∘ getAg) aggregation
```

Asynchrouniously reading log items from the queue and their processing

```
spawnDispatcher :: Configuration
          → AggregationMap
          → TBQ.TBQueue (Maybe NamedLogItem)
          → Trace.Trace IO
          → IO (Async.Async ())
spawnDispatcher conf aggMap aggregationQueue trace = Async.async $ qProc aggMap
  where
    qProc aggregatedMap = do
      maybeItem ← atomically $ TBQ.readTBQueue aggregationQueue
      case maybeItem of
        Just (LogNamed logname lo@(LogObject lm _)) → do
          (updatedMap, aggregations) ← update lo logname aggregatedMap
          unless (null aggregations) $
            sendAggregated (LogObject lm (AggregatedMessage aggregations)) logname
          qProc updatedMap
        Nothing → return ()
    createNupdate name value lme agmap = do
      case HM.lookup name agmap of
        Nothing → do
          -- if Aggregated does not exist; initialize it.
          aggregatedKind ← getAggregatedKind conf name
          case aggregatedKind of
            StatsAK → return $ singletonStats value
            EwmaAK aEWMA → do
              let initEWMA = EmptyEWMA aEWMA
              return $ AggregatedEWMA $ ewma initEWMA value
        Just a → return $ updateAggregation value (aeAggregated a) lme (aeResetAfter a)
    update :: LogObject
    → LoggerName
    → AggregationMap
    → IO (AggregationMap, [(Text, Aggregated)])
update (LogObject lme (LogValue iname value)) logname agmap = do
  let fullname = logname <> "." <> iname
  aggregated ← createNupdate fullname value lme agmap
  now ← getMonotonicTimeNSec
  let aggregatedX = AggregatedExpanded {
      aeAggregated = aggregated
      , aeResetAfter = Nothing
      , aeLastSent = now
      }
      namedAggregated = [(iname, aeAggregated aggregatedX)]
      updatedMap = HM.alter (const $ Just $ aggregatedX) fullname agmap
  return (updatedMap, namedAggregated)
update (LogObject lme (ObserveDiff counterState)) logname agmap =
  updateCounters (csCounters counterState) lme (logname, "diff") agmap [ ]
update (LogObject lme (ObserveOpen counterState)) logname agmap =
  updateCounters (csCounters counterState) lme (logname, "open") agmap [ ]
update (LogObject lme (ObserveClose counterState)) logname agmap =
  updateCounters (csCounters counterState) lme (logname, "close") agmap [ ]
update (LogObject lme (LogMessage msg)) logname agmap = do
  let iname = T.pack $ show (liSeverity msg)
  let fullname = logname <> "." <> iname
  aggregated ← createNupdate fullname (PureI 0) lme agmap
  now ← getMonotonicTimeNSec
  let aggregatedX = AggregatedExpanded {
      aeAggregated = aggregated
      , aeResetAfter = Nothing
      , aeLastSent = now
      }
      namedAggregated = [(iname, aeAggregated aggregatedX)]
      updatedMap = HM.alter (const $ Just $ aggregatedX) fullname agmap
  return (updatedMap, namedAggregated)
-- everything else
update _ _ agmap = return (agmap, [ ])
updateCounters :: [Counter]
                → LOMeta
                → (LoggerName, LoggerName)
                → AggregationMap
                → [(Text, Aggregated)]
                → IO (AggregationMap, [(Text, Aggregated)])
updateCounters [ ] _ _ aggrMap aggs = return $ (aggrMap, aggs)
updateCounters (counter : cs) lme (logname, msgname) aggrMap aggs = do
  let name = cName counter
      subname = msgname <> "." <> (nameCounter counter) <> "." <> name
      fullname = logname <> "." <> subname
```

```
            value = cValue counter
        aggregated ← createNupdate fullname value lme aggrMap
        now ← getMonotonicTimeNSec
        let aggregatedX = AggregatedExpanded {
            aeAggregated = aggregated
            ,aeResetAfter = Nothing
            ,aeLastSent = now
            }
            namedAggregated = (subname, aggregated)
            updatedMap = HM.alter (const $ Just $ aggregatedX) fullname aggrMap

        updateCounters cs lme (logname, msgname) updatedMap (namedAggregated : aggs)
    sendAggregated :: LogObject → Text → IO ()
    sendAggregated aggregatedMsg@(LogObject _ (AggregatedMessage _)) logname = do
        -- enter the aggregated message into the Trace
        trace′ ← Trace.appendName logname trace
        liftIO $ Trace.traceNamedObject trace′ aggregatedMsg
    -- ingnore every other message
    sendAggregated _ _ = return ()
```

Update aggregation

We distinguish an unitialized from an already initialized aggregation. The latter is properly initialized.
We use Welford's online algorithm to update the estimation of mean and variance of the sample statistics. (see https://en.wikipedia.org/wiki/Algorithms_for_calculating_variance#Welford's_Online

```
updateAggregation :: Measurable → Aggregated → LOMeta → Maybe Int → Aggregated
updateAggregation v (AggregatedStats s) lme resetAfter =
        let count = fcount (fbasic s)
            reset = maybe False (count ⩾) resetAfter
        in
        if reset
        then
            singletonStats v
        else
            AggregatedStats $! Stats {flast = v
                ,fold = mkTimestamp
                ,fbasic = updateBaseStats (count ⩾ 1) v (fbasic s)
                ,fdelta = updateBaseStats (count ⩾ 2) (v − flast s) (fdelta s)
                ,ftimed = updateBaseStats (count ⩾ 2) (mkTimestamp − fold s) (ftimed s)
                }
    where
        mkTimestamp = utc2ns (tstamp lme)
        utc2ns (UTCTime days secs) =
            let yearsecs :: Rational
                yearsecs = 365 ∗ 24 ∗ 3600
                rdays, rsecs :: Rational
```

```
          rdays = toRational $ toModifiedJulianDay days
          rsecs = toRational secs
          s2ns = 1000000000
        in
        Nanoseconds $ round $ (fromRational $ s2ns * rsecs + rdays * yearsecs :: Double)
updateAggregation v (AggregatedEWMA e) _ _ = AggregatedEWMA $! ewma e v

updateBaseStats :: Bool → Measurable → BaseStats → BaseStats
updateBaseStats False _ s = s {fcount = fcount s + 1}
updateBaseStats True v s =
    let newcount = fcount s + 1
        newvalue = getDouble v
        delta = newvalue − fsum_A s
        dincr = (delta / fromIntegral newcount)
        delta2 = newvalue − fsum_A s − dincr
    in
    BaseStats {fmin = min (fmin s) v
        ,fmax        = max v (fmax s)
        ,fcount = newcount
        ,fsum_A = fsum_A s + dincr
        ,fsum_B = fsum_B s + (delta * delta2)
        }
```

Calculation of EWMA

Following https://en.wikipedia.org/wiki/Moving_average#Exponential_moving_average we calculate the exponential moving average for a series of values Y_t according to:

$$S_t = \begin{cases} Y_1, & t = 1 \\ \alpha \cdot Y_t + (1 - \alpha) \cdot S_{t-1}, & t > 1 \end{cases}$$

The pattern matching below ensures that the EWMA will start with the first value passed in, and will not change type, once determined.

```
ewma :: EWMA → Measurable → EWMA
ewma (EmptyEWMA a) v = EWMA a v
ewma (EWMA a s@(Microseconds _)) y@(Microseconds _) =
  EWMA a $ Microseconds $ round $ a * (getDouble y) + (1 − a) * (getDouble s)
ewma (EWMA a s@(Seconds _)) y@(Seconds _) =
  EWMA a $ Seconds $ round $ a * (getDouble y) + (1 − a) * (getDouble s)
ewma (EWMA a s@(Bytes _)) y@(Bytes _) =
  EWMA a $ Bytes $ round $ a * (getDouble y) + (1 − a) * (getDouble s)
ewma (EWMA a (PureI s)) (PureI y) =
  EWMA a $ PureI $ round $ a * (fromInteger y) + (1 − a) * (fromInteger s)
ewma (EWMA a (PureD s)) (PureD y) =
  EWMA a $ PureD $ a * y + (1 − a) * s
ewma _ _ = error "Cannot average on values of different type"
```

1.4.30 Cardano.BM.Output.Monitoring

Structure of Monitoring

```
type MonitorMVar = MVar MonitorInternal
newtype Monitor = Monitor
  {getMon :: MonitorMVar}
data MonitorInternal = MonitorInternal
  {monQueue :: TBQ.TBQueue (Maybe NamedLogItem)
  }
```

Relation from context name to monitoring state

We remember the state of each monitored context name.

