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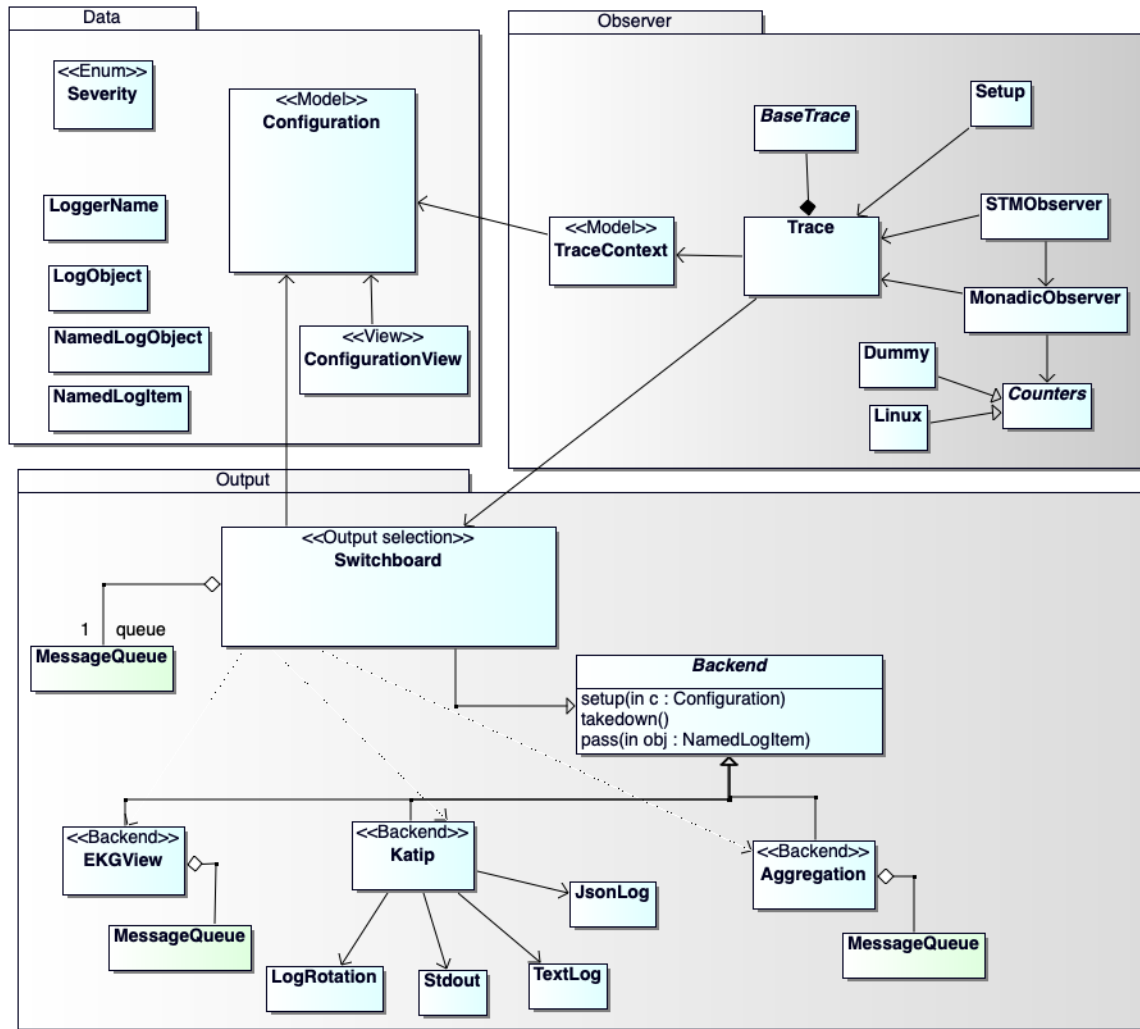
Figure 1.1: Overview of module relationships. The arrows indicate import of a module. The arrows with a triangle at one end would signify "inheritance" in object-oriented programming, but we use it to show that one module replaces the other in the namespace, thus specializes its interface.

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
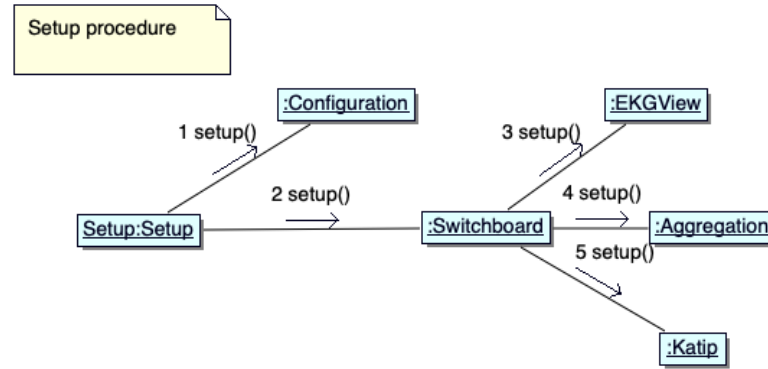
Figure 1.2: Setup procedure

