Cardano.BM - logging, benchmarking and monitoring

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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.

Contents

Chapter 1

Logging, benchmarking and monitoring

1.1 Overview

In figure 1.1 we display the relationships among modules in *Cardano.BM*. Central is the Switchboard (see Cardano.BM.Output.Switchboard) that will redirect incoming log messages to selected backends according the Configuration (see Cardano.BM.Configuration.Model). The log items are created in the application's context and passed via a hierarchy of Traces (see Cardano.BM.Trace). Such a hierarchy can be built with the function subTrace. The newly added child Trace will add its name to the logging context and behave as configured. Among the different kinds of Traces implemented are NoTrace which suppresses all log items, FilterTrace which filters the log items passing through it, and ObservableTrace which allows capturing of operating system counters (see Cardano.BM.Data.SubTrace). The backend EKGView (see Cardano.BM.Output.EKGView) displays selected values in a browser. The Log backend is based on *katip* and outputs log items in files or the console. The format can be chosen to be textual or JSON representation. And finally, the Aggregation backend computes simple statistics over incoming log items (e.g. last, min, max, mean, etc.) (see Cardano.BM.Data.Aggregated).

Output selection determines which log items of a named context are routed to which backend. In the case of the Log output, this includes a configured output sink (e.g. which file). Items that are aggregated lead to the creation of an output of their current statistics. To prevent a potential infinite loop these aggregation statistics cannot be routed again back into the Aggregation.

With *Monitoring* we aim to shortcut the logging-analysis cycle and immediately evaluate monitors on logged values when they become available. In case a monitor is triggered a number of actions can be run: either internal actions that can alter the Configuration, or actions that can lead to alerting in external systems.

It is not the intention that this framework should (as part of normal use) record sufficient information so as to make the sequence of events reproducible, i.e. it is not an audit or transaction log.

1.2 Requirements

1.2.1 Observables

We can observe the passage of the flow of execution through particular points in the code (really the points at which the graph is reduced). Typically observables would be part of an outcome (which has a start and an end). Where the environment permits these outcomes could also

gather additional environmental context (e.g read system counters, 'know' the time). The proposed framework would be able to aggregate, filter such outcome measures so as to calculation things (where appropriate) such as:

- min/max/mean/variance of the resource costs of achieving an outcome

- elapsed wall-clock time

- CPU cycles

- memory allocations, etc

- exponentially weighted moving average of outcomes, events

- min/max/mean/variance of inter-arrival times of demand for service (the arrival pattern)

- measuring offered load against the system (e.g rate/distribution of requests against the wallet by an exchange, transactions being forwarded between nodes)

STM evaluation

We treat STM evaluation as a black box and register measurables (counters) before entering, and report the difference at exit together with the result. Logging in an STM will keep a list of log items which at the exit of the evaluation will be passed to the logging subsystem. Since we do not know the exact time an event occurred in the STM action, we annotate the event afterwards with the time interval of the STM action.

Function evaluation

We treat a function call as a black box and register measurables (counters) before entering, and report the difference at exit together with the result. The function is expected to accept a 'Trace' argument which receives the events.

QuickCheck properties *tentatively*

The function

```
quickCheckResult :: Testable prop => prop -> IO Result
```

will return a *Result* data structure from which we can extract the number of tests performed. Recording the start and end times allows us to derive the time spent for a single test. (although this measurement is wrong as it includes the time spent in QuickCheck setting up the test case (and shrinking?))

1.2.2   Traces

Log items are sent as streams of events to the logging system for processing (aggregation, ..) before output. Functions that need to log events must accept a *Trace* argument. There is no monad related to logging in the monad stack, thus this can work in any monadic environment.

Trace Context

A Trace maintains a named context stack. A new name can be put onto it, and all subsequent log messages are labeled with this named context. This is also true to all downstream functions which receive the modified Trace. We thus can see the call tree and how the evaluation entered the context where a logging function was called. The context also maintains a mapping from name to Severity: this way a logging function call can early end and not produce a log item when the minimum severity is not reached.

SubTrace

A Trace is created in *IO* within setupTrace with the intent to pass the traced items to a downstream logging framework for outputting to various destinations in different formats. Apart from adding a name to the naming stack we can also alter the behaviour of the Trace. The newly created Trace with a specific function to process the recorded items will forward these to the upstream Trace. This way we can, for example, locally turn on aggregation of observables and only report a summary to the logs.

1.2.3 Aggregation

Log items contain a named context, severity and a payload (message, structured value). Thinking of a relation

```
(name, severity) -> value
```

, folding a summarizing function over it outputs

```
(name, severity) -> Summary
```

. Depending on the type of *value*, the summary could provide for example:

- * : first, last, count, the time between events (mean, sigma)

- Num : min, max, median, quartiles, mean, sigma, the delta between events (mean, sigma)

  Other possible aggregations:

- exponentially weighted moving average

- histograms

1.2.4 Monitoring

- Enable (or disable) measuring events and performance at runtime (e.g. measure how block holding time has changed).

- Send alarms when observables give evidence for abnormalities

- Observe actions in progress, i.e. have started and not yet finished

- Bridge to *Datadog*?

1.2.5   Reporting

We might want to buffer events in case an exception is detected. This FIFO queue could then be output to the log for post-factum inspection.

1.2.6   Visualisation

EKG

`https://hackage.haskell.org/package/ekg`
This library allows live monitor a running instance over HTTP. There is a way we can add our own metrics to it and update them.

Log files

The output of observables immediately or aggregated to log files. The format is chosen to be JSON for easier post-processing.

Web app

Could combine EKG, log files and parameterization into one GUI.
(e.g. `https://github.com/HeinrichApfelmus/threepenny-gui`)

1.3   Description

1.3.1   Logging with Trace

Setup procedure

Hierarchy of Traces

1.3.2   Micro-benchmarks record observables

Micro-benchmarks are recording observables that measure resource usage of the whole program for a specific time. These measurements are then associated with the subsystem that was observed at that time. Caveat: if the executable under observation runs on a multiprocessor computer where more than one parallel thread executes at the same time, it becomes difficult to associate resource usage to a single function. Even more so, as Haskell's thread do not map directly to operating system threads. So the expressiveness of our approach is only valid statistically when a large number of observables have been captured.

Counters

The framework provides access to the following O/S counters (defined in ObservableInstance) on *Linux*:

- monotonic clock (see MonotonicClock)

- CPU or total time (*/proc/<pid >/stat*) (see ProcessStats)

- memory allocation (*/proc/<pid >/statm*) (see MemoryStats)

- network bytes received/sent (*/proc/<pid >/net/netstat*) (see NetStats)

- disk input/output (*/proc/<pid >/io*) (see IOStats)

On all platforms, access is provided to the *RTS* counters (see GhcRtsStats).

Implementing micro-benchmarks

In a micro-benchmark we capture operating system counters over an STM evaluation or a function, before and afterwards. Then, we compute the difference between the two and report all three measurements via a *Trace* to the logging system. Here we refer to the example that can be found in complex example.

The capturing of STM actions is defined in Cardano.BM.Observer.STM and the function *STM.bracketObserveIO* has type:

```
STM.bracketObserveIO trace "observeSTM" (stmAction args)
```

```
bracketObserveIO :: Trace IO -> Text -> STM.STM t -> IO t
```

It accepts a Trace to which it logs, adds a name to the context name and enters this with a SubTrace, and finally the STM action which will be evaluated. Because this evaluation can be retried, we cannot pass to it a Trace to which it could log directly. A variant of this function bracketObserveLogIO also captures log items in its result, which then are threaded through the Trace.
Capturing observables for a function evaluation in *IO*, the type of bracketObserveIO (defined in Cardano.BM.Observer.Monadic) is:

```
bracketObserveIO :: Trace IO -> Text -> IO t -> IO t
```

It accepts a Trace to which it logs items, adds a name to the context name and enters this with a SubTrace, and then the IO action which will be evaluated.

Counters are evaluated before the evaluation and afterwards. We trace these as log items ObserveOpen and ObserveClose, as well as the difference with type ObserveDiff.

```
bracketObserveIO trace "observeDownload" $ do
    license <- openURI "http://www.gnu.org/licenses/gpl.txt"
    case license of
        Right bs -> logInfo trace $ pack $ BS8.unpack bs
        Left e   -> logError trace $ "failed to download; error: " ++ (show e)
    threadDelay 50000  -- .05 second
    pure ()
```

Configuration of mu-benchmarks

Observed STM actions or functions enter a new named context with a SubTrace. Thus, they need a configuration of the behaviour of this SubTrace in the new context. We can define this in the configuration for our example:

```
CM.setSubTrace c "complex.observeDownload" (Just $ ObservableTrace [NetStats,IOStats])
```

This enables the capturing of network and I/O stats from the operating system. Other Observables are implemented in Cardano.BM.Data.Observable.
Captured observables need to be routed to backends. In our example we configure:

```
CM.setBackends c "complex.observeIO" (Just [AggregationBK])
```

to direct observables from named context *complex.observeIO* to the Aggregation backend.

1.3.3   Configuration

Format

The configuration is parsed from a file in *Yaml* format (see `https://en.wikipedia.org/wiki/YAML`) on startup. In a first parsing step the file is loaded into an internal *Representation*. This structure is then further processed and validated before copied into the runtime Configuration.

Configuration editor

The configuration editor (figure 1.3) provides a minimalistic GUI accessible through a browser that directly modifies the runtime configuration of the logging system. Most importantly, the global minimum severity filter can be set. This will suppress all log messages that have a severity assigned that is lower than this setting. Moreover, the following behaviours of the logging system can be changed through the GUI:

- *Backends*: relates the named logging context to a BackendKind

- *Scribes*: if the backend is *KatipBK*, defines to which outputs the messages are directed (see ScribeId)

- *Severities* a local minimum severity filter for just the named context (see Severity)

- *SubTrace* entering a new named context can create a new Trace with a specific behaviour (see SubTrace)

- *Aggregation* if the backend is *AggregationBK*, defines which aggregation method to use (see AggregatedKind)

1.3.4   Information reduction in Aggregation

Statistics

Configuration

1.3.5   Output selection

Configuration

1.3.6   Monitoring

Configuration

Evaluation of monitors

Actions fired

1.4   Examples

1.4.1   Simple example showing plain logging

```
{-# LANGUAGE OverloadedStrings #-}
module Main
```

```
  (main)
    where
import Control.Concurrent (threadDelay)
import Cardano.BM.Configuration.Static (defaultConfigStdout)
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

  return ()
```

1.4.2 Complex example showing logging, aggregation, and observing *IO* actions

Module header and import directives

```
{-# LANGUAGE CPP #-}
{-# LANGUAGE OverloadedStrings #-}
# if defined (linux_HOST_OS)
# define LINUX
# endif
 {-define the parallel procedures that create messages -}
# define RUN_ProcMessageOutput
# define RUN_ProcObserveIO
# define RUN_ProcObseverSTM
# define RUN_ProcObseveDownload
# define RUN_ProcRandom
module Main
  (main)
    where
import Control.Concurrent (threadDelay)
import qualified Control.Concurrent.Async as Async
import Control.Monad (forM_)
 # ifdef ENABLE_OBSERVABLES
import Control.Monad (forM)
import qualified Data.ByteString.Char8 as BS8
import GHC.Conc.Sync (atomically, STM, TVar, newTVar, readTVar, writeTVar)
import Network.Download (openURI)
```

```
# endif
import Data.Text (pack)
# ifdef LINUX
# endif
import System.Random

# ifdef ENABLE_GUI
import qualified Cardano.BM.Configuration.Editor as CME
# endif
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
# ifdef ENABLE_OBSERVABLES
import Cardano.BM.Observer.Monadic (bracketObserveIO)
import qualified Cardano.BM.Observer.STM as STM
# endif
import Cardano.BM.Setup
import Cardano.BM.Trace
```