```
data MonitorState = MonitorState {
  _expression :: MEvExpr
  , _actions     :: [MEvAction]
  , _environment :: Environment
  }
type MonitorMap = HM.HashMap LoggerName MonitorState
```

Monitor view is an effectuator

Function *effectuate* is called to pass in a NamedLogItem for monitoring.

```
instance IsEffectuator Monitor where
  effectuate monitor item = do
    mon ← readMVar (getMon monitor)
    nocapacity ← atomically $ TBQ.isFullTBQueue (monQueue mon)
    if nocapacity
    then handleOverflow monitor
    else atomically $ TBQ.writeTBQueue (monQueue mon) $ Just item
  handleOverflow _ = putStrLn "Notice: Monitor′s queue full, dropping log items!"
```

Monitor implements Backend functions

Monitor is an IsBackend

```
instance IsBackend Monitor where
  typeof _ = MonitoringBK
  realize config = do
    monref ← newEmptyMVar
    let monitor = Monitor monref
    queue ← atomically $ TBQ.newTBQueue 512
    dispatcher ← spawnDispatcher queue config
    -- link the given Async to the current thread, such that if the Async
```

```
        -- raises an exception, that exception will be re-thrown in the current
        -- thread, wrapped in ExceptionInLinkedThread.
        Async.link dispatcher
        putMVar monref $ MonitorInternal
          {monQueue = queue
          -- , monState = mempty
          }
        return monitor
      unrealize _ = return ()
```

Asynchrouniously reading log items from the queue and their processing

```
  spawnDispatcher :: TBQ.TBQueue (Maybe NamedLogItem)
                  → Configuration
                  → IO (Async.Async ())
  spawnDispatcher mqueue config =
      Async.async (initMap >>= qProc)
    where
      qProc state = do
        maybeItem ← atomically $ TBQ.readTBQueue mqueue
        case maybeItem of
          Just (LogNamed logname logvalue) → do
            state' ← evalMonitoringAction state logname logvalue
            qProc state'
          Nothing → return ()-- stop here
      initMap = do
        ls ← getMonitors config
        return $ HM.fromList $ map (λ(n, (e, as)) → (n, MonitorState e as HM.empty)) $ HM.toList ls
```

Evaluation of monitoring action

Inspect the log message and match it against configured thresholds. If positive, then run the action on the current state and return the updated state.

```
  evalMonitoringAction :: MonitorMap → LoggerName → LogObject → IO MonitorMap
  evalMonitoringAction mmap logname logvalue =
      case HM.lookup logname mmap of
          Nothing → return mmap
          Just mon@(MonitorState expr acts env0) → do
            let env' = updateEnv env0 logvalue
            if evaluate env' expr
            then do
              now ← getMonotonicTimeNSec
              let env'' = HM.insert "lastalert" (Nanoseconds now) env'
              TIO.putStrLn $ "alert! " <> logname <> " " <> (pack $ show acts) <> " " <> (pack $ show env'')
              return $ HM.insert logname mon {_environment = env''} mmap
            else return mmap
    where
      utc2ns (UTCTime days secs) =
            let yearsecs :: Rational
                yearsecs = 365 ∗ 24 ∗ 3600
                rdays, rsecs :: Rational
                rdays = toRational $ toModifiedJulianDay days
                rsecs = toRational secs
                s2ns = 1000000000
            in
            Nanoseconds $ round $ (fromRational $ s2ns ∗ rsecs + rdays ∗ yearsecs :: Double)
      updateEnv env (LogObject _ (ObserveOpen _)) = env
      updateEnv env (LogObject _ (ObserveDiff _)) = env
      updateEnv env (LogObject _ (ObserveClose _)) = env
      updateEnv env (LogObject lometa (LogValue vn val)) =
            let addenv = HM.fromList [(vn, val)
                  , ("timestamp", utc2ns (tstamp lometa))
                  ]
            in
            HM.union addenv env
      updateEnv env (LogObject lometa (LogMessage logitem)) =
            let addenv = HM.fromList [("severity", (Severity (liSeverity logitem)))
                -- , ("selection", (liSelection logitem))
                -- , ("message", (liPayload logitem))
                  , ("timestamp", utc2ns (tstamp lometa))
                  ]
            in
            HM.union addenv env
      updateEnv env (LogObject lometa (AggregatedMessage vals)) =
            let addenv = ("timestamp", utc2ns (tstamp lometa)) : aggs2measurables vals [ ]
            in
            HM.union (HM.fromList addenv) env
          where
            aggs2measurables [ ] acc = acc
            aggs2measurables ((n, AggregatedEWMA ewma) : r) acc = aggs2measurables r $ (n <> ".avg", avg ewm
            aggs2measurables ((n, AggregatedStats s) : r) acc = aggs2measurables r $
                (n <> ".mean", PureD ∘ meanOfStats $ fbasic s)
                : (n <> ".flast", flast s)
                : (n <> ".fcount", PureI ∘ fromIntegral ∘ fcount $ fbasic s)
                : acc
      -- catch all
      updateEnv env _ = env
```

Chapter 2

Testing

2.1 Test coverage

Test coverage is calculated as the fraction of functions which are called from test routines. This percentage is calculated by the tool *hpc* with a call to

```
cabal new-test
```

Add to a local `cabal.project.local file these lines:`

```
tests:             True
coverage:          True
library-coverage:  True
```

2.2 Test main entry point

```
module Main
  (
    main
  ) where
import Test.Tasty
import qualified Cardano.BM.Test.Aggregated (tests)
import qualified Cardano.BM.Test.STM (tests)
import qualified Cardano.BM.Test.Trace (tests)
import qualified Cardano.BM.Test.Configuration (tests)
import qualified Cardano.BM.Test.Routing (tests)
import qualified Cardano.BM.Test.Monitoring (tests)
main :: IO ()
main = defaultMain tests
tests :: TestTree
tests =
  testGroup "iohk-monitoring"
  [Cardano.BM.Test ∘ Aggregated.tests
  ,Cardano.BM.Test ∘ STM.tests
  ,Cardano.BM.Test ∘ Trace.tests
  ,Cardano.BM.Test ∘ Configuration.tests
```

Cardano.BM.Counters.Dummy	100%
Cardano.BM.Setup	100%
Cardano.BM.Data.Trace	100%
Cardano.BM.Counters.Common	100%
Cardano.BM.Counters	100%
Cardano.BM.Configuration.Static	100%
Cardano.BM.Configuration	100%
Cardano.BM.Configuration.Model	94%
Cardano.BM.Data.Configuration	83%
Cardano.BM.Output.Switchboard	81%
Cardano.BM.BaseTrace	80%
Cardano.BM.Observer.Monadic	75%
Cardano.BM.Output.Log	66%
Cardano.BM.Output.Aggregation	62%
Cardano.BM.Data.Aggregated	60%
Cardano.BM.Data.Counter	56%
Cardano.BM.Data.Output	55%
Cardano.BM.Data.BackendKind	50%
Cardano.BM.Data.Backend	50%
Cardano.BM.Data.LogItem	46%
Cardano.BM.Trace	43%
Cardano.BM.Data.MonitoringEval	42%
Cardano.BM.Data.Severity	41%
Cardano.BM.Data.Observable	40%
Cardano.BM.Observer.STM	33%
Cardano.BM.Data.AggregatedKind	33%
Cardano.BM.Data.SubTrace	10%
Cardano.BM.Data.Rotation	10%
Cardano.BM.Rotator	0%
Cardano.BM.Output.Monitoring	0%
Cardano.BM.Output.EKGView	0%
Paths_iohk_monitoring	0%
	52%

Figure 2.1: Test coverage of modules in percent as computed by the tool 'hpc'

```
    ,Cardano.BM.Test ∘ Routing.tests
    ,Cardano.BM.Test ∘ Monitoring.tests
    ]
```

2.3 Test case generation

2.3.1 instance Arbitrary Aggregated

We define an instance of *Arbitrary* for an Aggregated which lets *QuickCheck* generate arbitrary instances of Aggregated. For this an arbitrary list of *Integer* is generated and this list is aggregated into a structure of Aggregated.