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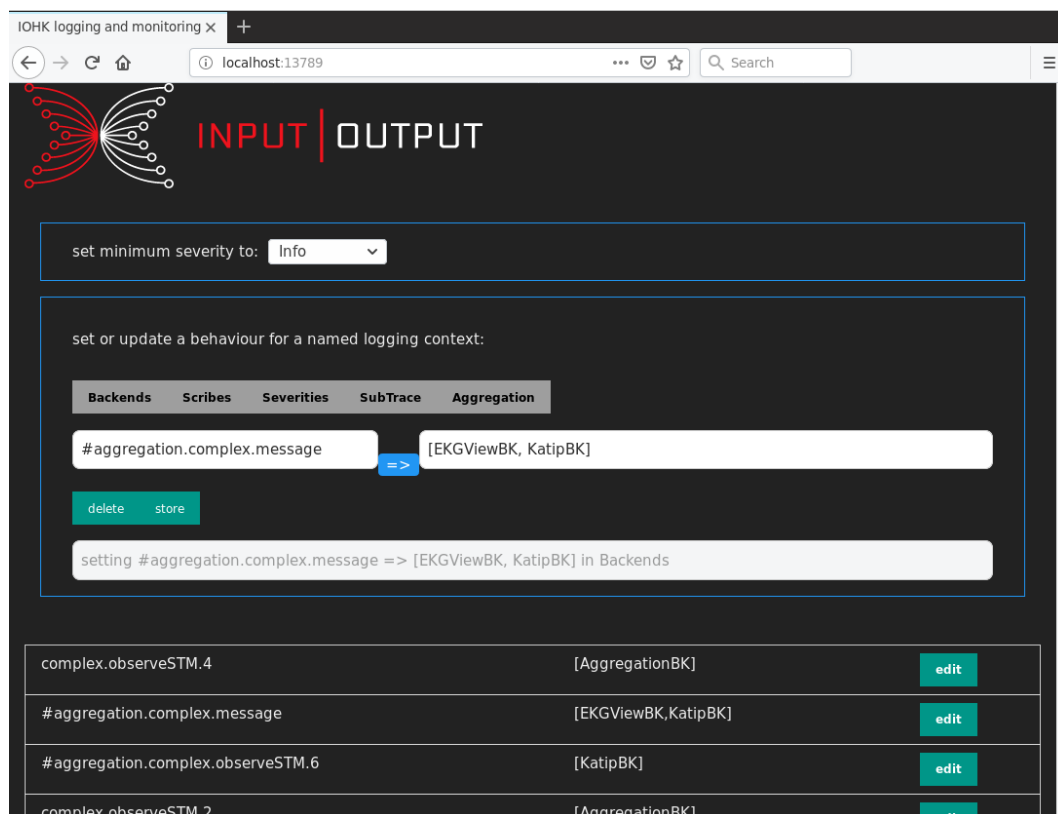
Figure 1.3: The configuration editor is listening on *localhost* and can be accessed through a browser. At the top is the setting for the global minimum severity filter, that drops all messages that have a severity lower than this setting. Below are the settings for various behaviours of the logging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

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 ScopedTypeVariables #-}
module Main
  (main)
  where
import Control.Concurrent (threadDelay)
import Cardano.BM.Configuration.Static (defaultConfigStdout)
import Cardano.BM.Setup (setupTrace)
import Cardano.BM.Trace (Trace, logDebug, logError, logInfo,
        logNotice, logWarning)
main :: IO ()
main = do
  c ← defaultConfigStdout
  tr :: Trace IO String ← 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 ScopedTypeVariables #-}
#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 *GHC.Conc.Sync* (*atomically, STM, TVar, newTVar, readTVar, writeTVar*)
ifdef LINUX
import *qualified Data.ByteString.Char8 as BS8*
import *Network.Download* (*openURI*)
endif
endif
import *Data.Text* (*Text, pack*)
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.Output
import Cardano.BM.Data.Rotation
import Cardano.BM.Data.Severity
import Cardano.BM.Data.SubTrace
ifdef ENABLE_OBSERVABLES
import Cardano.BM.Data.Observable
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:
```

```
        else
            CM.setScribes c ("#aggregation.complex.observeSTM." <> (pack $ show x)) $ Just ["FileJsonSK:
# ifdef LINUX
# ifdef ENABLE_OBSERVABLES
    CM.setSubTrace c "complex.observeDownload" (Just $ ObservableTrace [IOStats, NetStats])
# endif
    CM.setBackends c "complex.observeDownload" (Just [KatipBK])
    CM.setScribes c "complex.observeDownload" (Just ["StdoutSK::stdout","FileJsonSK::logs/down.
# endif
    CM.setSubTrace c "complex.random" (Just $ TeeTrace "ewma")
    CM.setSubTrace c "#ekgview"
        (Just $ FilterTrace [(Drop (StartsWith "#ekgview.#aggregation.complex.random"),
            Unhide [(EndsWith ".count"),
              (EndsWith ".avg"),
              (EndsWith ".mean")]),
          (Drop (StartsWith "#ekgview.#aggregation.complex.observeIO"),
            Unhide [(Contains "diff.RTS.cpuNs.timed.")]),
          (Drop (StartsWith "#ekgview.#aggregation.complex.observeSTM"),
            Unhide [(Contains "diff.RTS.gcNum.timed.")]),
          (Drop (StartsWith "#ekgview.#aggregation.complex.message"),
            Unhide [(Contains ".timed.m")])
        ])
# ifdef ENABLE_OBSERVABLES
    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])
# endif