Define configuration

Selected values can be viewed in EKG on `http://localhost:12789`.
The configuration editor listens on `http://localhost:13789`.

```
config :: IO CM.Configuration
config = do
  c ← CM.empty
  CM.setMinSeverity c Debug
  CM.setSetupBackends c [KatipBK
# ifdef ENABLE_AGGREGATION
      , AggregationBK
# endif
# ifdef ENABLE_EKG
      , EKGViewBK
# endif
      ]
  CM.setDefaultBackends c [KatipBK]
  CM.setSetupScribes c [ScribeDefinition {
      scName = "stdout"
      , scKind = StdoutSK
      , scPrivacy = ScPublic
```

```
          ,scRotation = Nothing
          }
      ,ScribeDefinition {
          scName = "logs/out.odd.json"
          ,scKind = FileJsonSK
          ,scPrivacy = ScPublic
          ,scRotation = Nothing
          }
      ,ScribeDefinition {
          scName = "logs/out.even.json"
          ,scKind = FileJsonSK
          ,scPrivacy = ScPublic
          ,scRotation = Nothing
          }
      ,ScribeDefinition {
          scName = "logs/downloading.json"
          ,scKind = FileJsonSK
          ,scPrivacy = ScPublic
          ,scRotation = Nothing
          }
      ,ScribeDefinition {
          scName = "logs/out.txt"
          ,scKind = FileTextSK
          ,scPrivacy = ScPublic
          ,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, NetStats])
  CM.setBackends c "complex.observeDownload" (Just [KatipBK])
  CM.setScribes c "complex.observeDownload" (Just ["StdoutSK::stdout","FileJsonSK::logs/downloa
# endif
  CM.setSubTrace c "complex.random" (Just $ TeeTrace "ewma")
  CM.setSubTrace c "#ekgview"
```

```haskell
    (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])
# ifdef ENABLE_AGGREGATION
  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])
# endif
  forM_ [(1 :: Int)..10] $ λx → do
# ifdef ENABLE_AGGREGATION
    CM.setBackends c
      ("complex.observeSTM." <> (pack $ show x))
      (Just [AggregationBK])
# endif
    CM.setBackends c
      ("#aggregation.complex.observeSTM." <> (pack $ show x))
      (Just [KatipBK])
  CM.setAggregatedKind c "complex.random.rr" (Just StatsAK)
  CM.setAggregatedKind c "complex.random.ewma.rr" (Just (EwmaAK 0.42))
# ifdef ENABLE_EKG
  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
# endif
  CM.setGUIport c 13789

  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 Debug) < * > pure (LogValue "rr" (PureD num))
         traceConditionally tr lo
         loop tr
```

Thread that observes an *IO* action

```
# ifdef ENABLE_OBSERVABLES
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 Debug "observeIO" $ do
            num ← randomRIO (100000, 200000) :: IO Int
            ls ← return $ reverse $ init $ reverse $ 42 : [1..num]
            pure $ const ls ()
         loop tr
# endif
```

Threads that observe *STM* actions on the same TVar

```
# ifdef ENABLE_OBSERVABLES
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 Debug ("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 ()
   # endif
```

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

```
   # ifdef LINUX
   # ifdef ENABLE_OBSERVABLES
   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' Debug "" $ 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
   # 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
# ifdef ENABLE_GUI
  -- start configuration editor
  CME.startup c
# endif
  -- create initial top-level Trace
  tr ← setupTrace (Right c) "complex"

  logNotice tr "starting program; hit CTRL-C to terminate"
-- user can watch the progress only if EKG is enabled.
# ifdef ENABLE_EKG
  logInfo tr "watch its progress on http://localhost:12789"
# endif
# ifdef RUN_ProcRandom
    {-start thread sending unbounded sequence of random numbers to a trace which aggregates them into a
  procRandom ← randomThr tr
# endif
# ifdef RUN_ProcObserveIO
  -- start thread endlessly reversing lists of random length
# ifdef ENABLE_OBSERVABLES
  procObsvIO ← observeIO tr
# endif
# endif
# ifdef RUN_ProcObseverSTM
  -- start threads endlessly observing STM actions operating on the same TVar
# ifdef ENABLE_OBSERVABLES
  procObsvSTMs ← observeSTM tr
# endif
# endif
# ifdef LINUX
# ifdef RUN_ProcObseveDownload
  -- start thread endlessly which downloads sth in order to check the I/O usage
# ifdef ENABLE_OBSERVABLES
  procObsvDownload ← observeDownload tr
# endif
# endif
# endif
```

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

1.5 Code listings

1.5.1 Cardano.BM.Observer.STM

$stmWithLog :: STM.STM\,(t, [\text{LogObject}]) \rightarrow STM.STM\,(t, [\text{LogObject}])$
$stmWithLog\ action = action$

Observe *STM* action in a named context

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

$bracketObserveIO :: \text{Trace}\ IO \rightarrow \text{Severity} \rightarrow Text \rightarrow STM.STM\ t \rightarrow IO\ t$
$bracketObserveIO\ logTrace0\ severity\ name\ action = \textbf{do}$

```haskell
      logTrace ← subTrace name logTrace0
      let subtrace = typeofTrace logTrace
      bracketObserveIO' subtrace severity logTrace action
    where
      bracketObserveIO' :: SubTrace → Severity → Trace IO → STM.STM t → IO t
      bracketObserveIO' NoTrace _ _ act =
        STM.atomically act
      bracketObserveIO' subtrace sev logTrace act = do
        mCountersid ← observeOpen subtrace sev logTrace

        -- run action; if an exception is caught, then it 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 sev 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.

```haskell
      bracketObserveLogIO :: Trace IO → Severity → Text → STM.STM (t, [LogObject]) → IO t
      bracketObserveLogIO logTrace0 severity name action = do
        logTrace ← subTrace name logTrace0
        let subtrace = typeofTrace logTrace
        bracketObserveLogIO' subtrace severity logTrace action
    where
      bracketObserveLogIO' :: SubTrace → Severity → Trace IO → STM.STM (t, [LogObject]) → IO t
      bracketObserveLogIO' NoTrace _ _ act = do
        (t, _) ← STM.atomically $ stmWithLog act
        pure t
      bracketObserveLogIO' subtrace sev logTrace act = do
        mCountersid ← observeOpen subtrace sev logTrace

        -- run action, return result and log items; if an exception is
        -- caught, then it 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 sev logTrace countersid as
         case res of
            Left ex → logNotice logTrace ("ObserveClose:  " <> pack (show ex))
            _ → pure ()
   pure t
```

1.5.2   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 → Severity → Text → IO t → IO t
bracketObserveIO logTrace0 severity name action = do
    logTrace ← subTrace name logTrace0
    bracketObserveIO' (typeofTrace logTrace) severity logTrace action
  where
    bracketObserveIO' :: SubTrace → Severity → Trace IO → IO t → IO t
    bracketObserveIO' NoTrace _ _ act = act
    bracketObserveIO' subtrace sev logTrace act = do
      mCountersid ← observeOpen subtrace sev 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 sev 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 → Severity → Text → m t → m t
bracketObserveM logTrace0 severity name action = do
    logTrace ← liftIO $ subTrace name logTrace0
    bracketObserveM' (typeofTrace logTrace) severity logTrace action
  where
    bracketObserveM' :: (MonadCatch m, MonadIO m) ⇒ SubTrace → Severity → Trace IO → m t → m t
    bracketObserveM' NoTrace _ _ act = act
    bracketObserveM' subtrace sev logTrace act = do
      mCountersid ← liftIO $ observeOpen subtrace sev 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 sev logTrace countersid [ ]
          case res of
            Left ex → liftIO (logNotice logTrace ("ObserveClose: " <> pack (show ex)))
            _ → pure ()
      pure t
```

observerOpen

```
observeOpen :: SubTrace → Severity → Trace IO → IO (Either SomeException CounterState)
observeOpen subtrace severity 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
    traceConditionally logTrace ≪
      LogObject < $ > (mkLOMeta severity) < * > pure (ObserveOpen state)
  return (Right state)) 'catch' (return ∘ Left)
```

observeClose

```
observeClose
    :: SubTrace
    → Severity
```

```
          → Trace IO
          → CounterState
          → [LogObject]
          → IO (Either SomeException ())
      observeClose subtrace sev logTrace initState logObjects = (do
          let identifier = csIdentifier initState
              initialCounters = csCounters initState

          -- take measurement
          counters ← readCounters subtrace
          if counters ≡ [ ]
          then return ()
          else do
              mle ← mkLOMeta sev
              -- send closing message to Trace
              traceConditionally logTrace $
                  LogObject mle (ObserveClose (CounterState identifier counters))
              -- send diff message to Trace
              traceConditionally logTrace $
                  LogObject mle (ObserveDiff (CounterState identifier (diffCounters initialCounters counters)))
          -- trace the messages gathered from inside the action
          forM_ logObjects $ traceConditionally logTrace
          return (Right ())) ʻcatchʻ (return ∘ Left)
```

1.5.3 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 → a", which when applied to a BaseTrace of type "Op (m ()) s", yields "s → 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 → b) → f a → f b". In case of a contravariant functor, it is the dual function "contramap :: (a → b) → f b → f a" which is defined.