```
instance Arbitrary Aggregated where
  arbitrary = do
    vs' ← arbitrary :: Gen [Integer]
    let vs = 42 : 17 : vs'
      ds = map (λ(a,b) → a − b) $ zip vs (tail vs)
      (m1,s1) = updateMeanVar $ map fromInteger vs
      (m2,s2) = updateMeanVar $ map fromInteger ds
      mkBasicStats = BaseStats
        (PureI (minimum vs))
        (PureI (maximum vs))
        (fromIntegral $ length vs)
        (m1)
        (s1)
      mkDeltaStats = BaseStats
        (PureI (minimum ds))
        (PureI (maximum ds))
        (fromIntegral $ length ds)
        (m2)
        (s2)
      mkTimedStats = BaseStats
        (Nanoseconds 0)
        (Nanoseconds 0)
        (0)
        (0)
        (0)
    return $ AggregatedStats (Stats
      (PureI (last vs))
      (Nanoseconds 0)
      mkBasicStats
      mkDeltaStats
      mkTimedStats)
```

Estimators for mean and variance must be updated the same way as in the code.

```
updateMeanVar :: [Double] → (Double, Double)
updateMeanVar [ ] = (0, 0)
updateMeanVar (val : vals) = updateMeanVar′ (val, 0) 1 vals
  where
    updateMeanVar′ (m, s) _ [ ] = (m, s)
    updateMeanVar′ (m, s) cnt (a : r) =
      let delta = a − m
          newcount = cnt + 1
          m′ = m + (delta / newcount)
          s′ = s + (delta ∗ (a − m′))
      in
      updateMeanVar′ (m′, s′) newcount r
```

2.4 Tests

2.4.1 Testing aggregation

```
tests :: TestTree
tests = testGroup "Aggregation measurements" [
  propertyTests
  , unitTests1
  , unitTests2
  ]
propertyTests :: TestTree
propertyTests = testGroup "Properties" [
  testProperty "minimal" prop_Aggregation_minimal
  , testProperty "commutative" prop_Aggregation_comm
  ]
unitTests1 :: TestTree
unitTests1 = testGroup "Unit tests for Aggregated" [
  testCase "compare equal >" unitAggregatedEqualGT
  , testCase "compare equal <" unitAggregatedEqualLT
  , testCase "compare different >" unitAggregatedDiffGT
  , testCase "compare different <" unitAggregatedDiffLT
  ]
unitTests2 :: TestTree
unitTests2 = testGroup "Unit tests for Aggregation" [
  testCase "initial -1" unitAggregationInitialMinus1
  , testCase "initial +1" unitAggregationInitialPlus1
  , testCase "initial +0" unitAggregationInitialZero
  , testCase "initial +1, -1" unitAggregationInitialPlus1Minus1
  , testCase "stepwise" unitAggregationStepwise
  ]
```

Property tests

```
prop_Aggregation_minimal :: Bool
prop_Aggregation_minimal = True
```

```
lometa :: LOMeta
lometa = unsafePerformIO $ mkLOMeta

prop_Aggregation_comm :: Integer → Integer → Aggregated → Bool
prop_Aggregation_comm v1 v2 ag =
   let AggregatedStats stats1 = updateAggregation (PureI v1) (updateAggregation (PureI v2) ag lometa Noth
       AggregatedStats stats2 = updateAggregation (PureI v2) (updateAggregation (PureI v1) ag lometa Nothi
   in
   fbasic stats1 ≡ fbasic stats2 ∧
   (v1 ≡ v2) ‘implies‘ (flast stats1 ≡ flast stats2)

-- implication:  if p1 is true, then return p2; otherwise true
implies :: Bool → Bool → Bool
implies p1 p2 = (¬ p1) ∨ p2
```

Unit tests for Aggregation

```
unitAggregationInitialMinus1 :: Assertion
unitAggregationInitialMinus1 = do
      let AggregatedStats stats1 = updateAggregation (−1) firstStateAggregatedStats lometa Nothing
      flast stats1 @? = (−1)
      (fbasic stats1) @? = BaseStats (−1) 0 2 (−0.5) 0.5
      (fdelta stats1) @? = BaseStats 0 0 1 0 0
        -- AggregatedStats (Stats (-1) 0 (BaseStats (-1) 0 2 (-0.5) 0.5) (BaseStats 0 0 1 0
unitAggregationInitialPlus1 :: Assertion
unitAggregationInitialPlus1 = do
      let AggregatedStats stats1 = updateAggregation 1 firstStateAggregatedStats lometa Nothing
      flast stats1 @? = 1
      (fbasic stats1) @? = BaseStats 0 1 2 0.5 0.5
      (fdelta stats1) @? = BaseStats 0 0 1 0 0
        -- AggregatedStats (Stats 1 0 (BaseStats 0 1 2 0.5 0.5) (BaseStats 0 0 1 0 0) (Base
unitAggregationInitialZero :: Assertion
unitAggregationInitialZero = do
      let AggregatedStats stats1 = updateAggregation 0 firstStateAggregatedStats lometa Nothing
      flast stats1 @? = 0
      (fbasic stats1) @? = BaseStats 0 0 2 0 0
      (fdelta stats1) @? = BaseStats 0 0 1 0 0
        -- AggregatedStats (Stats 0 0 (BaseStats 0 0 2 0 0) (BaseStats 0 0 1 0 0) (BaseStat
unitAggregationInitialPlus1Minus1 :: Assertion
unitAggregationInitialPlus1Minus1 = do
      let AggregatedStats stats1 = updateAggregation (PureI (−1)) (updateAggregation (PureI 1) firstStateAg
      (fbasic stats1) @? = BaseStats (PureI (−1)) (PureI 1) 3 0.0 2.0
      (fdelta stats1) @? = BaseStats (PureI (−2)) (PureI 0) 2 (−1.0) 2.0

unitAggregationStepwise :: Assertion
unitAggregationStepwise = do
      stats0 ← pure $ singletonStats (Bytes 3000)
      -- putStrLn (show stats0)
      threadDelay 50000-- 0.05 s
```

```
        t1 ← mkLOMeta
        stats1 ← pure $ updateAggregation (Bytes 5000) stats0 t1 Nothing
        -- putStrLn (show stats1)
        -- showTimedMean stats1
        threadDelay 50000-- 0.05 s
        t2 ← mkLOMeta
        stats2 ← pure $ updateAggregation (Bytes 1000) stats1 t2 Nothing
        -- putStrLn (show stats2)
        -- showTimedMean stats2
        checkTimedMean stats2
        threadDelay 50000-- 0.05 s
        t3 ← mkLOMeta
        stats3 ← pure $ updateAggregation (Bytes 3000) stats2 t3 Nothing
        -- putStrLn (show stats3)
        -- showTimedMean stats3
        checkTimedMean stats3
        threadDelay 50000-- 0.05 s
        t4 ← mkLOMeta
        stats4 ← pure $ updateAggregation (Bytes 1000) stats3 t4 Nothing
        -- putStrLn (show stats4)
        -- showTimedMean stats4
        checkTimedMean stats4
      where
        checkTimedMean (AggregatedEWMA _) = return ()
        checkTimedMean (AggregatedStats s) = do
          let mean = meanOfStats (ftimed s)
          assertBool "the mean should be >= the minimum" (mean ⩾ getDouble (fmin (ftimed s)))
          assertBool "the mean should be =< the maximum" (mean ⩽ getDouble (fmax (ftimed s)))
```

commented out:

```
    showTimedMean (AggregatedEWMA _) = return ()
    showTimedMean (AggregatedStats s) = putStrLn $ "mean = " ++ show (meanOfStats (ftimed s)) ++ showUnits (fm


    firstStateAggregatedStats :: Aggregated
    firstStateAggregatedStats = AggregatedStats (Stats z z (BaseStats z z 1 0 0) (BaseStats z z 0 0 0) (BaseStats z z 0 0
      where
        z = PureI 0
```

Unit tests for Aggregated

```
    unitAggregatedEqualGT :: Assertion
    unitAggregatedEqualGT = do
      assertBool "comparing seconds"
        ((Seconds 3) > (Seconds 2))
      assertBool "comparing microseconds"
        ((Microseconds 3000) > (Microseconds 2000))
      assertBool "comparing nanoseconds"
        ((Nanoseconds 3000000) > (Nanoseconds 2000000))
      assertBool "comparing bytes"
        ((Bytes 2048) > (Bytes 1024))
      assertBool "comparing doubles"
        ((PureD 2.34) > (PureD 1.42))
      assertBool "comparing integers"
        ((PureI 2) > (PureI 1))
      assertBool "comparing severities"
        ((Severity Error) > (Severity Warning))
    unitAggregatedEqualLT :: Assertion
    unitAggregatedEqualLT = do
      assertBool "comparing seconds"
        ((Seconds 2) < (Seconds 3))
      assertBool "comparing microseconds"
        ((Microseconds 2000) < (Microseconds 3000))
      assertBool "comparing nanoseconds"
        ((Nanoseconds 2000000) < (Nanoseconds 3000000))
      assertBool "comparing bytes"
        ((Bytes 1024) < (Bytes 2048))
      assertBool "comparing doubles"
        ((PureD 1.34) < (PureD 2.42))
      assertBool "comparing integers"
        ((PureI 1) < (PureI 2))
      assertBool "comparing severities"
        ((Severity Info) < (Severity Notice))
    unitAggregatedDiffGT :: Assertion
    unitAggregatedDiffGT = do
      assertBool "comparing time (μs vs. s)"
        ((Microseconds 3000000) > (Seconds 2))
      assertBool "comparing time (μs vs. ns)"
        ((Microseconds 30) > (Nanoseconds 29999999))
      assertBool "comparing nanoseconds"
        ((Nanoseconds 3000000) > (Microseconds 2900))
      assertBool "comparing bytes"
        ((Bytes 2048) > (PureI 1024))
      assertBool "comparing doubles"
        ((PureD 2.34) > (PureI 1))
      assertBool "comparing integers"
        ((PureI 2) > (PureD 1.42))
    unitAggregatedDiffLT :: Assertion
    unitAggregatedDiffLT = do
      assertBool "comparing time (μs vs. s)"
        ((Microseconds 2999999) < (Seconds 3))
      assertBool "comparing time (μs vs. ns)"
        ((Microseconds 30) < (Nanoseconds 30001))
      assertBool "comparing nanoseconds"
        ((Nanoseconds 3000000) < (Microseconds 3001))
      assertBool "comparing bytes"
        ((PureI 1024) < (Bytes 2048))
      assertBool "comparing doubles"
        ((PureD 2.34) < (PureI 3))
      assertBool "comparing integers"
        ((PureI 2) < (PureD 3.42))
```

2.4.2 Cardano.BM.Test.STM

```
module Cardano.BM.Test.STM (
  tests
  ) where
import Test.Tasty
import Test.Tasty.QuickCheck
tests :: TestTree
tests = testGroup "Observing STM actions" [
  testProperty "minimal" prop_STM_observer
    ]
prop_STM_observer :: Bool
prop_STM_observer = True
```

2.4.3 Cardano.BM.Test.Trace

```
tests :: TestTree
tests = testGroup "Testing Trace" [
    unit_tests
  ,testCase "forked traces stress testing" stressTraceInFork
  ,testCase "stress testing: ObservableTrace vs. NoTrace" timingObservableVsUntimed
  ,testCaseInfo "demonstrating logging" simpleDemo
  ,testCaseInfo "demonstrating nested named context logging" exampleWithNamedContexts
  ]
unit_tests :: TestTree
unit_tests = testGroup "Unit tests" [
    testCase "opening messages should not be traced" unitNoOpeningTrace
  ,testCase "hierarchy of traces" unitHierarchy
  ,testCase "forked traces" unitTraceInFork
  ,testCase "hierarchy of traces with NoTrace" $
      unitHierarchy' [Neutral,NoTrace,(ObservableTrace observablesSet)]
        onlyLevelOneMessage
  ,testCase "hierarchy of traces with DropOpening" $
      unitHierarchy' [Neutral,DropOpening,(ObservableTrace observablesSet)]
        notObserveOpen
  ,testCase "hierarchy of traces with UntimedTrace" $
```

```
        unitHierarchy' [Neutral,UntimedTrace,UntimedTrace]
          observeNoMeasures
    ,testCase "changing the minimum severity of a trace at runtime"
        unitTraceMinSeverity
    ,testCase "changing the minimum severity of a named context at runtime"
        unitNamedMinSeverity
    ,testCase "appending names should not exceed 80 chars" unitAppendName
    ,testCase "creat subtrace which duplicates messages" unitTraceDuplicate
    ,testCase "testing name filtering" unitNameFiltering
    ,testCase "testing throwing of exceptions" unitExceptionThrowing
    ,testCase "NoTrace: check lazy evaluation" unitTestLazyEvaluation
    ]
    where
      observablesSet = [MonotonicClock,MemoryStats]
      notObserveOpen :: [LogObject] → Bool
      notObserveOpen = all (λcase {LogObject _ (ObserveOpen _) → False; _ → True})
      notObserveClose :: [LogObject] → Bool
      notObserveClose = all (λcase {LogObject _ (ObserveClose _) → False; _ → True})
      notObserveDiff :: [LogObject] → Bool
      notObserveDiff = all (λcase {LogObject _ (ObserveDiff _) → False; _ → True})
      onlyLevelOneMessage :: [LogObject] → Bool
      onlyLevelOneMessage = λcase
        [LogObject _ (LogMessage (LogItem _ _ "Message from level 1."))] → True
        _ → False
      observeNoMeasures :: [LogObject] → Bool
      observeNoMeasures obs = notObserveOpen obs ∧ notObserveClose obs ∧ notObserveDiff obs
```

Helper routines

```
data TraceConfiguration = TraceConfiguration
  {tcOutputKind :: OutputKind
  ,tcName       :: LoggerName
  ,tcSubTrace   :: SubTrace
  ,tcSeverity   :: Severity
  }
setupTrace :: TraceConfiguration → IO (Trace IO)
setupTrace (TraceConfiguration outk name subTr sev) = do
  c ← liftIO $ Cardano.BM.Configuration ∘ Model.empty
  mockSwitchboard ← newMVar $ error "Switchboard uninitialized."
  ctx ← liftIO $ newContext name c sev $ Switchboard mockSwitchboard
  let logTrace0 = case outk of
      TVarList tvar → BaseTrace.natTrace liftIO $ traceInTVarIO tvar
      TVarListNamed tvar → BaseTrace.natTrace liftIO $ traceNamedInTVarIO tvar
  setSubTrace (configuration ctx) name (Just subTr)
  logTrace' ← subTrace "" (ctx,logTrace0)
  return logTrace'
```

```
setTransformer_ :: Trace IO → LoggerName → Maybe SubTrace → IO ()
setTransformer_ (ctx, _) name subtr = do
  let c = configuration ctx
      n = (loggerName ctx) <> "." <> name
  setSubTrace c n subtr
```

Simple demo of logging.