# 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 Text → IO (Async.Async ())
randomThr trace = do
   logInfo trace "starting random generator"
   trace' ← appendName "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 ← (, ) < $ > (mkLOMeta Debug Public) < ∗ > pure (LogValue "rr" (PureD num))
         traceNamedObject tr lo
         loop tr
```

Thread that observes an *IO* action

```
# ifdef ENABLE_OBSERVABLES
observeIO :: Trace IO Text → 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 Text → 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 Text → 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 Text → IO (Async.Async ())
    msgThr trace = do
        logInfo trace "start messaging .."
        trace' ← appendName "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 :: Trace IO Text ← 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 in
  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 - basic-tracer package

1.5.1   Cardano.BM.Tracer

Tracing using the contravariant Tracer naturally reads:

```
let logTrace = tracing $ showTracing $ stdoutTracer
in logTrace "hello world"
```

```
example1 :: IO ()
example1 = do
  let logTrace a = tracingWith (showTracing (contramap ("Debug:  " ++) stdoutTracer)) a
  void $ callFun1 logTrace
callFun1 :: (String → IO ()) → IO Int
callFun1 logTrace = do
  logTrace "in function 1"
  return 42
```

1.5.2   Cardano.BM.Tracer.Class

Contravariant Tracer

The notion of a Tracer is an action that can be used to observe information of interest during evaluation. Tracers can capture (and annotate) such observations with additional information from their execution context.

> **newtype** Tracer *m s* = Tracer {*tracing* :: *Op* (*m* ()) *s*}

A Tracer is an instance of *Contravariant*, which permits new Tracers to be constructed that feed into the existing Tracer by use of *contramap*.

> **instance** *Contravariant* (Tracer *m*) **where**
>   *contramap f* = Tracer ∘ *contramap f* ∘ *tracing*

Although a Tracer is invoked in a monadic context (which may be *Identity*), the construction of a new Tracer is a pure function.

This brings with it the constraint that the derived Tracers form a hierachy which has its root at the top level tracer.

nullTracer

The simplest tracer - one that suppresses all output.

> nullTracer :: (*Applicative m*) ⇒ Tracer *m a*
> nullTracer = Tracer $ *Op* $ _ → *pure* ()

tracingWith

Accepts a Tracer and some payload *s*. First it gets the contravariant from the Tracer as type "*Op* (*m* ()) *s*" and, after "*getOp* :: *b* → *a*" which translates to "*s* → *m* ()".

> tracingWith :: Tracer *m a* → *a* → *m* ()
> tracingWith = *getOp* ∘ *tracing*

1.5.3   Cardano.BM.Tracer.Output

+

Directing a Tracer's output to stdout

The Tracer that prints a string (as a line) to stdout (usual caveats about interleaving should be heeded).

> stdoutTracer :: (*MonadIO m*) ⇒ Tracer *m String*
> stdoutTracer = Tracer $ *Op* $ *liftIO* ∘ *putStrLn*

   +

Outputting a Tracer with *Debug.Trace*

A Tracer that uses *TraceM* (from Debug.Trace) as its output mechanism.

> debugTracer :: (*Applicative m*) ⇒ Tracer *m String*
> debugTracer = Tracer $ *Op traceM*

1.5.4 Cardano.BM.Tracer.Transformers

Applying *show* **on a Tracer's messages**

The Tracer transformer exploiting Show.

$$showTracing :: (Show\ a) \Rightarrow Tracer\ m\ String \rightarrow Tracer\ m\ a$$
$$showTracing = contramap\ show$$

Conditional tracing - statically defined

The Tracer transformer that allows for on/off control of tracing at trace creation time.

$$condTracing :: (Monad\ m) \Rightarrow (a \rightarrow Bool) \rightarrow Tracer\ m\ a \rightarrow Tracer\ m\ a$$
$$condTracing\ active\ tr = Tracer\ \$\ Op\ \$\ \lambda s \rightarrow \textbf{do}$$
$$\quad when\ (active\ s)\ (tracingWith\ tr\ s)$$

Conditional tracing - dynamically evaluated

The tracer transformer that can exercise dynamic control over tracing, the dynamic decision being made using the context accessible in the monadic context.