In the following instance, runTrace extracts type "Op (m ()) s" to which contramap applies f, thus "f s → 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 → a"* which translates to *"s → 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* ())

1.5.4 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*) = *return* (*ctx* {loggerName = *appendWithDot* (loggerName *ctx*) *name*}, *trace*)
>
> *appendWithDot* :: LoggerName → LoggerName → LoggerName
> *appendWithDot* " " *newName* = *T.take* 80 *newName*
> *appendWithDot xs* " " = *xs*
> *appendWithDot xs newName* = *T.take* 80 $ *xs* <> " . " <> *newName*

Change 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.

```
modifyName :: MonadIO m ⇒ LoggerName → Trace m → m (Trace m)
modifyName name (ctx, trace) = return (ctx {loggerName = name}, trace)
```

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 meta _) = do
    globminsev ← liftIO $ Config.minSeverity (configuration ctx)
    globnamesev ← liftIO $ Config.inspectSeverity (configuration ctx) (loggerName ctx)
    let minsev = max globminsev $ fromMaybe Debug globnamesev
        flag = (severity meta) ⩾ minsev
    when flag $ traceNamedObject logTrace msg
```

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 s)
            < ∗ > pure (LogMessage LogItem {liSelection = p
              , 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
```

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 ()
                               _ → traceConditionally tr lo)
      ObservableTrace _ → do
                         tr' ← appendName name tr
                         return $ updateTracetype subtrace tr'
```

1.5.5 Cardano.BM.Setup

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
    fst < $ > setupTrace_ c name
setupTrace (Right c) name = fst < $ > setupTrace_ c name

setupTrace_ :: MonadIO m ⇒ Config.Configuration → Text → m (Trace m, Switchboard.Switchboard)
setupTrace_ c name = do
    sb ← liftIO $ Switchboard.realize c
    ctx ← liftIO $ newContext "" c

    tr ← subTrace name $ natTrace liftIO (ctx, Switchboard.mainTrace sb)
    return (tr, sb)
```

shutdown

Shut down the Switchboard and all the Traces related to it.

```
shutdown :: Switchboard.Switchboard → IO ()
shutdown = Switchboard.unrealize
```

withTrace

Setup a Trace from Configuration and pass it to the action. At the end, shutdown all the components and close the trace.

```
withTrace :: (MonadIO m, MonadMask m) ⇒ Config.Configuration → Text → (Trace m → m t) → m t
withTrace cfg name action =
    bracket
      (setupTrace_ cfg name)             -- aquire
      (λ(_, sb) → liftIO $ shutdown sb) -- release
      (λ(tr, _) → action tr)             -- action
```

newContext

```
newContext :: LoggerName
    → Config.Configuration
    → IO TraceContext
newContext name cfg = do
    return $ TraceContext {
        loggerName = name
        , configuration = cfg
        , tracetype = Neutral
        }
```

1.5.6 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
```

1.5.7 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*)

1.5.8 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)
      ,(GhcRtsStats, readRTSStats)
      ]
```

1.5.9   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) = do
    pid ← getProcessID
    foldrM (λ(sel, fun) a →
      if any (≡ sel) tts
      then (fun ≫ λxs → return $ a ++ xs)
      else return a) [ ] (selectors pid)
  where
    selectors pid = [(MonotonicClock, getMonoClock)
      ,(MemoryStats, readProcStatM pid)
      ,(ProcessStats, readProcStats pid)
      ,(NetStats, readProcNet pid)
      ,(IOStats, readProcIO pid)
      ,(GhcRtsStats, readRTSStats)
      ]


pathProc :: FilePath
pathProc = "/proc/"
```

$pathProcStat :: ProcessID \rightarrow FilePath$

$pathProcStat\ pid = pathProc </> (show\ pid) </> $ `"stat"`

$pathProcStatM :: ProcessID \rightarrow FilePath$

$pathProcStatM\ pid = pathProc </> (show\ pid) </> $ `"statm"`

$pathProcIO :: ProcessID \rightarrow FilePath$

$pathProcIO\ pid = pathProc </> (show\ pid) </> $ `"io"`

$pathProcNet :: ProcessID \rightarrow FilePath$

$pathProcNet\ pid = pathProc </> (show\ pid) </> $ `"net"` $</> $ `"netstat"`

Reading from a file in /proc/<pid >

$readProcList :: FilePath \rightarrow IO\ [Integer]$

$readProcList\ fp = \textbf{do}$

   $cs \leftarrow readFile\ fp$

   $return\ \$\ map\ (\lambda s \rightarrow maybe\ 0\ id\ \$\ (readMaybe\ s :: Maybe\ Integer))\ (words\ cs)$

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)
```

$readProcStatM :: ProcessID \rightarrow IO\ [Counter]$

$readProcStatM\ pid = \textbf{do}$

   $ps0 \leftarrow readProcList\ (pathProcStatM\ pid)$

   $\textbf{let}\ ps = zip\ colnames\ ps0$

     $psUseful = filter\ (($`"unused"`$\not\equiv) \circ fst)\ ps$

   $return\ \$\ map\ (\lambda(n,i) \rightarrow Counter\ MemoryCounter\ n\ (PureI\ i))\ psUseful$

  $\textbf{where}$

   $colnames :: [Text]$

   $colnames = [$`"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).
```

$readProcStats :: ProcessID \rightarrow IO\,[Counter]$
$readProcStats\;pid = \textbf{do}$
  $ps0 \leftarrow readProcList\,(pathProcStat\;pid)$
  $\textbf{let}\;ps = zip\;colnames\;ps0$
   $psUseful = filter\,(("unused" \not\equiv)\circ fst)\;ps$
  $return\;\$\;map\,(\lambda(n,i) \rightarrow Counter\;StatInfo\;n\,(PureI\;i))\;psUseful$
 $\textbf{where}$
  $colnames :: [Text]$
  $colnames = [\,"pid","unused","unused","ppid","pgrp","session","ttynr","tpgid","flags","minfl$
   $,"cminflt","majflt","cmajflt","utime","stime","cutime","cstime","priority","nice","num$
   $,"itrealvalue","starttime","vsize","rss","rsslim","startcode","endcode","startstack","$
   $,"signal","blocked","sigignore","sigcatch","wchan","nswap","cnswap","exitsignal","proc$
   $,"policy","blkio","guesttime","cguesttime","startdata","enddata","startbrk","argstart"$
   $,"envend","exitcode"$
   $]$

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).
```

$readProcIO :: ProcessID \rightarrow IO\,[Counter]$

$readProcIO\ pid = \mathbf{do}$

$\quad ps0 \leftarrow readProcList\,(pathProcIO\ pid)$

$\quad \mathbf{let}\ ps = zip3\ colnames\ ps0\ units$

$\quad return\ \$\ map\,(\lambda(n,i,u) \rightarrow Counter\ IOCounter\ n\,(u\ i))\ ps$

$\quad \mathbf{where}$

$\quad\quad colnames :: [Text]$

$\quad\quad colnames = ["\mathtt{rchar}","\mathtt{wchar}","\mathtt{syscr}","\mathtt{syscw}","\mathtt{rbytes}","\mathtt{wbytes}","\mathtt{cxwbytes}"]$

$\quad\quad units = [Bytes \circ fromInteger, Bytes \circ fromInteger, PureI, PureI, Bytes \circ fromInteger, Bytes \circ fromInteger, Bytes$

Network TCP/IP counters

```
 example:
 \\
 cat /proc/<pid>/net/netstat
 \\
 TcpExt: SyncookiesSent SyncookiesRecv SyncookiesFailed EmbryonicRsts PruneCalled RcvPruned OfoPruned OutOfWindowIcmps Lo!
 !ckDroppedIcmps ArpFilter TW TWRecycled TWKilled PAWSActive PAWSEstab DelayedACKs DelayedACKLocked DelayedACKLost ListenO!
 !verflows ListenDrops TCPHPHits TCPPureAcks TCPHPAcks TCPRenoRecovery TCPSackRecovery TCPSACKReneging TCPSACKReorder TCPR!
 !enoReorder TCPTSReorder TCPFullUndo TCPPartialUndo TCPDSACKUndo TCPLossUndo TCPLostRetransmit TCPRenoFailures TCPSackFai!
 !lures TCPLossFailures TCPFastRetrans TCPSlowStartRetrans TCPTimeouts TCPLossProbes TCPLossProbeRecovery TCPRenoRecoveryF!
 !ail TCPSackRecoveryFail TCPRcvCollapsed TCPDSACKOldSent TCPDSACKOfoSent TCPDSACKRecv TCPDSACKOfoRecv TCPAbortOnData TCPA!
 !bortOnClose TCPAbortOnMemory TCPAbortOnTimeout TCPAbortOnLinger TCPAbortFailed TCPMemoryPressures TCPMemoryPressuresChro!
 !no TCPSACKDiscard TCPDSACKIgnoredOld TCPDSACKIgnoredNoUndo TCPSpuriousRTOs TCPMD5NotFound TCPMD5Unexpected TCPMD5Failure!
 ! TCPSackShifted TCPSackMerged TCPSackShiftFallback TCPBacklogDrop PFMemallocDrop TCPMinTTLDrop TCPDeferAcceptDrop IPReve!
 !rsePathFilter TCPTimeWaitOverflow TCPReqQFullDoCookies TCPReqQFullDrop TCPRetransFail TCPRcvCoalesce TCPOFOQueue TCPOFOD!
 !rop TCPOFOMerge TCPChallengeACK TCPSYNChallenge TCPFastOpenActive TCPFastOpenActiveFailTCPFastOpenPassive TCPFastOpenPas!
 !siveFail TCPFastOpenListenOverflow TCPFastOpenCookieReqd TCPFastOpenBlackhole TCPSpuriousRtxHostQueues BusyPollRxPackets!
 ! TCPAutoCorking TCPFromZeroWindowAdv TCPToZeroWindowAdv TCPWantZeroWindowAdv TCPSynRetrans TCPOrigDataSent TCPHystartTra!
```

```
!inDetect TCPHystartTrainCwnd TCPHystartDelayDetect TCPHystartDelayCwnd TCPACKSkippedSynRecv TCPACKSkippedPAWS TCPACKSkip!
!pedSeq TCPACKSkippedFinWait2 TCPACKSkippedTimeWait TCPACKSkippedChallenge TCPWinProbe TCPKeepAlive TCPMTUPFail TCPMTUPSu!
!ccess TCPDelivered TCPDeliveredCE TCPAckCompressed
 TcpExt: 0 0 0 0 28 0 0 0 0 0 1670 1 0 0 6 6029 1 1766 0 0 384612 66799 105553 0 21 0 638 0 1 7 1 1 32 128 0 1 0 22 0 116!
! 383 19 0 0 0 1788 224 178 0 435 224 0 13 0 0 0 0 0 0 0 67 0 0 0 0 3 1 668 0 0 0 4 0 0 0 0 91870 4468 0 224 22 23 0 0 0 !
!0 0 0 0 6 0 21492 0 0 11 188 188680 6 145 13 425 0 3 4 0 0 1 117 22984 0 0 192495 0 4500
 IpExt: InNoRoutes InTruncatedPkts InMcastPkts OutMcastPkts InBcastPkts OutBcastPkts InOctets OutOctets InMcastOctets Out!
!McastOctets InBcastOctets OutBcastOctets InCsumErrors InNoECTPkts InECT1Pkts InECTOPkts InCEPkts
 IpExt: 0 0 20053 8977 2437 23 3163525943 196480057 2426648 1491754 394285 5523 0 3513269 0 217426 0
```

```
readProcNet :: ProcessID → IO [Counter]
readProcNet pid = do
    ls0 ← lines < $ > readFile (pathProcNet pid)
    let ps0 = readinfo ls0
    let ps1 = map (λ(n,c) → (n, readMaybe c :: Maybe Integer)) ps0
    return $ mapCounters $ filter selcolumns ps1
  where
    construct "IpExt:OutOctets" i = Bytes $ fromInteger i
    construct "IpExt:InOctets" i = Bytes $ fromInteger i
    construct _ i = PureI i
    -- only a few selected columns will be returned
    selcolumns (n, _) = n ∈ ["IpExt:OutOctets","IpExt:InOctets"]
    mapCounters [] = []
    mapCounters ((n,c):r) = case c of
      Nothing → mapCounters r
      Just i → mapCounters r <> [Counter NetCounter (pack n) (construct n i)]
    readinfo :: [String] → [(String, String)]
    readinfo []      = []
    readinfo (_:[]) = []
    readinfo (l1 : l2 : r) =
      let col0 = words l1
        cols = tail col0
        vals = tail $ words l2
        pref = head col0
      in
      readinfo r <> zip (map (λn → pref ++ n) cols) vals
```