```
simpleDemo :: IO String
simpleDemo = do
  cfg ← defaultConfigTesting
  logTrace ← Setup.setupTrace (Right cfg) "test"
  putStrLn "\n"
  logDebug     logTrace "This is how a Debug message likes."
  logInfo      logTrace "This is how an Info message likes."
  logNotice    logTrace "This is how a Notice message likes."
  logWarning   logTrace "This is how a Warning message likes."
  logError     logTrace "This is how an Error message likes."
  logCritical  logTrace "This is how a Critical message likes."
  logAlert     logTrace "This is how an Alert message likes."
  logEmergency logTrace "This is how an Emergency message likes."
  return ""
```

Example of using named contexts with Trace

```
exampleWithNamedContexts :: IO String
exampleWithNamedContexts = do
    cfg ← defaultConfigTesting
    logTrace ← Setup.setupTrace (Right cfg) "test"
    putStrLn "\n"
    logInfo logTrace "entering"
    logTrace0 ← appendName "simple-work-0" logTrace
    work0 ← complexWork0 logTrace0 "0"
    logTrace1 ← appendName "complex-work-1" logTrace
    work1 ← complexWork1 logTrace1 "42"
    Async.wait work0
    Async.wait work1
    -- the named context will include "complex" in the logged message
    logInfo logTrace "done."
    threadDelay 1000
    -- force garbage collection to allow exceptions to be thrown
    performMajorGC
    threadDelay 1000
    return ""
  where
```

```
    complexWork0 tr msg = Async.async $ logInfo tr ("let's see (0): " `append` msg)
    complexWork1 tr msg = Async.async $ do
      logInfo tr ("let's see (1): " `append` msg)
      trInner@(ctx, _) ← appendName "inner-work-1" tr
      let observablesSet = [MonotonicClock]
      setSubTrace (configuration ctx) "test.complex-work-1.inner-work-1.STM-action" $
        Just $ ObservableTrace observablesSet
      _ ← STMObserver.bracketObserveIO trInner "STM-action" setVar_
      logInfo trInner "let's see: done."
```

Show effect of turning off observables

```
runTimedAction :: Trace IO → Int → IO Measurable
runTimedAction logTrace reps = do
    runid ← newUnique
    t0 ← getMonoClock
    forM_ [(1 :: Int)..reps] $ const $ observeAction logTrace
    t1 ← getMonoClock
    return $ diffTimeObserved (CounterState runid t0) (CounterState runid t1)
  where
    observeAction trace = do
      _ ← MonadicObserver.bracketObserveIO trace "" action
      return ()
    action = return $ forM [1 :: Int..100] $ λx → [x] ++ (init $ reverse [1 :: Int..10000])
timingObservableVsUntimed :: Assertion
timingObservableVsUntimed = do
    msgs1 ← STM.newTVarIO [ ]
    traceObservable ← setupTrace $ TraceConfiguration
      (TVarList msgs1)
      "observables"
      (ObservableTrace observablesSet)
      Debug
    msgs2 ← STM.newTVarIO [ ]
    traceUntimed ← setupTrace $ TraceConfiguration
      (TVarList msgs2)
      "no timing"
      UntimedTrace
      Debug
    msgs3 ← STM.newTVarIO [ ]
    traceNoTrace ← setupTrace $ TraceConfiguration
      (TVarList msgs3)
      "no trace"
      NoTrace
      Debug
    t_observable ← runTimedAction traceObservable 100
    t_untimed ← runTimedAction traceUntimed 100
    t_notrace  ← runTimedAction traceNoTrace 100
    assertBool
      ("Untimed consumed more time than ObservableTrace " ++ (show [t_untimed, t_observable]))
      (t_untimed < t_observable)
    assertBool
      ("NoTrace consumed more time than ObservableTrace" ++ (show [t_notrace, t_observable]))
      (t_notrace < t_observable)
    assertBool
      ("NoTrace consumed more time than Untimed" ++ (show [t_notrace, t_untimed]))
      True
  where
    observablesSet = [MonotonicClock, GhcRtsStats, MemoryStats, IOStats, ProcessStats]
```

Control tracing in a hierarchy of Traces

We can lay out traces in a hierarchical manner, that the children forward traced items to the parent Trace. A NoTrace introduced in this hierarchy will cut off a branch from messaging to the root.

```
unitHierarchy :: Assertion
unitHierarchy = do
  msgs ← STM.newTVarIO [ ]
  trace0 ← setupTrace $ TraceConfiguration (TVarList msgs) "test" Neutral Debug
  logInfo trace0 "This should have been displayed!"
  -- subtrace of trace which traces nothing
  setTransformer_ trace0 "inner" (Just NoTrace)
  trace1 ← subTrace "inner" trace0
  logInfo trace1 "This should NOT have been displayed!"
  setTransformer_ trace1 "innermost" (Just Neutral)
  trace2 ← subTrace "innermost" trace1
  logInfo trace2 "This should NOT have been displayed also due to the trace one level above
  -- acquire the traced objects
  res ← STM.readTVarIO msgs
  -- only the first message should have been traced
  assertBool
    ("Found more or less messages than expected: " ++ show res)
    (length res ≡ 1)
```

Change a trace's minimum severity

A trace is configured with a minimum severity and filters out messages that are labelled with a lower severity. This minimum severity of the current trace can be changed.

```
unitTraceMinSeverity :: Assertion
unitTraceMinSeverity = do
  msgs ← STM.newTVarIO [ ]
```

```
    trace@(ctx, _) ← setupTrace $ TraceConfiguration (TVarList msgs) "test min severity" Neutral Debug
    logInfo trace "Message #1"
    -- raise the minimum severity to Warning
    setMinSeverity (configuration ctx) Warning
    msev ← Cardano.BM.Configuration.minSeverity (configuration ctx)
    assertBool ("min severity should be Warning, but is " ++ (show msev))
      (msev ≡ Warning)
    -- this message will not be traced
    logInfo trace "Message #2"
    -- lower the minimum severity to Info
    setMinSeverity (configuration ctx) Info
    -- this message is traced
    logInfo trace "Message #3"
    -- acquire the traced objects
    res ← STM.readTVarIO msgs
    -- only the first and last messages should have been traced
    assertBool
      ("Found more or less messages than expected: " ++ show res)
      (length res ≡ 2)
    assertBool
      ("Found Info message when Warning was minimum severity: " ++ show res)
      (all (λcase {LogObject _ (LogMessage (LogItem _ Info "Message #2")) → False; _ → True}) res)
```

Define a subtrace's behaviour to duplicate all messages

The SubTrace will duplicate all messages that pass through it. Each message will be in its own named context.

```
  unitTraceDuplicate :: Assertion
  unitTraceDuplicate = do
    msgs ← STM.newTVarIO [ ]
    trace0@(ctx, _) ← setupTrace $ TraceConfiguration (TVarList msgs) "test duplicate" Neutral Debug
    logInfo trace0 "Message #1"
    -- create a subtrace which duplicates all messages
    setSubTrace (configuration ctx) "test duplicate.orig" $ Just (TeeTrace "dup")
    trace ← subTrace "orig" trace0
    -- this message will be duplicated
    logInfo trace "You will see me twice!"
    -- acquire the traced objects
    res ← STM.readTVarIO msgs
    -- only the first and last messages should have been traced
    assertBool
      ("Found more or less messages than expected: " ++ show res)
      (length res ≡ 3)
```

Change the minimum severity of a named context

A trace of a named context can be configured with a minimum severity, such that the trace will filter out messages that are labelled with a lower severity.