$$condTracingM :: (Monad\ m) \Rightarrow m\ (a \rightarrow Bool) \rightarrow Tracer\ m\ a \rightarrow Tracer\ m\ a$$
$$condTracingM\ activeP\ tr = Tracer\ \$\ Op\ \$\ \lambda s \rightarrow \textbf{do}$$
$$\quad active \leftarrow activeP$$
$$\quad when\ (active\ s)\ (tracingWith\ tr\ s)$$

natTrace

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

$$natTrace :: (forall\ x \circ m\ x \rightarrow n\ x) \rightarrow Tracer\ m\ s \rightarrow Tracer\ n\ s$$
$$natTrace\ nat\ (Tracer\ (Op\ tr)) = Tracer\ \$\ Op\ \$\ nat \circ tr$$

1.6 Code listings - iohk-monitoring package

1.6.1 Cardano.BM.Observer.STM

$$stmWithLog :: STM.STM\ (t, [(LOMeta, LOContent\ a)]) \rightarrow STM.STM\ (t, [(LOMeta, LOContent\ a)])$$
$$stmWithLog\ action = action$$

Observe *STM* **action in a named context**

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

$$bracketObserveIO :: Trace\ IO\ a \rightarrow Severity \rightarrow Text \rightarrow STM.STM\ t \rightarrow IO\ t$$
$$bracketObserveIO\ trace@(ctx, \_)\ severity\ name\ action = \textbf{do}$$
$$\quad subTrace \leftarrow fromMaybe\ Neutral <\$> Config.findSubTrace\ (configuration\ ctx)\ name$$
$$\quad bracketObserveIO'\ subTrace\ severity\ trace\ action$$

where
  bracketObserveIO' :: SubTrace → Severity → Trace *IO a* → *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*) → (*TIO.hPutStrLn stderr* (*pack* (*show e*)) ≫ *thr*

    case *mCountersid* **of**
      Left openException →
        `-- since observeOpen faced an exception there is no reason to call observeClo`
        `-- however the result of the action is returned`
        TIO.hPutStrLn stderr (`"ObserveOpen: "` <> *pack* (*show openException*))
      Right countersid → **do**
        res ← *observeClose subtrace sev logTrace countersid* [ ]
        case *res* **of**
          Left ex → *TIO.hPutStrLn stderr* (`"ObserveClose: "` <> *pack* (*show ex*))
          _ → *pure* ()
  pure t

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

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

  bracketObserveLogIO :: Trace *IO a* → Severity → *Text* → *STM.STM* (*t*, [(LOMeta, LOContent *a*)]) → *IO t*
  bracketObserveLogIO *trace*@(*ctx*, _) *severity name action* = **do**
    subTrace ← *fromMaybe* Neutral < $ > *Config.findSubTrace* (configuration *ctx*) *name*
    bracketObserveLogIO' subTrace severity trace action
  where
    bracketObserveLogIO' :: SubTrace → Severity → Trace *IO a* → *STM.STM* (*t*, [(LOMeta, LOContent *a*)])
    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*) → (*TIO.hPutStrLn stderr* (*pack* (*show e*)) ≫ *throwM e*))

      case *mCountersid* **of**
        Left openException →
          `-- since observeOpen faced an exception there is no reason to call observeClo`
          `-- however the result of the action is returned`
          TIO.hPutStrLn stderr (`"ObserveOpen: "` <> *pack* (*show openException*))
        Right countersid → **do**
          res ← *observeClose subtrace sev logTrace countersid as*
          case *res* **of**
            Left ex → *TIO.hPutStrLn stderr* (`"ObserveClose: "` <> *pack* (*show ex*))
            _ → *pure* ()
    pure t

1.6.2   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' (λ*ProtocolStopped* → *return* ())

and use bracketObserveIO. e.g.:

bracketObserveIO *trace* `"submit-tx"` $
  runProtocolWithPipe x hdl proto 'catch' (λ*ProtocolStopped* → *return* ())

bracketObserveIO :: Trace *IO a* → Severity → *Text* → *IO t* → *IO t*
bracketObserveIO *trace*@(*ctx*, _) *severity name action* = **do**
    subTrace ← *fromMaybe* Neutral < $ > *Config.findSubTrace* (configuration *ctx*) *name*
    bracketObserveIO′ subTrace severity trace action
  where
    bracketObserveIO′ :: SubTrace → Severity → Trace *IO a* → *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 it will be logged and rethrown.`
      t ← *act* 'catch' (λ(*e* :: *SomeException*) → (*TIO.hPutStrLn stderr* (*pack* (*show e*)) ≫ *throwM e*))

      case *mCountersid* **of**
        Left openException →
          `-- since observeOpen faced an exception there is no reason to call observeClo`
          `-- however the result of the action is returned`
          TIO.hPutStrLn stderr (`"ObserveOpen: "` <> *pack* (*show openException*))
        Right countersid → **do**
          res ← *observeClose subtrace sev logTrace countersid* [ ]
          case *res* **of**
            Left ex → *TIO.hPutStrLn stderr* (`"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 a* → Severity → *Text* → *m t* → *m t*
bracketObserveM trace@(*ctx*, _) *severity name action* = **do**
    subTrace ← *liftIO* $ *fromMaybe* Neutral < $ > *Config.findSubTrace* (configuration *ctx*) *name*
    bracketObserveM′ subTrace severity trace action
  where
    bracketObserveM′ :: (*MonadCatch m*, *MonadIO m*) ⇒ SubTrace → Severity → Trace *IO a* → *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 it will be logged and rethrown.`
      t ← *act* 'catch' (λ(*e* :: *SomeException*) → *liftIO* (*TIO.hPutStrLn stderr* (*pack* (*show e*)) ≫ *throwM e*))