1.5.10   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 (Microseconds a) (Nanoseconds b)  = compare (a * 1000) b
  compare (Microseconds a) (Seconds b)       = compare a (b * 1000000)
  compare (Nanoseconds a) (Seconds b)        = compare a (b * 1000000000)
  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 (Seconds a)      (PureI b) | b ⩾ 0 = compare (toInteger a) b
  compare (Microseconds a) (PureI b) | b ⩾ 0 = compare (toInteger a) b
  compare (Nanoseconds a) (PureI b)  | b ⩾ 0 = compare (toInteger a) b
  compare (Bytes a)        (PureI b) | b ⩾ 0 = compare (toInteger a) b
  compare a@(PureD _) (PureI b)              = compare (getInteger a) b
  compare (PureI a) b@(PureD _)              = compare a (getInteger b)
  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
```
$showSI\ (Microseconds\ a) = show\ (fromFloatDigits\ ((fromIntegral\ a) / (1000000 :: Float))) \mathbin{+\!\!+}$
$\qquad\qquad\qquad\qquad\qquad showUnits\ (Seconds\ a)$
$showSI\ (Nanoseconds\ a) = show\ (fromFloatDigits\ ((fromIntegral\ a) / (1000000000 :: Float))) \mathbin{+\!\!+}$
$\qquad\qquad\qquad\qquad\qquad showUnits\ (Seconds\ a)$
```
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**
$\quad (BaseStats\ mina\ maxa\ counta\ sumAa\ sumBa) \equiv (BaseStats\ minb\ maxb\ countb\ sumAb\ sumBb) =$

$$mina \equiv minb \wedge maxa \equiv maxb \wedge counta \equiv countb \wedge$$
$$abs\ (sumAa - sumAb) < 1.0e{-}4 \wedge$$
$$abs\ (sumBa - sumBb) < 1.0e{-}4$$

```
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 counta = 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
  $showStats' :: BaseStats \rightarrow String$
  $showStats'\ s =$
    `", { 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 $\rightarrow$ Aggregated
$singletonStats\ a =$
  let $stats =$ Stats $\{flast = a$
    $, fold \qquad\qquad = Nanoseconds\ 0$
    $, fbasic = BaseStats$
      $\{fmin = a$
      $, fmax = a$
      $, fcount = 1$
      $, fsum\_A = getDouble\ a$

```
          ,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
```

1.5.11   Cardano.BM.Data.AggregatedKind

AggregatedKind

This identifies the type of Aggregated.

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

1.5.12   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 ()
    }
```

1.5.13 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)
```

1.5.14 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}
# ifdef ENABLE_EKG
    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]}
# else
    remove_ekgview_if_not_defined = id
    add_ekgview_if_port_defined = id
# endif
```

```
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
```

1.5.15 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
    | NetCounter
    | 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 NetCounter        _ _) = "Net"
nameCounter (Counter CpuCounter        _ _) = "Cpu"
nameCounter (Counter RTSStats          _ _) = "RTS"
```

CounterState

```
data CounterState = CounterState {
    csIdentifier :: Unique
```

```haskell
    , 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

```haskell
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}
```

1.5.16 Cardano.BM.Data.LogItem

LoggerName

A LoggerName has currently type *Text*.

```haskell
type LoggerName = Text
```

NamedLogItem

```haskell
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. Text was selected over ThreadId in order to be able to use the logging system under SimM of ouroboros-network because ThreadId from Control.Concurrent lacks a Read instance.

> **data** LOMeta = LOMeta {
>   *tstamp* :: {-# UNPACK #-} ! *UTCTime*
>   , *tid*   :: {-# UNPACK #-} ! *Text*
>   , *severity* :: !Severity
>   }
>   **deriving** (*Show*)
>
> **instance** *ToJSON* LOMeta **where**
>   *toJSON* (LOMeta _tstamp _tid _sev) =
>   *object* ["tstamp" . = _tstamp, "tid" . = *show* _tid, "severity" . = *show* _sev]
>
> *mkLOMeta* :: Severity → *IO* LOMeta
> *mkLOMeta sev* =
>   LOMeta < $ > *getCurrentTime*
>   < * > (*pack* ∘ *show* < $ > *myThreadId*)
>   < * > *pure sev*

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
  ,liPayload :: Text-- TODO should become ToObject
  } deriving (Show,Generic,ToJSON)


data LogSelection =
  Private-- only to private logs.
  |Both -- to public and private logs.
  deriving (Show,Generic,ToJSON,FromJSON)
```

1.5.17   Cardano.BM.Data.Observable

ObservableInstance

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

1.5.18   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)
```

ScribePrivacy

This declares if a scribe will be public (and must not contain sensitive data) or private.

```
data ScribePrivacy = ScPublic | ScPrivate
  deriving (Generic, Eq, Ord, Show, FromJSON, ToJSON)
```

ScribeDefinition

This identifies katip's scribes by type.

```
data ScribeDefinition = ScribeDefinition
  {scKind    :: ScribeKind
  , scName    :: Text
  , scPrivacy :: ScribePrivacy
  , scRotation :: Maybe RotationParameters
  }
  deriving (Generic, Eq, Ord, Show, ToJSON)
instance FromJSON ScribeDefinition where
  parseJSON (Object o) = do
    kind      ← o.: "scKind"
    name      ← o.: "scName"
    mayPrivacy ← o.:? "scPrivacy"
    rotation ← o.:? "scRotation"
    return $ ScribeDefinition
      {scKind    = kind
      , scName   = name
      , scPrivacy = fromMaybe ScPublic mayPrivacy
      , scRotation = rotation
      }
  parseJSON invalid = typeMismatch "ScribeDefinition" invalid
```

1.5.19   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)
```

1.5.20 Cardano.BM.Data.Severity

Severity

The intended meaning of severity codes:

Debug *detailed information about values and decision flow* Info *general information of events;*
progressing properly Notice *needs attention; something* ¬ *progressing properly* Warning *may con-*
tinue 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
```

1.5.21 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)
```

1.5.22   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
  }
```

1.5.23   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
```

1.5.24   Cardano.BM.Configuration.Model

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 mapscribes = cgMapScribe cg
      let find_s lname = case HM.lookup lname mapscribes 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
```

dropToDot :: *Text* → *Maybe Text*
dropToDot ts = *dropToDot′* (*breakOnEnd* `"."` *ts*)
  where
    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) $ λ*cg* →
      return cg {*cgMapScribe* = *HM.alter* (_ → *scribes*) *name* (*cgMapScribe cg*)}

setCachedScribes :: Configuration → LoggerName → *Maybe* [ScribeId] → *IO* ()
setCachedScribes configuration *name scribes* =
    *modifyMVar_* (*getCG* configuration) $ λ*cg* →
      return cg {*cgMapScribeCache* = *HM.alter* (_ → *scribes*) *name* (*cgMapScribeCache cg*)}

setDefaultScribes :: Configuration → [ScribeId] → *IO* ()
setDefaultScribes configuration *scs* =
    *modifyMVar_* (*getCG* configuration) $ λ*cg* →
      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) $ λ*cg* →
      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 mapseverities0 = HM.lookup "mapSeverity" (R.options r)
        mapbackends = HM.lookup "mapBackends" (R.options r)
        mapsubtrace  = HM.lookup "mapSubtrace" (R.options r)
        mapscribes0  = HM.lookup "mapScribes"  (R.options r)
        mapaggregatedkinds = HM.lookup "mapAggregatedkinds" (R.options r)
        mapmonitors = HM.lookup "mapMonitors" (R.options r)
        mapseverities = parseSeverityMap mapseverities0
        mapscribes    = parseScribeMap mapscribes0

    cgref ← newMVar $ ConfigurationInternal
        {cgMinSeverity      = R.minSeverity r
        ,cgMapSeverity      = mapseverities
        ,cgMapSubtrace      = parseSubtraceMap mapsubtrace
        ,cgOptions          = R.options r
        ,cgMapBackend       = parseBackendMap mapbackends
        ,cgDefBackendKs     = R.defaultBackends r
        ,cgSetupBackends    = R.setupBackends r
        ,cgMapScribe        = mapscribes
        ,cgMapScribeCache   = mapscribes
        ,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
```

```haskell
    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
```

1.5.25   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
    , scPrivacy = ScPublic
    , 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
# ifdef ENABLE_AGGREGATION
  CM.setSetupBackends c [KatipBK, AggregationBK]
  CM.setDefaultBackends c [KatipBK, AggregationBK]
# else
  CM.setSetupBackends c [KatipBK]
  CM.setDefaultBackends c [KatipBK]
# endif
  CM.setSetupScribes c [ScribeDefinition {
    scName = "stdout"
    , scKind = StdoutSK
    , scPrivacy = ScPublic
    , scRotation = Nothing
    }
    ]
  CM.setDefaultScribes c ["StdoutSK::stdout"]
  return c
```

1.5.26   Cardano.BM.Configuration.Editor

This simple configuration editor is accessible through a browser on `http://127.0.0.1:13789`, or whatever port has been set in the configuration.

A number of maps that relate logging context name to behaviour can be changed. And, most importantly, the global minimum severity that defines the filtering of log messages.

links

The GUI is built on top of *Threepenny-GUI* (`http://hackage.haskell.org/package/threepenny-gui`). The appearance is due to *w3-css* (`https://www.w3schools.com/w3css`).

```
startup :: Configuration → IO ()
startup config = do
  port ← getGUIport config
  if port > 0
  then do
    thd ← Async.async $
      startGUI defaultConfig {jsPort = Just port
        , jsAddr              = Just "127.0.0.1"
        , jsStatic            = Just "static"
        , jsCustomHTML = Just "configuration-editor.html"
        } $ prepare config
    Async.link thd
```

```
      pure ()
    else pure ()

  data Cmd = Backends | Scribes | Severities | SubTrace | Aggregation
    deriving (Show, Read)

  prepare :: Configuration → Window → UI ()
  prepare config window = void $ do
    void $ return window # set title "IOHK logging and monitoring"

    -- editing or adding map entry
    inputKey ← UI.input #. "w3-input w3-border w3-round-large"
    inputValue ← UI.input #. "w3-input w3-border w3-round-large"
    inputMap ← UI.p #. "inputmap"
    void $ element inputKey # set UI.size "30"
    void $ element inputValue # set UI.size "60"
    outputMsg ← UI.input #. "w3-input w3-border w3-round-large"
    void $ element outputMsg # set UI.size "60"
       # set UI.enabled False

    let mkPairItem :: Show t ⇒ Cmd → LoggerName → t → UI Element
        mkPairItem cmd n v =
          let entries = [ UI.td #+ [string (unpack n)]
                   , UI.td #+ [string (show v)]
                   , UI.td #+ [do
                       b ← UI.button #. "w3-small w3-btn w3-ripple w3-teal" #+ [UI.bold #+ [string "edit"]]
                       on UI.click b $ const $ do
                          void $ element inputKey # set UI.value (unpack n)
                          void $ element inputValue # set UI.value (show v)
                          void $ element inputMap # set UI.value (show cmd)
                       return b]
                   ]
          in UI.tr #. "itemrow" #+ entries
    let apply2output f = do
        tgt ← getElementById window "output"
        case tgt of
           Nothing → pure ()
           Just t → f t
    let listPairs cmd sel = do
        apply2output $ λt → void $ element t # set children [ ]
        cg ← liftIO $ readMVar (CM.getCG config)
        mapM_ (λ(n, v) → apply2output $ λt → void $ element t #+ [mkPairItem cmd n v]
           ) $ HM.toList (sel cg)