```
unitNamedMinSeverity :: Assertion
unitNamedMinSeverity = do
  msgs ← STM.newTVarIO [ ]
  trace0 ← setupTrace $ TraceConfiguration (TVarList msgs) "test named severity" Neutral Debug
  trace@(ctx, _) ← appendName "sev-change" trace0
  logInfo trace "Message #1"
  -- raise the minimum severity to Warning
  setSeverity (configuration ctx) (loggerName ctx) (Just Warning)
  msev ← Cardano.BM.Configuration.inspectSeverity (configuration ctx) (loggerName ctx)
  assertBool ("min severity should be Warning, but is " ++ (show msev))
    (msev ≡ Just Warning)
  -- this message will not be traced
  logInfo trace "Message #2"
  -- lower the minimum severity to Info
  setSeverity (configuration ctx) (loggerName ctx) (Just Info)
  -- this message is traced
  logInfo trace "Message #3"
  -- acquire the traced objects
  res ← STM.readTVarIO msgs
  -- only the first and last messages should have been traced
  assertBool
    ("Found more or less messages than expected: " ++ show res)
    (length res ≡ 2)
  assertBool
    ("Found Info message when Warning was minimum severity: " ++ show res)
    (all (λcase {LogObject _ (LogMessage (LogItem _ Info "Message #2")) → False; _ → True}) res)
```

```
unitHierarchy' :: [SubTrace] → ([LogObject] → Bool) → Assertion
unitHierarchy' subtraces f = do
  let (t1 : t2 : t3 : _) = cycle subtraces
  msgs ← STM.newTVarIO [ ]
  -- create trace of type 1
  trace1 ← setupTrace $ TraceConfiguration (TVarList msgs) "test" t1 Debug
  logInfo trace1 "Message from level 1."
  -- subtrace of type 2
  setTransformer_ trace1 "inner" (Just t2)
  trace2 ← subTrace "inner" trace1
  logInfo trace2 "Message from level 2."
  -- subsubtrace of type 3
  setTransformer_ trace2 "innermost" (Just t3)
  _ ← STMObserver.bracketObserveIO trace2 "innermost" setVar_
  logInfo trace2 "Message from level 3."
```

```
    -- acquire the traced objects
    res ← STM.readTVarIO msgs
    -- only the first message should have been traced
    assertBool
      ("Found more or less messages than expected: " ++ show res)
      (f res)
```

Logging in parallel

```
  unitTraceInFork :: Assertion
  unitTraceInFork = do
      msgs ← STM.newTVarIO [ ]
      trace ← setupTrace $ TraceConfiguration (TVarListNamed msgs) "test" Neutral Debug
      trace0 ← appendName "work0" trace
      trace1 ← appendName "work1" trace
      work0 ← work trace0
      threadDelay 5000
      work1 ← work trace1
      Async.wait $ work0
      Async.wait $ work1
      res ← STM.readTVarIO msgs
      let names@(_ : namesTail) = map lnName res
      -- each trace should have its own name and log right after the other
      assertBool
        ("Consecutive loggernames are not different: " ++ show names)
        (and $ zipWith (≢) names namesTail)
    where
      work :: Trace IO → IO (Async.Async ())
      work trace = Async.async $ do
        logInfoDelay trace "1"
        logInfoDelay trace "2"
        logInfoDelay trace "3"
      logInfoDelay :: Trace IO → Text → IO ()
      logInfoDelay trace msg =
        logInfo trace msg ≫
        threadDelay 10000
```

Stress testing parallel logging

```
  stressTraceInFork :: Assertion
  stressTraceInFork = do
      msgs ← STM.newTVarIO [ ]
      trace ← setupTrace $ TraceConfiguration (TVarListNamed msgs) "test" Neutral Debug
      let names = map (λa → ("work-" <> pack (show a))) [1 . . (10 :: Int)]
      ts ← forM names $ λname → do
```

```
        trace′ ← appendName name trace
        work trace′
      forM_ ts Async.wait

      res ← STM.readTVarIO msgs
      let resNames = map lnName res
      let frequencyMap = fromListWith (+) [(x, 1) | x ← resNames]

      -- each trace should have traced totalMessages′ messages
      assertBool
        ("Frequencies of logged messages according to loggername: " ++ show frequencyMap)
        (all (λname → (lookup ("test." <> name) frequencyMap) ≡ Just totalMessages) names)
    where
      work :: Trace IO → IO (Async.Async ())
      work trace = Async.async $ forM_ [1 .. totalMessages] $ (logInfo trace) ∘ pack ∘ show
      totalMessages :: Int
      totalMessages = 10
```

Dropping *ObserveOpen* messages in a subtrace

```
  unitNoOpeningTrace :: Assertion
  unitNoOpeningTrace = do
    msgs ← STM.newTVarIO [ ]
    logTrace ← setupTrace $ TraceConfiguration (TVarList msgs) "test" DropOpening Debug
    _ ← STMObserver.bracketObserveIO logTrace "setTVar" setVar_
    res ← STM.readTVarIO msgs
    assertBool
      ("Found non-expected ObserveOpen message: " ++ show res)
      (all (λcase {LogObject _ (ObserveOpen _) → False; _ → True}) res)
```

Assert maximum length of log context name

The name of the log context cannot grow beyond a maximum number of characters, currently the limit is set to 80.

```
  unitAppendName :: Assertion
  unitAppendName = do
      cfg ← defaultConfigTesting
      Setup.withTrace cfg "test" $ λtrace0 → do
        trace1 ← appendName bigName trace0
        (ctx2, _) ← appendName bigName trace1
        assertBool
          ("Found logger name with more than 80 chars: " ++ show (loggerName ctx2))
          (T.length (loggerName ctx2) ⩽ 80)
    where
      bigName = T.replicate 30 "abcdefghijklmnopqrstuvwxyz"

  setVar_ :: STM.STM Integer
  setVar_ = do
```

```
    t ← STM.newTVar 0
    STM.writeTVar t 42
    res ← STM.readTVar t
    return res
```

Testing log context name filters

```
unitNameFiltering :: Assertion
unitNameFiltering = do
    let contextName = "test.sub.1"
    let loname = "sum"-- would be part of a "LogValue loname 42"
    let filter1 = [(Drop (Exact "test.sub.1"), Unhide [ ])]
    assertBool ("Dropping a specific name should filter it out and thus return False")
        (False ≡ evalFilters filter1 contextName)
    let filter2 = [(Drop (EndsWith ".1"), Unhide [ ])]
    assertBool ("Dropping a name ending with a specific text should filter out the context nam
        (False ≡ evalFilters filter2 contextName)
    let filter3 = [(Drop (StartsWith "test."), Unhide [ ])]
    assertBool ("Dropping a name starting with a specific text should filter out the context n
        (False ≡ evalFilters filter3 contextName)
    let filter4 = [(Drop (Contains ".sub."), Unhide [ ])]
    assertBool ("Dropping a name starting containing a specific text should filter out the con
        (False ≡ evalFilters filter4 contextName)
    let filter5 = [(Drop (StartsWith "test."),
            Unhide [(Exact "test.sub.1")])]
    assertBool ("Dropping all and unhiding a specific name should the context name allow passi
        (True ≡ evalFilters filter5 contextName)
    let filter6 = [(Drop (StartsWith "test."),
            Unhide [(EndsWith ".sum"),
                (EndsWith ".other")])]
    assertBool ("Dropping all and unhiding some names, the LogObject should pass the filter")
        (True ≡ evalFilters filter6 (contextName <> "." <> loname))
    let filter7 = [(Drop (StartsWith "test."),
            Unhide [(EndsWith ".product")])]
    assertBool ("Dropping all and unhiding an inexistant named value, the LogObject should not
        (False ≡ evalFilters filter7 (contextName <> "." <> loname))
    let filter8 = [(Drop (StartsWith "test."),
            Unhide [(Exact "test.sub.1")]),
        (Drop (StartsWith "something.else."),
            Unhide [(EndsWith ".this")])]
    assertBool ("Disjunction of filters that should pass")
        (True ≡ evalFilters filter8 contextName)
    let filter9 = [(Drop (StartsWith "test."),
            Unhide [(Exact ".that")]),
        (Drop (StartsWith "something.else."),
            Unhide [(EndsWith ".this")])]
    assertBool ("Disjunction of filters that should not pass")
      (False ≡ evalFilters filter9 contextName)
```

Exception throwing

Exceptions encountered should be thrown.