      case *mCountersid* **of**
        Left openException →
          `-- since observeOpen faced an exception there is no reason to call observeClo`
          `-- however the result of the action is returned`

```
            liftIO $ TIO.hPutStrLn stderr ("ObserveOpen: " <> pack (show openException))
         Right countersid → do
            res ← liftIO $ observeClose subtrace sev logTrace countersid [ ]
            case res of
               Left ex → liftIO (TIO.hPutStrLn stderr ("ObserveClose: " <> pack (show ex)))
               _ → pure ()
      pure t
```

observerOpen

```
observeOpen :: SubTrace → Severity → Trace IO a → 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
      traceNamedObject logTrace ≪
         (, ) < $ > (mkLOMeta severity Confidential) < ∗ > pure (ObserveOpen state)
   return (Right state)) 'catch' (return ∘ Left)
```

observeClose

```
observeClose
   :: SubTrace
   → Severity
   → Trace IO a
   → CounterState
   → [ (LOMeta, LOContent a) ]
   → 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 Confidential
      -- send closing message to Trace
      traceNamedObject logTrace $
         (mle, ObserveClose (CounterState identifier counters))
      -- send diff message to Trace
      traceNamedObject logTrace $
         (mle, ObserveDiff (CounterState identifier (diffCounters initialCounters counters)))
   -- trace the messages gathered from inside the action
```

> *forM_ logObjects* $ traceNamedObject *logTrace*
> *return* (*Right* ())) 'catch' (*return* ∘ *Left*)

1.6.3   Cardano.BM.Trace

Utilities

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

> natTrace :: (*forall x* ∘ *m x* → *n x*) → Trace *m a* → Trace *n a*
> natTrace *nat* (*ctx*, *trace*) = (*ctx*, *TracerT*.natTrace *nat trace*)

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 a* → *m* (Trace *m a*)
> appendName *name* =
>   modifyName (λ*prevLoggerName* → *appendWithDot name prevLoggerName*)
>
> *appendWithDot* :: LoggerName → LoggerName → LoggerName
> *appendWithDot* "" *newName* = *newName*
> *appendWithDot xs* "" = *xs*
> *appendWithDot xs newName* = *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 → LoggerName) → Trace *m a* → *m* (Trace *m a*)
> modifyName *f* (*ctx*, *basetrace0*) =
>   **let** *basetrace* = *modifyNameBase f basetrace0*
>   **in**
>   *return* (*ctx*, *basetrace*)
>
> *modifyNameBase*
>   :: (LoggerName → LoggerName)
>   → Tracer *m* (LogObject *a*)
>   → Tracer *m* (LogObject *a*)
> *modifyNameBase k* = *contramap f*
>   **where**
>   *f* (LogObject *name meta item*) = LogObject (*k name*) *meta item*

Contramap a trace and produce the naming context

> named :: Tracer *m* (LogObject *a*) → Tracer *m* (LOMeta, LOContent *a*)
> named = *contramap* $ *uncurry* (LogObject *mempty*)

Trace a LogObject through

```
traceNamedObject
  :: MonadIO m
  ⇒ Trace m a
  → (LOMeta, LOContent a)
  → m ()
traceNamedObject (_, logTrace) lo =
  tracingWith (named logTrace) lo
```

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 "LogObject *a* → *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 :: Tracer IO (LogObject T.Text)
stdoutTrace = Tracer $ Op $ λ(LogObject logname _ lc) →
    withMVar locallock $ \_ →
      case lc of
        (LogMessage logItem) →
          output logname $ logItem
        obj →
          output logname $ toStrict (encodeToLazyText obj)
  where
    output nm msg = TIO.putStrLn $ nm <> "  ::  " <> msg
```

Concrete Trace into a *TVar*

```
traceInTVar :: STM.TVar [a] → Tracer STM.STM a
traceInTVar tvar = Tracer $ Op $ λa → STM.modifyTVar tvar ((:) a)

traceInTVarIO :: STM.TVar [LogObject a] → Tracer IO (LogObject a)
traceInTVarIO tvar = Tracer $ Op $ λln →
    STM.atomically $ STM.modifyTVar tvar ((:) ln)

traceInTVarIOConditionally :: STM.TVar [LogObject a] → TraceContext → Tracer IO (LogObject a)
traceInTVarIOConditionally tvar ctx =
    Tracer $ Op $ λitem@(LogObject loggername meta _) → do
      let conf = configuration ctx
      globminsev ← Config.minSeverity conf
      globnamesev ← Config.inspectSeverity conf loggername
      let minsev = max globminsev $ fromMaybe Debug globnamesev

      subTrace ← fromMaybe Neutral < $ > Config.findSubTrace conf loggername
      let doOutput = subtraceOutput subTrace item