    -- commands
    let switchTo c@Backends  = listPairs c CM.cgMapBackend
        switchTo c@Severities   = listPairs c CM.cgMapSeverity
        switchTo c@Scribes      = listPairs c CM.cgMapScribe
        switchTo c@SubTrace    = listPairs c CM.cgMapSubtrace
        switchTo c@Aggregation = listPairs c CM.cgMapAggregatedKind
    let mkCommandButtons =
```

```
    let btns = map (λn → do
             b ← UI.button #. "w3-small w3-btn w3-ripple w3-grey" #+ [UI.bold #+ [string (show n)]
             on UI.click b $ const $ (switchTo n)
             return b)
             [Backends, Scribes, Severities, SubTrace, Aggregation]
    in row btns
-- control global minimum severity
confMinSev ← liftIO $ minSeverity config
let setMinSev _el Nothing = pure ()
    setMinSev _el (Just sev) = liftIO $ do
        setMinSeverity config (toEnum sev :: Severity)
      mkSevOption sev = UI.option # set UI.text (show sev)
        # set UI.value (show sev)
        # if (confMinSev ≡ sev) then set UI.selected True else id
minsev ← UI.select #. "minsevfield" #+
    map mkSevOption (enumFrom Debug)-- for all severities
on UI.selectionChange minsev $ setMinSev minsev
let mkMinSevEntry = row [string "set minimum severity to:", UI.span # set html "  ", eleme
let setError m = void $ element outputMsg # set UI.value ("ERROR:  " ++ m)
let setMessage m = void $ element outputMsg # set UI.value m
-- construct row with input fields
let removeItem Backends k = CM.setBackends config k Nothing
    removeItem Severities  k = CM.setSeverity config k Nothing
    removeItem Scribes     k = CM.setScribes config k Nothing
    removeItem SubTrace  k = CM.setSubTrace config k Nothing
    removeItem Aggregation k = CM.setAggregatedKind config k Nothing
let delItem = do
        k ← inputKey # get UI.value
        m ← inputMap # get UI.value
        case (readMay m :: Maybe Cmd) of
            Nothing → setError "parse error on cmd"
            Just c → do
                setMessage $ "deleting " ++ k ++ " from " ++ m
                liftIO $ removeItem c (pack k)
                switchTo c
let updateItem Backends  k v = case (readMay v :: Maybe [BackendKind]) of
                            Nothing → setError "parse error on backend list"
                            Just v' → liftIO $ CM.setBackends config k $ Just v'
    updateItem Severities  k v = case (readMay v :: Maybe Severity) of
                            Nothing → setError "parse error on severity"
                            Just v' → liftIO $ CM.setSeverity config k $ Just v'
    updateItem Scribes     k v = case (readMay v :: Maybe [ScribeId]) of
                            Nothing → setError "parse error on scribe list"
                            Just v' → liftIO $ CM.setScribes config k $ Just v'
    updateItem SubTrace  k v = case (readMay v :: Maybe SubTrace) of
                            Nothing → setError "parse error on subtrace"
                            Just v' → liftIO $ CM.setSubTrace config k $ Just v'
```

```
        updateItem Aggregation k v = case (readMay v :: Maybe AggregatedKind) of
                              Nothing → setError "parse error on aggregated kind"
                              Just v' → liftIO $ CM.setAggregatedKind config k $ Just v'
    let setItem = do
        k ← inputKey # get UI.value
        v ← inputValue # get UI.value
        m ← inputMap # get UI.value
        case (readMay m :: Maybe Cmd) of
           Nothing → setError "parse error on cmd"
           Just c → do
              setMessage $ "setting " ++ k ++ " => " ++ v ++ " in " ++ m
              updateItem c (pack k) v
              switchTo c
    let mkRowEdit = row [element inputKey, UI.span #. "w3-tag w3-round w3-blue midalign" # set UI.text "
        mkRowBtns = row [do {b ← UI.button #. "w3-small w3-btn w3-ripple w3-teal" #+ [string "delete"]
                    ; on UI.click b $ const $ (delItem)
                    ; return b}
                  , do {b ← UI.button #. "w3-small w3-btn w3-ripple w3-teal" #+ [string "store"]
                    ; on UI.click b $ const $ (setItem)
                    ; return b}
                  ]
    -- layout
    let topGrid = UI.div #. "w3-panel" #+ [
        UI.div #. "w3-panel w3-border w3-border-blue" #+ [
              UI.div #. "w3-panel" #+ [mkMinSevEntry]
              ]
            , UI.div #. "w3-panel w3-border w3-border-blue" #+ [
              UI.div #. "w3-panel" #+ [UI.p # set UI.text "set or update a behaviour for a named logg
              , UI.div #. "w3-panel" #+ [mkCommandButtons]
              , UI.div #. "w3-panel" #+ [mkRowEdit]
              , UI.div #. "w3-panel" #+ [mkRowBtns]
              , UI.div #. "w3-panel" #+ [element outputMsg]
              ]
            ]
    tgt ← getElementById window "gridtarget"
    case tgt of
        Nothing → pure ()
        Just t → void $ element t #+ [topGrid]
```

1.5.27 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 = do
        now ← getCurrentTime
        let messageCounters = resetCounters now
        countersMVar ← newMVar messageCounters
        let traceInQueue q =
              BaseTrace.BaseTrace $ Op $ λlognamed → do
                nocapacity ← atomically $ TBQ.isFullTBQueue q
                if nocapacity
                then putStrLn "Error: Switchboard's queue full, dropping log items!"
                else atomically $ TBQ.writeTBQueue q lognamed
            ctx = TraceContext { loggerName = ""
              , configuration = cfg
              , tracetype = Neutral
              }
        _timer ← Async.async $ sendAndResetAfter
          (ctx, traceInQueue queue)
          "#messagecounters.switchboard"
          countersMVar
          60000 -- 60000 ms = 1 min
          Warning -- Debug

        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 counters = do
            nli ← atomically $ TBQ.readTBQueue queue
            -- do not count again messages that contain the results of message counters
            when (lnName nli ≢ "#messagecounters.switchboard") $
              -- increase the counter for the specific severity
              modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt $ lnItem nli
            case lnItem nli of
              LogObject _ KillPill →
                forM_ backends (λ(_, be) → bUnrealize be)
# ifdef ENABLE_AGGREGATION
              LogObject _ (AggregatedMessage _) → do
                sendMessage nli (filter (≢ AggregationBK))
                qProc counters
# endif
# ifdef ENABLE_MONITORING
              LogObject _ (MonitoringEffect inner) → do
```

```
                        sendMessage (nli {lnItem = inner}) (filter (≢ MonitoringBK))
                        qProc counters
# endif
                    _ → sendMessage nli id ≫ qProc counters
            Async.async $ qProc countersMVar
      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 Warning) < * > 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"
# ifdef ENABLE_MONITORING
setupBackend' MonitoringBK c sb = do
   let trace = mainTrace sb
```

```haskell
    ctx = TraceContext {loggerName = ""
          ,configuration = c
          ,tracetype = Neutral
          }
  be :: Cardano.BM.Output ◦ Monitoring.Monitor ← Cardano.BM.Output ◦ Monitoring.realizefrom (ctx, trace) s
  return MkBackend
    {bEffectuate = Cardano.BM.Output ◦ Monitoring.effectuate be
    ,bUnrealize = Cardano.BM.Output ◦ Monitoring.unrealize be
    }
# else
-- We need it anyway, to avoid "Non-exhaustive patterns" warning.
setupBackend' MonitoringBK _ _ =
  error "Impossible happened: monitoring is disabled by Cabal-flag, we mustn't match this b
# endif
# ifdef ENABLE_EKG
setupBackend' EKGViewBK c sb = do
  let trace = mainTrace sb
    ctx = TraceContext {loggerName = ""
          ,configuration = c
          ,tracetype = Neutral
          }
  be :: Cardano.BM.Output ◦ EKGView.EKGView ← Cardano.BM.Output ◦ EKGView.realizefrom (ctx, trace) sb
  return MkBackend
    {bEffectuate = Cardano.BM.Output ◦ EKGView.effectuate be
    ,bUnrealize = Cardano.BM.Output ◦ EKGView.unrealize be
    }
# else
-- We need it anyway, to avoid "Non-exhaustive patterns" warning.
setupBackend' EKGViewBK _ _ =
  error "Impossible happened: EKG is disabled by Cabal-flag, we mustn't match this backend!
# endif
# ifdef ENABLE_AGGREGATION
setupBackend' AggregationBK c sb = do
  let trace = mainTrace sb
    ctx = TraceContext {loggerName = ""
          ,configuration = c
          ,tracetype = Neutral
          }
  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
    }
# else
-- We need it anyway, to avoid "Non-exhaustive patterns" warning.
setupBackend' AggregationBK _ _ =
  error "Impossible happened: aggregation is disabled by Cabal-flag, we mustn't match this
```

```
  # endif
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
      }
```

1.5.28   Cardano.BM.Output.Log

Internal representation

```
type LogMVar = MVar LogInternal
newtype Log = Log
   { getK :: LogMVar }

data LogInternal = LogInternal
   { kLogEnv        :: K.LogEnv
   , msgCounters :: MessageCounter
   , configuration :: Config.Configuration }
```