```
unitExceptionThrowing :: Assertion
unitExceptionThrowing = do
    action ← work msg
    res ← Async.waitCatch action
    assertBool
      ("Exception should have been rethrown")
      (isLeft res)
  where
    msg :: Text
    msg = error "faulty message"
    work :: Text → IO (Async.Async ())
    work message = Async.async $ do
      cfg ← defaultConfigTesting
      trace ← Setup.setupTrace (Right cfg) "test"
      logInfo trace message
      threadDelay 10000
```

Check lazy evaluation of trace

Exception should not be thrown when type of Trace is NoTrace.

```
unitTestLazyEvaluation :: Assertion
unitTestLazyEvaluation = do
    action ← work msg
    res ← Async.waitCatch action
    assertBool
      ("Exception should not have been rethrown when type of Trace is NoTrace")
      (isRight res)
  where
    msg :: Text
    msg = error "faulty message"
    work :: Text → IO (Async.Async ())
    work message = Async.async $ do
      cfg ← defaultConfigTesting
      trace0@(ctx, _) ← Setup.setupTrace (Right cfg) "test"
      setSubTrace (configuration ctx) "test.work" (Just NoTrace)
      trace ← subTrace "work" trace0
      logInfo trace message
```

2.4.4 Testing configuration

Test declarations

```
tests :: TestTree
tests = testGroup "config tests" [
    propertyTests
    , unitTests
    ]
propertyTests :: TestTree
propertyTests = testGroup "Properties" [
    testProperty "minimal" prop_Configuration_minimal
    ]
unitTests :: TestTree
unitTests = testGroup "Unit tests" [
    testCase "static representation" unitConfigurationStaticRepresentation
    , testCase "parsed representation" unitConfigurationParsedRepresentation
    , testCase "parsed configuration" unitConfigurationParsed
    , testCase "include EKG if defined" unitConfigurationCheckEKGpositive
    , testCase "not include EKG if not def" unitConfigurationCheckEKGnegative
    , testCase "check scribe caching" unitConfigurationCheckScribeCache
    , testCase "test ops on Configuration" unitConfigurationOps
    ]
```

Property tests

```
prop_Configuration_minimal :: Bool
prop_Configuration_minimal = True
```

Unit tests

The configuration file only indicates that EKG is listening on port nnnnn. Infer that *EKGViewBK* needs to be started as a backend.

```
unitConfigurationCheckEKGpositive :: Assertion
unitConfigurationCheckEKGpositive = do
    let c = ["rotation:"
        ,"  rpLogLimitBytes: 5000000"
        ,"  rpKeepFilesNum: 10"
        ,"  rpMaxAgeHours: 24"
        ,"minSeverity: Info"
        ,"defaultBackends:"
        ,"  - KatipBK"
        ,"setupBackends:"
        ,"  - KatipBK"
        ,"defaultScribes:"
        ,"- - StdoutSK"
        ,"  - stdout"
        ,"setupScribes:"
        ,"- scName: stdout"
        ,"  scRotation: null"
        ,"  scKind: StdoutSK"
        ,"hasEKG: 18321"
        ,"options:"
        ,"  test:"
        ,"    value: nothing"
        ]
        fp = "/tmp/test_ekgv_config.yaml"
    writeFile fp $ unlines c
    repr ← parseRepresentation fp
    assertBool "expecting EKGViewBK to be setup" $
        EKGViewBK ∈ (setupBackends repr)
```

If there is no port defined for EKG, then do not start it even if present in the config.

```
unitConfigurationCheckEKGnegative :: Assertion
unitConfigurationCheckEKGnegative = do
  let c = ["rotation:"
    ,"  rpLogLimitBytes: 5000000"
    ,"  rpKeepFilesNum: 10"
    ,"  rpMaxAgeHours: 24"
    ,"minSeverity: Info"
    ,"defaultBackends:"
    ,"  - KatipBK"
    ,"  - EKGViewBK"
    ,"setupBackends:"
    ,"  - KatipBK"
    ,"  - EKGViewBK"
    ,"defaultScribes:"
    ,"- - StdoutSK"
    ,"  - stdout"
    ,"setupScribes:"
    ,"- scName: stdout"
    ,"  scRotation: null"
    ,"  scKind: StdoutSK"
    ,"###hasEKG: 18321"
    ,"options:"
    ,"  test:"
    ,"    value: nothing"
    ]
    fp = "/tmp/test_ekgv_config.yaml"
  writeFile fp $ unlines c
  repr ← parseRepresentation fp
  assertBool "EKGViewBK shall not be setup" $
    ¬ $ EKGViewBK ∈ (setupBackends repr)
  assertBool "EKGViewBK shall not receive messages" $
    ¬ $ EKGViewBK ∈ (defaultBackends repr)

unitConfigurationStaticRepresentation :: Assertion
unitConfigurationStaticRepresentation =
  let r = Representation
        {minSeverity = Info
        ,rotation = Just $ RotationParameters
                              {rpLogLimitBytes = 5000000
                              ,rpMaxAgeHours   = 24
                              ,rpKeepFilesNum = 10
                              }
        ,setupScribes =
          [ScribeDefinition {scName = "stdout"
                            ,scKind = StdoutSK
                            ,scRotation = Nothing}
          ]
        ,defaultScribes = [(StdoutSK, "stdout")]
        ,setupBackends = [EKGViewBK, KatipBK]
        ,defaultBackends = [KatipBK]
        ,hasGUI = Just 12789
        ,hasEKG = Just 18321
        ,options =
          HM.fromList [("test1", (HM.singleton "value" "object1"))
            ,("test2", (HM.singleton "value" "object2"))]
        }
  in
  encode r @? = ""
"rotation:\n"
"  rpLogLimitBytes: 5000000\n"
"  rpKeepFilesNum: 10\n"
"  rpMaxAgeHours: 24\n"
"defaultBackends:\n"
"- KatipBK\n"
"setupBackends:\n"
"- EKGViewBK\n"
"- KatipBK\n"
"hasGUI: 12789\n"
"defaultScribes:\n"
"- - StdoutSK\n"
"  - stdout\n"
"options:\n"
"  test2:\n"
"    value: object2\n"
"  test1:\n"
"    value: object1\n"
```