      when ((severity meta) ⩾ minsev ∧ doOutput) $
        STM.atomically $ STM.modifyTVar tvar ((:) item)

      case subTrace of
        TeeTrace secName →
          STM.atomically $ STM.modifyTVar tvar ((:) item {loName = secName})
        _ → return ()
subtraceOutput :: SubTrace → LogObject a → Bool
subtraceOutput subTrace (LogObject loname _ loitem) =
  case subTrace of
    FilterTrace filters →
      case loitem of
        LogValue name _ →
            evalFilters filters (loname <> "." <> name)
        _ →
            evalFilters filters loname
    DropOpening → case loitem of
      ObserveOpen _ → False
      _ → True
    NoTrace    → False
    _          → True
```

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 a
    → PrivacyAnnotation
    → Severity
    → a
    → m ()
traceNamedItem trace p s m =
```

$$traceNamedObject\ trace \lll$$
$$(,) <\$> liftIO\ (mkLOMeta\ s\ p)$$
$$<*> pure\ (\text{LogMessage}\ m)$$

Logging functions

logDebug, logInfo, logNotice, logWarning, logError, logCritical, logAlert, logEmergency
  :: *MonadIO m* ⇒ Trace *m a* → *a* → *m* ()
logDebug   *logTrace* = traceNamedItem *logTrace* Public Debug
logInfo   *logTrace* = traceNamedItem *logTrace* Public Info
logNotice   *logTrace* = traceNamedItem *logTrace* Public Notice
logWarning *logTrace* = traceNamedItem *logTrace* Public Warning
logError   *logTrace* = traceNamedItem *logTrace* Public Error
logCritical *logTrace* = traceNamedItem *logTrace* Public Critical
logAlert   *logTrace* = traceNamedItem *logTrace* Public Alert
logEmergency *logTrace* = traceNamedItem *logTrace* Public Emergency

logDebugS, logInfoS, logNoticeS, logWarningS, logErrorS, logCriticalS, logAlertS, logEmergencyS
  :: *MonadIO m* ⇒ Trace *m a* → *a* → *m* ()
logDebugS   *logTrace* = traceNamedItem *logTrace* Confidential Debug
logInfoS   *logTrace* = traceNamedItem *logTrace* Confidential Info
logNoticeS   *logTrace* = traceNamedItem *logTrace* Confidential Notice
logWarningS *logTrace* = traceNamedItem *logTrace* Confidential Warning
logErrorS   *logTrace* = traceNamedItem *logTrace* Confidential Error
logCriticalS *logTrace* = traceNamedItem *logTrace* Confidential Critical
logAlertS   *logTrace* = traceNamedItem *logTrace* Confidential Alert
logEmergencyS *logTrace* = traceNamedItem *logTrace* Confidential Emergency

1.6.4 Cardano.BM.Setup
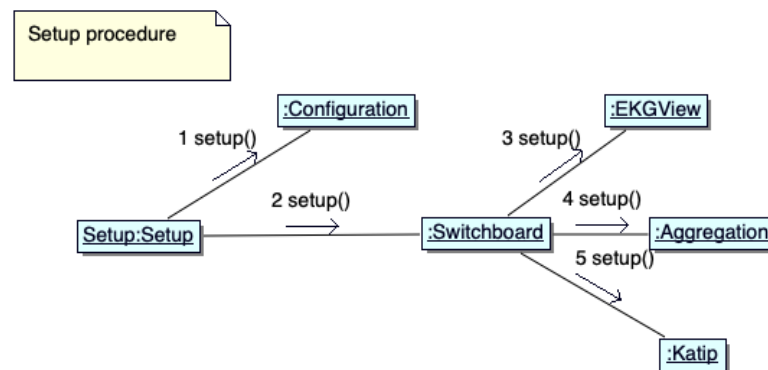

Figure 1.4: Setup procedure

setupTrace

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

setupTrace :: (*MonadIO m, Show a, ToJSON a*) ⇒ *Either FilePath Config.*Configuration → *Text* → *m* (Trace *n*
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, Show a, ToJSON a*) ⇒ *Config.*Configuration → *Text* → *m* (Trace *m a*, Switchboar
setupTrace_ c name = **do**
   sb ← *liftIO* $ Switchboard.*realize c*
   ctx ← *liftIO* $ newContext *c*
   tr ← appendName *name* $ natTrace *liftIO* (*ctx*, Switchboard.*mainTraceConditionally ctx sb*)
   return (*tr, sb*)

shutdown

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

shutdown :: (*Show a, ToJSON a*) ⇒ Switchboard.Switchboard *a* → *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, Show a, ToJSON a*) ⇒ *Config.*Configuration → *Text* → (Trace *m a*
withTrace *cfg name action* =
   bracket
     (*setupTrace_ cfg name*)   `-- aquire`
     (λ(_, *sb*) → *liftIO* $ shutdown *sb*) `-- release`
     (λ(*tr*, _) → *action tr*)   `-- action`

newContext

newContext :: *Config.*Configuration
   → *IO* TraceContext
newContext *cfg* =
   return $ TraceContext {
     configuration = *cfg*
     }