Log implements *effectuate*

```
instance IsEffectuator Log where
   effectuate katip item = do
       let logMVar = getK katip
       c ← configuration < $ > readMVar logMVar
       setupScribes ← getSetupScribes c
       selscribes ← getScribes c (lnName item)
       let selscribesFiltered =
             case lnItem item of
               LogObject _ (LogMessage (LogItem Private _))
                  → removePublicScribes setupScribes selscribes
               _ → selscribes
       forM_ selscribesFiltered $ λsc → passN sc katip item
       -- increase the counter for the specific severity and message type
       modifyMVar_ logMVar $ λli → return $
         li { msgCounters = updateMessageCounters (msgCounters li) (lnItem item) }
       -- reset message counters afer 60 sec = 1 min
       resetMessageCounters logMVar 60 Warning selscribesFiltered
     where
       removePublicScribes allScribes = filter $ λsc →
         let (_, nameD) = T.breakOn "::" sc
             -- drop "::" from the start of name
             name = T.drop 2 nameD
         in
         case find (λx → scName x ≡ name) allScribes of
```

```
                    Nothing → False
                    Just scribe → scPrivacy scribe ≡ ScPrivate
            resetMessageCounters logMVar interval sev scribes = do
                counters ← msgCounters < $ > readMVar logMVar
                let start = mcStart counters
                    now = case lnItem item of
                            LogObject meta _ → tstamp meta
                    diffTime = round $ diffUTCTime now start
                    when (diffTime > interval) $ do
                        countersObjects ← forM (HM.toList $ mcCountersMap counters) $ λ(key, count) →
                            LogObject
                                < $ > (mkLOMeta sev)
                                < ∗ > pure (LogValue (pack key) (PureI $ toInteger count))
                        intervalObject ←
                            LogObject
                                < $ > (mkLOMeta sev)
                                < ∗ > pure (LogValue "time_interval_(s)" (PureI diffTime))
                        let namedCounters = map (λlo → LogNamed "#messagecounters.katip" lo)
                            (countersObjects ++ [intervalObject])
                        forM_ scribes $ λsc →
                            forM_ namedCounters $ λnamedCounter →
                                passN sc katip namedCounter
                    modifyMVar_ logMVar $ λli → return $
                        li {msgCounters = resetCounters now}
            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

      messageCounters ← resetCounters < $ > getCurrentTime

      kref ← newMVar $ LogInternal le messageCounters 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 :: ScribeId → 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) →
                (severity lometa, liPayload logItem, Nothing)
              (ObserveDiff _) →
                let text = TL.toStrict (encodeToLazyText loitem)
                in
                (severity lometa, text, Just loitem)
              (ObserveOpen _) →
                let text = TL.toStrict (encodeToLazyText loitem)
                in
                (severity lometa, text, Just loitem)
              (ObserveClose _) →
                let text = TL.toStrict (encodeToLazyText loitem)
                in
                (severity lometa, text, Just loitem)
              (AggregatedMessage aggregated) →
                let text = T.concat $ (flip map) aggregated $ λ(name, agg) →
                  "\n" <> name <> ": " <> pack (show agg)
                in
                (severity lometa, text, Nothing)
              (LogValue name value) →
                (severity lometa, name <> " = " <> pack (showSI value), Nothing)
```

```haskell
            (MonitoringEffect logitem) →
               let text = TL.toStrict (encodeToLazyText logitem)
               in
               (severity lometa, text, Just loitem)
            KillPill →
               (severity lometa, "Kill pill received!", Nothing)
      if (msg ≡ "") ∧ (isNothing payload)
      then return ()
      else do
         let threadIdText = KC.ThreadIdText $ tid lometa
         let ns = lnName namedLogItem
         let itemTime = tstamp lometa
         let itemKatip = K.Item {
            _itemApp       = env ˆ. KC.logEnvApp
            , _itemEnv       = env ˆ. KC.logEnvEnv
            , _itemSeverity = sev2klog sev
            , _itemThread   = threadIdText
            , _itemHost      = env ˆ. KC.logEnvHost
            , _itemProcess  = env ˆ. KC.logEnvPid
            , _itemPayload  = payload
            , _itemMessage = K.logStr msg
            , _itemTime      = itemTime
            , _itemNamespace = (env ˆ. KC.logEnvApp) <> (K.Namespace [ns])
            , _itemLoc       = Nothing
            }
         void $ atomically $ KC.tryWriteTBQueue shChan (KC.NewItem itemKatip)
      else return ()
```

Scribes

```haskell
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
```

```haskell
    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 $ TL.toStrict $ toLazyText msg
                  -- do we need the severity from meta?
                  }
          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
```

$$
\begin{array}{ll}
\text{Notice} & \rightarrow K.NoticeS \\
\text{Warning} & \rightarrow K.WarningS \\
\text{Error} & \rightarrow K.ErrorS \\
\text{Critical} & \rightarrow K.CriticalS \\
\text{Alert} & \rightarrow K.AlertS \\
\text{Emergency} & \rightarrow K.EmergencyS
\end{array}
$$

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

1.5.29   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*
          ,tracetype = Neutral
          }
    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 _ = error "EKGView cannot be instantiated by 'realize'"
   realizefrom sbtrace@(ctx, _) _ = do
      let config = configuration ctx
      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 sbtrace 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
```

Asynchronously reading log items from the queue and their processing

```
   spawnDispatcher :: TBQ.TBQueue (Maybe NamedLogItem)
                 → Trace.Trace IO
                 → Trace.Trace IO
                 → IO (Async.Async ())
   spawnDispatcher evqueue sbtrace trace = do
       now ← getCurrentTime
       let messageCounters = resetCounters now
       countersMVar ← newMVar messageCounters
       _timer ← Async.async $ sendAndResetAfter
         sbtrace
         "#messagecounters.ekgview"
         countersMVar
         60000 -- 60000 ms = 1 min
         Warning -- Debug

       Async.async $ qProc countersMVar
     where
       qProc counters = do
         maybeItem ← atomically $ TBQ.readTBQueue evqueue
         case maybeItem of
           Just (LogNamed logname logvalue@(LogObject _ _)) → do
             trace' ← Trace.appendName logname trace
             Trace.traceConditionally trace' logvalue
             -- increase the counter for the type of message
             modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt logvalue
             qProc counters
           Nothing → return () -- stop here
```

Interactive testing EKGView

```
   test :: IO ()
   test = do
```

> $c \leftarrow$ *Cardano.BM.Setup.*setupTrace (*Left* `"test/config.yaml"`) `"ekg"`
> $ev \leftarrow$ *Cardano.BM.Output* ∘ EKGView.*realize c*
>
> *effectuate ev* $ LogNamed `"test.questions"` (LogValue `"answer"` 42)
> *effectuate ev* $ LogNamed `"test.monitor023"` (LogMessage (LogItem *Public* Warning `"!!!! ALARM !!!!"`

1.5.30   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**
> $ag \leftarrow$ *readMVar* (*getAg agg*)
> $nocapacity \leftarrow$ *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
```

Asynchronously 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 = do
    now ← getCurrentTime
    let messageCounters = resetCounters now
    countersMVar ← newMVar messageCounters
    _timer ← Async.async $ sendAndResetAfter
        trace
        "#messagecounters.aggregation"
```

```
        countersMVar
        60000 -- 60000 ms = 1 min
        Warning-- Debug
    Async.async $ qProc countersMVar aggMap
  where
    qProc counters 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
          -- increase the counter for the specific severity and message type
          modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt lo
          qProc counters 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 []
```

```haskell
update (LogObject lme (ObserveClose counterState)) logname agmap =
    updateCounters (csCounters counterState) lme (logname, "close") agmap [ ]

update (LogObject lme (LogMessage _)) logname agmap = do
    let iname = pack $ show (severity lme)
    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.traceConditionally 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"
```

1.5.31   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 _ = error "Monitoring cannot be instantiated by 'realize'"
  realizefrom sbtrace@(ctx, _) _ = do
    let config = configuration ctx
    monref ← newEmptyMVar
    let monitor = Monitor monref
    queue ← atomically $ TBQ.newTBQueue 512
    dispatcher ← spawnDispatcher queue config sbtrace
    -- 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
               → Trace.Trace IO
               → IO (Async.Async ())
spawnDispatcher mqueue config sbtrace = do
    now ← getCurrentTime
    let messageCounters = resetCounters now
```

```
      countersMVar ← newMVar messageCounters
      _timer ← Async.async $ sendAndResetAfter
         sbtrace
         "#messagecounters.monitoring"
         countersMVar
         60000 -- 60000 ms = 1 min
         Warning-- Debug
      Async.async (initMap ≫ qProc countersMVar)
   where
      qProc counters state = do
         maybeItem ← atomically $ TBQ.readTBQueue mqueue
         case maybeItem of
            Just (LogNamed logname logvalue@(LogObject _ _)) → do
               state' ← evalMonitoringAction state logname logvalue
               -- increase the counter for the type of message
               modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt logvalue
               qProc counters 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
```

```haskell
        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 (severity lometa)))
      -- , ("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
```
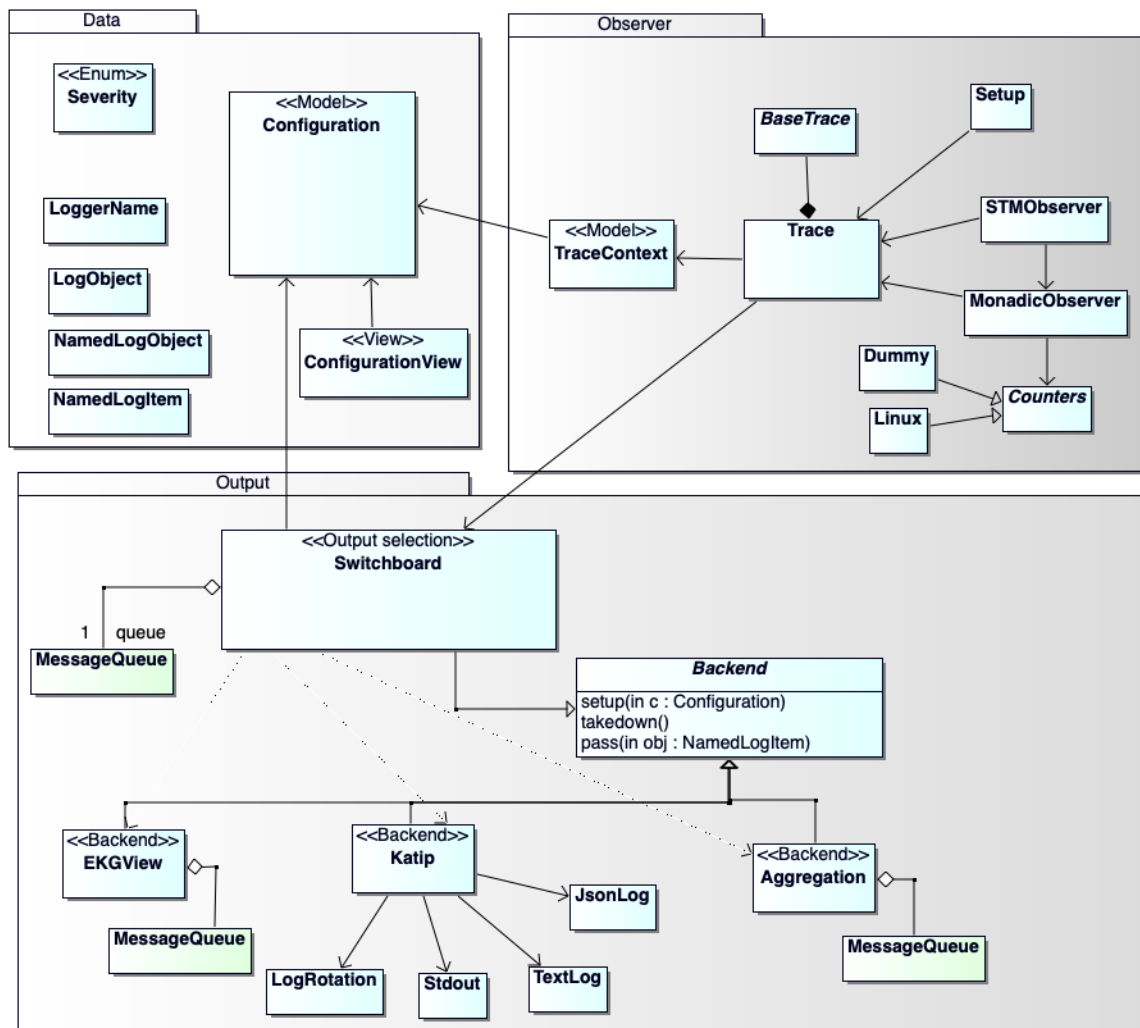
Figure 1.1: Overview of module relationships. The arrows indicate import of a module. The arrows with a triangle at one end would signify "inheritance" in object-oriented programming, but we use it to show that one module replaces the other in the namespace, thus specializes its interface.
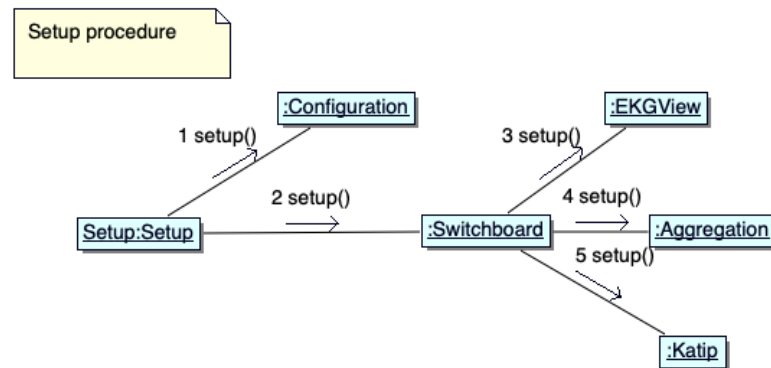
Figure 1.2: Setup procedure