```
"setupScribes:\n"
"- scName: stdout\n"
"  scRotation: null\n"
"  scKind: StdoutSK\n"
"hasEKG: 18321\n"
"minSeverity: Info\n"
unitConfigurationParsedRepresentation :: Assertion
unitConfigurationParsedRepresentation = do
  repr ← parseRepresentation "test/config.yaml"
  encode repr @? = ""
"rotation:\n"
"  rpLogLimitBytes: 5000000\n"
"  rpKeepFilesNum: 10\n"
"  rpMaxAgeHours: 24\n"
"defaultBackends:\n"
"- KatipBK\n"
"setupBackends:\n"
"- AggregationBK\n"
"- EKGViewBK\n"
"- KatipBK\n"
"hasGUI: null\n"
"defaultScribes:\n"
"- - StdoutSK\n"
"  - stdout\n"
"options:\n"
"  mapSubtrace:\n"
"    iohk.benchmarking:\n"
"      tag: ObservableTrace\n"
"      contents:\n"
"      - GhcRtsStats\n"
"      - MonotonicClock\n"
"    iohk.deadend: NoTrace\n"
"  mapSeverity:\n"
"    iohk.startup: Debug\n"
"    iohk.background.process: Error\n"
"    iohk.testing.uncritical: Warning\n"
"  mapAggregatedkinds:\n"
"    iohk.interesting.value: EwmaAK {alpha = 0.75}\n"
"    iohk.background.process: StatsAK\n"
"  cfokey:\n"
"    value: Release-1.0.0\n"
"  mapMonitors:\n"
"    chain.creation.block:\n"
"    - monitor: ((time > (23 s)) Or (time < (17 s)))\n"
"    - actions:\n"
"      - AlterMinSeverity \"chain.creation\" Debug\n"
"    ! '#aggregation.critproc.observable':\n"
"    - monitor: (mean >= (42))\n"
"    - actions:\n"
"      - CreateMessage \"exceeded\" \"the observable has been too long too high!\"\n"
"      - AlterGlobalMinSeverity Info\n"
"  mapScribes:\n"
"    iohk.interesting.value:\n"
"    - StdoutSK::stdout\n"
"    - FileTextSK::testlog\n"
"    iohk.background.process: FileTextSK::testlog\n"
"  mapBackends:\n"
"    iohk.interesting.value:\n"
"    - EKGViewBK\n"
"    - AggregationBK\n"
"setupScribes:\n"
"- scName: testlog\n"
"  scRotation:\n"
"    rpLogLimitBytes: 25000000\n"
"    rpKeepFilesNum: 3\n"
"    rpMaxAgeHours: 24\n"
"  scKind: FileTextSK\n"
"- scName: stdout\n"
"  scRotation: null\n"
"  scKind: StdoutSK\n"
"hasEKG: 12789\n"
"minSeverity: Info\n"
unitConfigurationParsed :: Assertion
unitConfigurationParsed = do
  cfg ← setup "test/config.yaml"
  cfgInternal ← readMVar $ getCG cfg
  cfgInternal @? = ConfigurationInternal
    {cgMinSeverity      = Info
    ,cgMapSeverity      = HM.fromList [("iohk.startup",Debug)
                          ,("iohk.background.process",Error)
                          ,("iohk.testing.uncritical",Warning)
                          ]
    ,cgMapSubtrace      = HM.fromList [("iohk.benchmarking",
                              ObservableTrace [GhcRtsStats,MonotonicClock])
                          ,("iohk.deadend",NoTrace)
                          ]
    ,cgOptions          = HM.fromList
      [("mapSubtrace",
        HM.fromList [("iohk.benchmarking",
                        Object (HM.fromList [("tag",String "ObservableTrace")
                          ,("contents",Array $ V.fromList
                                    [String "GhcRtsStats"
                                    ,String "MonotonicClock"])]))
          ,("iohk.deadend",String "NoTrace")])
      ,("mapMonitors",HM.fromList [("chain.creation.block",Array $ V.fromList
                          [Object (HM.fromList [("monitor",String "((time > (23 s)) Or (time < (17 s
                          ,Object (HM.fromList [("actions",Array $ V.fromList
                             [String "AlterMinSeverity \"chain.creation\" Debug"])])])
        ,("#aggregation.critproc.observable",Array $ V.fromList
                          [Object (HM.fromList [("monitor",String "(mean >= (42))")])
                          ,Object (HM.fromList [("actions",Array $ V.fromList
                             [String "CreateMessage \"exceeded\" \"the observable has been too lo
                             ,String "AlterGlobalMinSeverity Info"])])])])
      ,("mapSeverity",HM.fromList [("iohk.startup",String "Debug")
        ,("iohk.background.process",String "Error")
        ,("iohk.testing.uncritical",String "Warning")])
      ,("mapAggregatedkinds",HM.fromList [("iohk.interesting.value",
                                          String "EwmaAK {alpha = 0.75}")
                                       ,("iohk.background.process",
                                          String "StatsAK")])
      ,("cfokey",HM.fromList [("value",String "Release-1.0.0")])
      ,("mapScribes",HM.fromList [("iohk.interesting.value",
                          Array $ V.fromList [String "StdoutSK::stdout"
                             ,String "FileTextSK::testlog"])
        ,("iohk.background.process",String "FileTextSK::testlog")])
      ,("mapBackends",HM.fromList [("iohk.interesting.value",
                             Array $ V.fromList [String "EKGViewBK"
                                ,String "AggregationBK"])])
      ]
    ,cgMapBackend      = HM.fromList [("iohk.interesting.value",[EKGViewBK,AggregationBK])]
    ,cgDefBackendKs    = [KatipBK]
    ,cgSetupBackends   = [AggregationBK,EKGViewBK,KatipBK]
    ,cgMapScribe       = HM.fromList [("iohk.interesting.value",
                               ["StdoutSK::stdout","FileTextSK::testlog"])
                          ,("iohk.background.process",["FileTextSK::testlog"])
                          ]
    ,cgMapScribeCache = HM.fromList [("iohk.interesting.value",
                               ["StdoutSK::stdout","FileTextSK::testlog"])
                          ,("iohk.background.process",["FileTextSK::testlog"])
                          ]
    ,cgDefScribes      = ["StdoutSK::stdout"]
    ,cgSetupScribes    = [ScribeDefinition
                             {scKind = FileTextSK
                             ,scName = "testlog"
                             ,scRotation = Just $ RotationParameters
                                {rpLogLimitBytes = 25000000
                                ,rpMaxAgeHours  = 24
                                ,rpKeepFilesNum = 3
                                }
                             }
                          ,ScribeDefinition
                             {scKind = StdoutSK
```

```
                              ,scName = "stdout"
                              ,scRotation = Nothing
                              }
                            ]
      ,cgMapAggregatedKind = HM.fromList [("iohk.interesting.value",EwmaAK {alpha = 0.75})
                            ,("iohk.background.process",StatsAK)
                            ]
      ,cgDefAggregatedKind = StatsAK
      ,cgMonitors          = HM.fromList [("chain.creation.block",((OR (Compare "time" ((>),(Agg.Second
                            ,["AlterMinSeverity \"chain.creation\" Debug"]
                            )
                              )
                            ,("#aggregation.critproc.observable",(Compare "mean" ((≥),(Agg.PureI 42))
                              ,["CreateMessage \"exceeded\" \"the observable has been too long t
                              ,"AlterGlobalMinSeverity Info"]
                              )
                              )
                            ]
      ,cgPortEKG           = 12789
      ,cgPortGUI           = 0
      }
```

Test caching and inheritance of Scribes.

```
  unitConfigurationCheckScribeCache :: Assertion
  unitConfigurationCheckScribeCache = do
    configuration ← empty
    let defScribes = ["FileTextSK::node.log"]
    setDefaultScribes configuration defScribes
    let scribes12 = ["StdoutSK::stdout","FileTextSK::out.txt"]
    setScribes configuration "name1.name2" $ Just scribes12
    scribes1234 ← getScribes configuration "name1.name2.name3.name4"
    scribes1 ← getScribes configuration "name1"
    scribes1234cached ← getCachedScribes configuration "name1.name2.name3.name4"
    scribesXcached ← getCachedScribes configuration "nameX"
    assertBool "Scribes for name1.name2.name3.name4 must be the same as name1.name2" $
      scribes1234 ≡ scribes12
    assertBool "Scribes for name1 must be the default ones" $
      scribes1 ≡ defScribes
    assertBool "Scribes for name1.name2.name3.name4 must have been cached" $
      scribes1234cached ≡ Just scribes1234
    assertBool "Scribes for nameX must not have been cached since getScribes was not called" $
      scribesXcached ≡ Nothing
```

Test operations on Configuration.

```
  unitConfigurationOps :: Assertion
  unitConfigurationOps = do
```

```
configuration ← defaultConfigStdout
defBackends ← getDefaultBackends configuration
setDefaultAggregatedKind configuration $ EwmaAK 0.01
-- since loggername does not exist the default must be inherited
defAggregatedKind ← getAggregatedKind configuration "non-existent loggername"
setAggregatedKind configuration "name1" $ Just StatsAK
name1AggregatedKind ← getAggregatedKind configuration "name1"
setEKGport configuration 11223
ekgPort ← getEKGport configuration
setGUIport configuration 1080
guiPort ← getGUIport configuration
assertBool "Default backends" $
  defBackends ≡ [KatipBK]
assertBool "Default aggregated kind" $
  defAggregatedKind ≡ EwmaAK 0.01
assertBool "Specific name aggregated kind" $
  name1AggregatedKind ≡ StatsAK
assertBool "Set EKG port" $
  ekgPort ≡ 11223
assertBool "Set GUI port" $
  guiPort ≡ 1080
```

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