1.6.5   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
```

1.6.6 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)
```

1.6.7   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 []
#ifdef ENABLE_OBSERVABLES
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)
          ]
   # else
   readCounters (ObservableTrace _) = return [ ]
   # endif
```

1.6.8 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 [ ]
   # ifdef ENABLE_OBSERVABLES
   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)
         ]
   # else
   readCounters (ObservableTrace _) = return [ ]
   # endif

   # ifdef ENABLE_OBSERVABLES
   pathProc :: FilePath
   pathProc = "/proc/"
   pathProcStat :: ProcessID → FilePath
   pathProcStat pid = pathProc < / > (show pid) < / > "stat"
   pathProcStatM :: ProcessID → FilePath
   pathProcStatM pid = pathProc < / > (show pid) < / > "statm"
   pathProcIO :: ProcessID → FilePath
   pathProcIO pid = pathProc < / > (show pid) < / > "io"
   pathProcNet :: ProcessID → FilePath
   pathProcNet pid = pathProc < / > (show pid) < / > "net" < / > "netstat"
   # endif
```

Reading from a file in /proc/<pid >

```
# ifdef ENABLE_OBSERVABLES
readProcList :: FilePath → IO [Integer]
readProcList fp = do
   cs ← readFile fp
   return $ map (λs → maybe 0 id $ (readMaybe s :: Maybe Integer)) (words cs)
# endif
```

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)
```

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

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).
```

$\#\,ifdef\ ENABLE\_OBSERVABLES$
$readProcStats :: ProcessID \rightarrow IO\,[Counter]$
$readProcStats\ pid = \textbf{do}$
    $ps0 \leftarrow readProcList\ (pathProcStat\ pid)$
    $\textbf{let}\ ps = zip\ colnames\ ps0$
        $psUseful = filter\ ((\text{"unused"} \neq) \circ fst)\ ps$
    $return\ \$\ map\ (\lambda(n,i) \rightarrow Counter\ StatInfo\ n\ (PureI\ i))\ psUseful$

where
    colnames :: [*Text*]
    colnames = ["pid","unused","unused","ppid","pgrp","session","ttynr","tpgid","flags","mi
      ,"cminflt","majflt","cmajflt","utime","stime","cutime","cstime","priority","nice","r
      ,"itrealvalue","starttime","vsize","rss","rsslim","startcode","endcode","startstack
      ,"signal","blocked","sigignore","sigcatch","wchan","nswap","cnswap","exitsignal","p
      ,"policy","blkio","guesttime","cguesttime","startdata","enddata","startbrk","argsta
      ,"envend","exitcode"
      ]
   # endif

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).
```

```
# ifdef ENABLE_OBSERVABLES
```
readProcIO :: ProcessID → IO [Counter]
readProcIO pid = **do**

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

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 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 67 0 0 0 0 3 1 668 0 0 0 4 0 0 0 0 0 91870 4468 0 224 22 23 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 InECT0Pkts InCEPkts
 IpExt: 0 0 20053 8977 2437 23 3163525943 196480057 2426648 1491754 394285 5523 0 3513269 0 217426 0
```

```
# ifdef ENABLE_OBSERVABLES
```
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
# endif
```

1.6.9 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
```

Measurable can be transformed to an integral value.

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

Measurable can be transformed to a rational value.

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

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

```
instance Num Measurable where
  (+) (Microseconds a) (Microseconds b) = Microseconds (a + b)
  (+) (Nanoseconds a) (Nanoseconds b) = Nanoseconds (a + b)
  (+) (Seconds a)     (Seconds b)     = Seconds     (a + b)
  (+) (Bytes a)       (Bytes b)       = Bytes       (a + b)
  (+) (PureI a)       (PureI b)       = PureI       (a + b)
  (+) (PureD a)       (PureD b)       = PureD       (a + b)
  (+) _ _                             = error "Trying to add values with different units"

  (*) (Microseconds a) (Microseconds b) = Microseconds (a * b)
  (*) (Nanoseconds a)  (Nanoseconds b) = Nanoseconds (a * b)
  (*) (Seconds a)     (Seconds b)     = Seconds     (a * b)
  (*) (Bytes a)       (Bytes b)       = Bytes       (a * b)
  (*) (PureI a)       (PureI b)       = PureI       (a * b)
  (*) (PureD a)       (PureD b)       = PureD       (a * b)
  (*) _ _                             = error "Trying to multiply values with different units"

  abs (Microseconds a) = Microseconds (abs a)
  abs (Nanoseconds a)  = Nanoseconds (abs a)
  abs (Seconds a)     = Seconds     (abs a)
  abs (Bytes a)       = Bytes       (abs a)
  abs (PureI a)       = PureI       (abs a)
  abs (PureD a)       = PureD       (abs a)
  abs (Severity _)    = error "cannot compute absolute value for Severity"

  signum (Microseconds a) = Microseconds (signum a)
```

```
signum (Nanoseconds a) = Nanoseconds (signum a)
signum (Seconds a)      = Seconds     (signum a)
signum (Bytes a)        = Bytes       (signum a)
signum (PureI a)        = PureI       (signum a)
signum (PureD a)        = PureD       (signum a)
signum (Severity _)     = error "cannot compute sign of Severity"

negate (Microseconds a) = Microseconds (negate a)
negate (Nanoseconds a)  = Nanoseconds (negate a)
negate (Seconds a)      = Seconds     (negate a)
negate (Bytes a)        = Bytes       (negate a)
negate (PureI a)        = PureI       (negate a)
negate (PureD a)        = PureD       (negate a)
negate (Severity _)     = error "cannot negate Severity"

fromInteger = PureI
```