Figure 1.3: The configuration editor is listening on *localhost* and can be accessed through a browser. At the top is the setting for the global minimum severity filter, that drops all messages that have a severity lower than this setting. Below are the settings for various behaviours of the logging system.
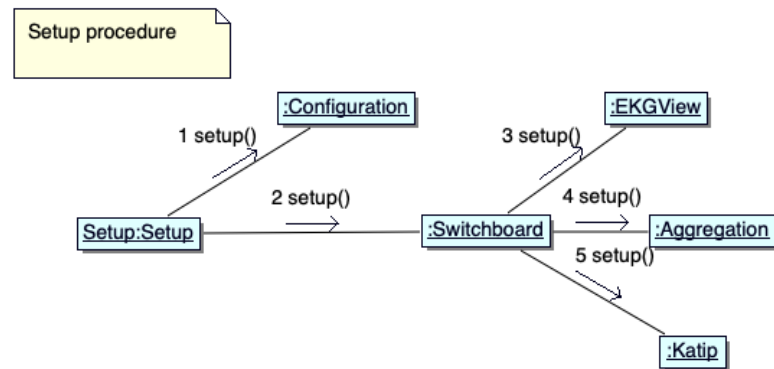
Figure 1.4: Setup procedure
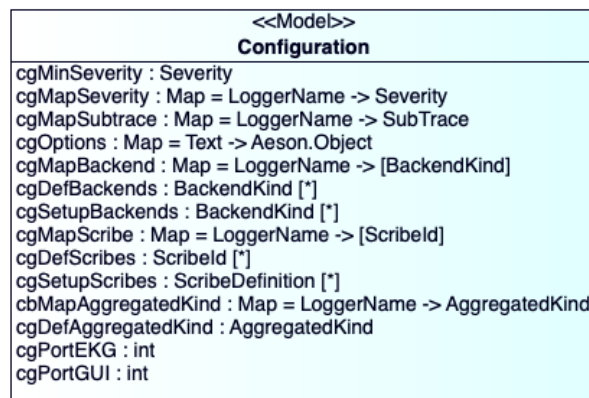
Figure 1.5: Configuration model

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
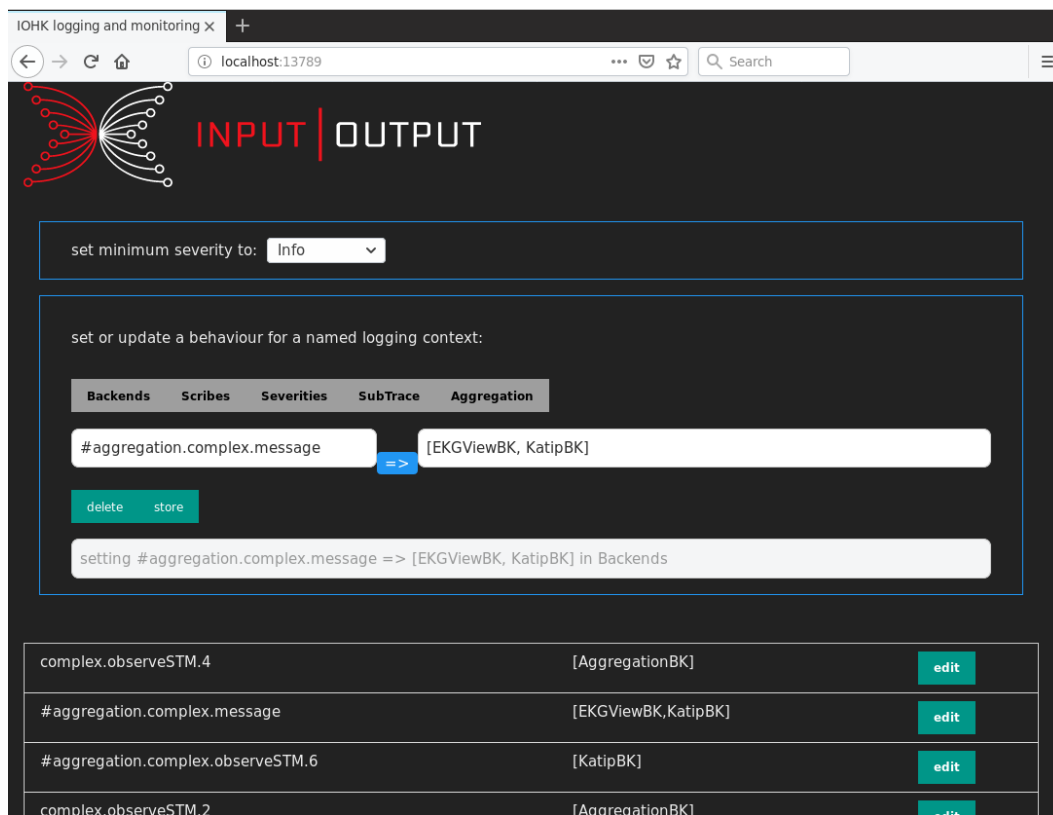
```
cabal new-test
```

Add to a local `cabal.project.local file these lines:`
```
tests:            True
coverage:         True
library-coverage: True
```

2.2 Test main entry point

```
{-# LANGUAGE CPP #-}
```
module *Main*
  (
    main
) **where**
import *Test.Tasty*
 # ifdef ENABLE_AGGREGATION
import *qualified* `Cardano.BM.Test.Aggregated` (*tests*)
 # endif
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.Rotator` (*tests*)
import *qualified* *Cardano.BM.Test.Routing* (*tests*)
 # ifdef ENABLE_MONITORING
import *qualified* *Cardano.BM.Test.Monitoring* (*tests*)
 # endif
main :: IO ()
main = defaultMain tests

Cardano.BM.Configuration	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.Model	94%
Cardano.BM.Data.MessageCounter	85%
Cardano.BM.Data.Configuration	83%
Cardano.BM.Counters.Linux	81%
Cardano.BM.Output.Switchboard	81%
Cardano.BM.Data.MonitoringEval	81%
Cardano.BM.BaseTrace	80%
Cardano.BM.Observer.Monadic	75%
Cardano.BM.Trace	69%
Cardano.BM.Output.Log	68%
Cardano.BM.Output.Aggregation	68%
Cardano.BM.Data.Aggregated	63%
Cardano.BM.Data.Counter	56%
Cardano.BM.Data.LogItem	53%
Cardano.BM.Data.Backend	50%
Cardano.BM.Rotator	50%
Cardano.BM.Data.BackendKind	50%
Cardano.BM.Data.Output	48%
Cardano.BM.Data.Severity	47%
Cardano.BM.Data.Observable	40%
Cardano.BM.Observer.STM	33%
Cardano.BM.Data.AggregatedKind	33%
Cardano.BM.Data.Rotation	20%
Cardano.BM.Data.SubTrace	10%
Cardano.BM.Output.Monitoring	0%
	63%

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

```
tests :: TestTree
tests =
  testGroup "iohk-monitoring"
  [
# ifdef ENABLE_AGGREGATION
    Cardano.BM.Test ◦ Aggregated.tests
  ,
# endif
    Cardano.BM.Test ◦ STM.tests
  , Cardano.BM.Test ◦ Trace.tests
  , Cardano.BM.Test ◦ Configuration.tests
  , Cardano.BM.Test ◦ Rotator.tests
  , Cardano.BM.Test ◦ Routing.tests
# ifdef ENABLE_MONITORING
  , Cardano.BM.Test ◦ Monitoring.tests
# endif
  ]
```

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 gener-
ated 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 Debug

prop_Aggregation_comm :: Integer → Integer → Aggregated → Property
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 → Property → Property
implies p1 p2 = property (¬ 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* **Debug**
    stats1 ← *pure* $ `updateAggregation` (*Bytes* 5000) *stats0 t1 Nothing*
    `-- putStrLn (show stats1)`
    `-- showTimedMean stats1`
    threadDelay 50000 `-- 0.05 s`
    t2 ← *mkLOMeta* **Debug**
    stats2 ← *pure* $ `updateAggregation` (*Bytes* 1000) *stats1 t2 Nothing*
    `-- putStrLn (show stats2)`
    `-- showTimedMean stats2`
    checkTimedMean stats2
    threadDelay 50000 `-- 0.05 s`
    t3 ← *mkLOMeta* **Debug**
    stats3 ← *pure* $ `updateAggregation` (*Bytes* 3000) *stats2 t3 Nothing*
    `-- putStrLn (show stats3)`
    `-- showTimedMean stats3`
    checkTimedMean stats3
    threadDelay 50000 `-- 0.05 s`
    t4 ← *mkLOMeta* **Debug**
    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* 29999))
  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`
ifdef ENABLE_OBSERVABLES
   , *testCase* `"stress testing: ObservableTrace vs. NoTrace"` *timingObservableVsUntimed*
```

```
   # endif
     ,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
    ,testCase "private messages should not be logged into private files" unitLoggingPrivate
    ]
  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
    }
setupTrace :: TraceConfiguration → IO (Trace IO)
setupTrace (TraceConfiguration outk name subTr) = do
    c ← liftIO $ Cardano.BM.Configuration ∘ Model.empty
    ctx ← liftIO $ newContext name c
    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
    Setup.withTrace cfg "test" $ λlogTrace → do
        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 100000
        -- force garbage collection to allow exceptions to be thrown
        performMajorGC
        threadDelay 100000
      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
# ifdef ENABLE_OBSERVABLES
        _ ← STMObserver.bracketObserveIO trInner Debug "STM-action" setVar_
# endif
        logInfo trInner "let's see: done."
```

Show effect of turning off observables

```
    # ifdef ENABLE_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 Debug "" 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)
  msgs2 ← STM.newTVarIO [ ]
  traceUntimed ← setupTrace $ TraceConfiguration
      (TVarList msgs2)
      "no timing"
      UntimedTrace
  msgs3 ← STM.newTVarIO [ ]
  traceNoTrace ← setupTrace $ TraceConfiguration
      (TVarList msgs3)
      "no trace"
      NoTrace
  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]
# endif
```

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
    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 la-
belled 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
  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 (LOMeta _ _ Info) (LogMessage (LogItem _ "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
  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
  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 (LOMeta _ _ Info) (LogMessage (LogItem _ "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
    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)
# ifdef ENABLE_OBSERVABLES
    _ ← STMObserver.bracketObserveIO trace2 Debug "innermost" setVar_
# endif
    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
    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
    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 [ ]
```

```
# ifdef ENABLE_OBSERVABLES
  logTrace ← setupTrace $ TraceConfiguration (TVarList msgs) "test" DropOpening
  _ ← STMObserver.bracketObserveIO logTrace Debug "setTVar" setVar_
# endif
  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"


 # ifdef ENABLE_OBSERVABLES
setVar_ :: STM.STM Integer
setVar_ = do
  t ← STM.newTVar 0
  STM.writeTVar t 42
  res ← STM.readTVar t
  return res
# endif
```

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
```

Check that private messages do not end up in public log files.

```
unitLoggingPrivate :: Assertion
unitLoggingPrivate = do
    tmpDir ← getTemporaryDirectory
    let privateFile = tmpDir </> "private.log"
        publicFile = tmpDir </> "public.log"
    conf ← empty
    setDefaultBackends conf [KatipBK]
    setSetupBackends conf [KatipBK]
    setDefaultScribes conf ["FileTextSK::" <> pack privateFile
      ,"FileTextSK::" <> pack publicFile
      ]
    setSetupScribes conf [ScribeDefinition
        {scKind    = FileTextSK
        ,scName    = pack privateFile
```

```
            ,scPrivacy = ScPrivate
            ,scRotation = Nothing
            }
        ,ScribeDefinition
            {scKind    = FileTextSK
            ,scName    = pack publicFile
            ,scPrivacy = ScPublic
            ,scRotation = Nothing
            }
        ]
    Setup.withTrace conf "test" $ λtrace → do
        -- should log in both files
        logInfo trace message
        -- should only log in private file
        logInfoS trace message
    countPublic ← length ∘ lines < $ > readFile publicFile
    countPrivate ← length ∘ lines < $ > readFile privateFile

    -- delete files
    forM_ [privateFile, publicFile] removeFile

    assertBool
        ("Private file should contain 2 lines and it contains " ⧺ show countPrivate ⧺ ".\n" ⧺
            "Public file should contain 1 line and it contains " ⧺ show countPublic ⧺ ".\n"
        )
        (countPublic ≡ 1 ∧ countPrivate ≡ 2)
    where
        message :: Text
        message = "Just a 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**
 # ifndef ENABLE_EKG
  return ()
 # else
  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*)
> # *endif*

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

> *unitConfigurationCheckEKGnegative* :: *Assertion*
> *unitConfigurationCheckEKGnegative* = **do**
> # *ifndef ENABLE_EKG*
>   *return* ()
> # **else**
>   **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*)
> # *endif*
>
>
> *unitConfigurationStaticRepresentation* :: *Assertion*
> *unitConfigurationStaticRepresentation* =
>   **let** *r* = *Representation*
>   {*minSeverity* = **Info**
>   , *rotation* = *Just* $ **RotationParameters**

```
                              {rpLogLimitBytes = 5000000
                              ,rpMaxAgeHours   = 24
                              ,rpKeepFilesNum = 10
                              }
        ,setupScribes =
          [ScribeDefinition {scName = "stdout"
            ,scKind = StdoutSK
            ,scPrivacy = ScPublic
            ,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 @? =
    (intercalate "\n"
      ["rotation:"
      ,"  rpLogLimitBytes: 5000000"
      ,"  rpKeepFilesNum: 10"
      ,"  rpMaxAgeHours: 24"
      ,"defaultBackends:"
      ,"- KatipBK"
      ,"setupBackends:"
      ,"- EKGViewBK"
      ,"- KatipBK"
      ,"hasGUI: 12789"
      ,"defaultScribes:"
      ,"- - StdoutSK"
      ,"  - stdout"
      ,"options:"
      ,"  test2:"
      ,"    value: object2"
      ,"  test1:"
      ,"    value: object1"
      ,"setupScribes:"
      ,"- scName: stdout"
      ,"  scRotation: null"
      ,"  scKind: StdoutSK"
      ,"  scPrivacy: ScPublic"
      ,"hasEKG: 18321"
      ,"minSeverity: Info"
      ,"""-- to force a line feed at the end of the file
```

```
            ]
          )
    unitConfigurationParsedRepresentation :: Assertion
    unitConfigurationParsedRepresentation = do
        repr ← parseRepresentation "test/config.yaml"
        encode repr @? =
          (intercalate "\n"
            ["rotation:"
            ,"   rpLogLimitBytes: 5000000"
            ,"   rpKeepFilesNum: 10"
            ,"   rpMaxAgeHours: 24"
            ,"defaultBackends:"
            ,"- KatipBK"
            ,"setupBackends:"
            ,"- AggregationBK"
            ,"- EKGViewBK"
            ,"- KatipBK"
            ,"hasGUI: null"
            ,"defaultScribes:"
            ,"- - StdoutSK"
            ,"  - stdout"
            ,"options:"
            ,"   mapSubtrace:"
            ,"     iohk.benchmarking:"
            ,"       tag: ObservableTrace"
            ,"       contents:"
            ,"       - GhcRtsStats"
            ,"       - MonotonicClock"
            ,"     iohk.deadend: NoTrace"
            ,"   mapSeverity:"
            ,"     iohk.startup: Debug"
            ,"     iohk.background.process: Error"
            ,"     iohk.testing.uncritical: Warning"
            ,"   mapAggregatedkinds:"
            ,"     iohk.interesting.value: EwmaAK {alpha = 0.75}"
            ,"     iohk.background.process: StatsAK"
            ,"   cfokey:"
            ,"     value: Release-1.0.0"
            ,"   mapMonitors:"
            ,"     chain.creation.block:"
            ,"     - monitor: ((time > (23 s)) Or (time < (17 s)))"
            ,"     - actions:"
            ,"       - AlterMinSeverity \"chain.creation\" Debug"
            ,"     ! '#aggregation.critproc.observable':"
            ,"     - monitor: (mean >= (42))"
            ,"     - actions:"
            ,"       - CreateMessage \"exceeded\" \"the observable has been too long too high!\""
```

```
          ,"          - AlterGlobalMinSeverity Info"
          ,"  mapScribes:"
          ,"     iohk.interesting.value:"
          ,"       - StdoutSK::stdout"
          ,"       - FileTextSK::testlog"
          ,"     iohk.background.process: FileTextSK::testlog"
          ,"  mapBackends:"
          ,"     iohk.interesting.value:"
          ,"       - EKGViewBK"
          ,"       - AggregationBK"
          ,"setupScribes:"
          ,"- scName: testlog"
          ,"  scRotation:"
          ,"     rpLogLimitBytes: 25000000"
          ,"     rpKeepFilesNum: 3"
          ,"     rpMaxAgeHours: 24"
          ,"  scKind: FileTextSK"
          ,"  scPrivacy: ScPrivate"
          ,"- scName: stdout"
          ,"  scRotation: null"
          ,"  scKind: StdoutSK"
          ,"  scPrivacy: ScPublic"
          ,"hasEKG: 12789"
          ,"minSeverity: Info"
          ,""-- to force a line feed at the end of the file
          ]
      )
```

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
                                  ,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"
                                ,scPrivacy = ScPrivate
                                ,scRotation = Just $ RotationParameters
                                  {rpLogLimitBytes = 25000000
                                  ,rpMaxAgeHours   = 24
                                  ,rpKeepFilesNum = 3
                                  }
                                }
                              ,ScribeDefinition
                                {scKind = StdoutSK
                                ,scName = "stdout"
                                ,scPrivacy = ScPublic
                                ,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`

2.4.5 Rotator

tests :: *TestTree*
tests = *testGroup* `"testing Trace"` [
  property_tests
  ]
property_tests :: *TestTree*
property_tests = *testGroup* `"Property tests"` [

```
  testProperty "rotator: name giving" propNameGiving
 ,testProperty "rotator: cleanup" $ propCleanup $ rot n
 ]
 where
   n = 5
   rot num = RotationParameters
     {rpLogLimitBytes = 10000000-- 10 MB
     ,rpMaxAgeHours   = 24
     ,rpKeepFilesNum = num
     }
```

Check that full file name has only added 15 digits to the base name of the file.

```
propNameGiving :: FilePath → Property
propNameGiving name = ioProperty $ do
  filename ← nameLogFile name
  return $ length filename === length name + 15
```

Test cleanup of rotator.

This test creates a random number of files with the same name but with different dates and afterwards it calls the *cleanupRotator* function which removes old log files keeping only `rpKeepFilesNum` files and deleting the others.

```
data LocalFilePath = Dir FilePath
  deriving (Show)
instance Arbitrary LocalFilePath where
  arbitrary = do
      start ← QC.sized $ λn → replicateM (n + 1) (QC.elements $ ['a'..'z'])
      x ← QC.sized $ λn → replicateM n (QC.elements $ ['a'..'d'] ++ "/")
      pure $ Dir $ start ++ removeAdjacentAndLastSlashes x
  shrink (Dir path) = map (Dir ∘ removeAdjacentAndLastSlashes ∘ (intercalate "/")) $
      product' $ map (filter (≢ "")) $ map QC.shrink (splitOn "/" path)
    where
      product' :: [[a]] → [[a]]
      product' = mapM (λx → x ≫ return)
removeAdjacentAndLastSlashes :: FilePath → FilePath
removeAdjacentAndLastSlashes = concat ∘ filter (≢ "/") ∘ groupBy (\_ b → b ≢ '/')
data SmallAndLargeInt = SL Int
  deriving (Show)
instance Arbitrary SmallAndLargeInt where
  arbitrary = do
      QC.oneof [smallGen
        ,largeGen
          ]
```

```haskell
  where
    smallGen :: QC.Gen SmallAndLargeInt
    smallGen = do
      QC.Small x ← (QC.arbitrary :: QC.Gen (QC.Small Int))
      pure $ SL $ abs x
    largeGen :: QC.Gen SmallAndLargeInt
    largeGen = do
      let maxBoundary = 00100000000000-- 10 years for the format which is used
          minBoundary = 00000000010000-- 1 hour for the format which is used
      x ← QC.choose (minBoundary, maxBoundary)
      pure $ SL x
  shrink _ = [ ]
propCleanup :: RotationParameters → LocalFilePath → Positive Int → SmallAndLargeInt → Property
propCleanup rotationParams (Dir filename) (Positive nFiles) (SL maxDev) = ioProperty $ do
  tmpDir ← getTemporaryDirectory
  let path = tmpDir < / > filename
  -- generate nFiles different dates
  now ← getCurrentTime
  let tsnow = formatTime defaultTimeLocale tsformat now
  deviations ← replicateM nFiles $ QC.generate $ QC.choose (1, maxDev + 1)
  -- TODO if generated within the same sec we have a problem
  let dates = map show $ scanl (+) (read tsnow) deviations
      files = map (λa → path ++ ('-' : a)) dates
      sortedFiles = reverse $ sort files
      keepFilesNum = fromIntegral $ rpKeepFilesNum rotationParams
      toBeKept = reverse $ take keepFilesNum sortedFiles
  createDirectoryIfMissing True $ takeDirectory path
  forM_ (files) $ λf → openFile f WriteMode
  cleanupRotator rotationParams path
  filesRemained ← listLogFiles path
  let kept = case filesRemained of
        Nothing → [ ]
        Just l → NE.toList l
  -- delete the files left
  forM_ kept removeFile
  -- delete folders created
  when (dropWhile (≢ '/') filename ≢ "") $
    removePathForcibly $ "/tmp" < / > takeWhile (≢ '/') filename
  return $ kept === toBeKept
```

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