Pretty printing of Measurable.

```
instance Show Measurable where
  show (Microseconds a) = show a
  show (Nanoseconds a)   = show a
  show (Seconds a)       = show a
  show (Bytes a)         = show a
  show (PureI a)         = show a
  show (PureD a)         = show a
  show (Severity a)      = show a

showUnits :: Measurable → String
showUnits (Microseconds _) = " μs"
showUnits (Nanoseconds _) = " ns"
showUnits (Seconds _)      = " s"
showUnits (Bytes _)        = " B"
showUnits (PureI _)        = ""
showUnits (PureD _)        = ""
showUnits (Severity _)     = ""

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

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

```
showSI v@(Severity a)   = show a ++ showUnits v
```

Stats

A Stats statistics is strictly computed.

```
data BaseStats = BaseStats {
  fmin :: !Measurable,
  fmax :: !Measurable,
  fcount ::  {-# UNPACK #-}  ! Int,
  fsum_A ::  {-# UNPACK #-}  ! Double,
  fsum_B ::  {-# UNPACK #-}  ! Double
  } deriving (Generic, ToJSON, Show)
instance Eq BaseStats where
  (BaseStats mina maxa counta sumAa sumBa) ≡ (BaseStats minb maxb countb sumAb sumBb) =
    mina ≡ minb ∧ maxa ≡ maxb ∧ counta ≡ countb ∧
    abs (sumAa − sumAb) < 1.0e−4 ∧
    abs (sumBa − sumBb) < 1.0e−4
data Stats = Stats {
  flast  :: !Measurable,
  fold   :: !Measurable,
  fbasic :: !BaseStats,
  fdelta :: !BaseStats,
  ftimed :: !BaseStats
  } deriving (Eq, Generic, ToJSON, Show)


meanOfStats :: BaseStats → Double
meanOfStats = fsum_A


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

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

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

```
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 → String
    showStats' s =
      ", { min=" ++ show (fmin s) ++
      ", max=" ++ show (fmax s) ++
      ", mean=" ++ show (meanOfStats s) ++ showUnits (fmin s) ++
      ", std-dev=" ++ show (stdevOfStats s) ++
      ", count=" ++ show (fcount s) ++
      " }"
```

Exponentially Weighted Moving Average (EWMA)

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

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

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

Aggregated

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

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

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

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

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

1.6.10   Cardano.BM.Data.AggregatedKind

AggregatedKind

This identifies the type of Aggregated.

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

1.6.11   Cardano.BM.Data.Backend

Accepts a Logging of outcomes with LogObject

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

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

Declaration of a Backend

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

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

1.6.12   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)
```

1.6.13   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
```

1.6.14   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
   ,csCounters :: [Counter]
   }
   deriving (Generic, ToJSON)
instance ToJSON Unique where
   toJSON = toJSON ∘ hashUnique
   toEncoding = toEncoding ∘ hashUnique
instance Show CounterState where
   show cs = (show ∘ hashUnique) (csIdentifier cs)
      <> " => " <> (show $ csCounters cs)
```

Difference between counters

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

            asNames = map getName as
            aPairs = zip asNames as

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

1.6.15   Cardano.BM.Data.LogItem

LoggerName

A LoggerName has currently type *Text*.

```
type LoggerName = Text
```

Logging of outcomes with LogObject

```
data LogObject a = LogObject
    {loName :: LoggerName
    ,loMeta  :: !LOMeta
    ,loContent :: (LOContent a)
    }
    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
    ,privacy :: !PrivacyAnnotation
```

```
      }
    deriving (Show)
  instance ToJSON LOMeta where
    toJSON (LOMeta _tstamp _tid _sev _priv) =
      object [ "tstamp" . = _tstamp
             , "tid"        . = show _tid
             , "severity" . = show _sev
             , "privacy"    . = show _priv
             ]
  mkLOMeta :: Severity → PrivacyAnnotation → IO LOMeta
  mkLOMeta sev priv =
    LOMeta < $ > getCurrentTime
      < * > (pack ∘ show < $ > myThreadId)
      < * > pure sev
      < * > pure priv
```

Payload of a LogObject:

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


  data PrivacyAnnotation =
    Confidential-- confidential information - handle with care
    | Public-- indifferent - can be public.
    deriving (Show, Generic, ToJSON, FromJSON)
```

Data structure for annotating the severity and privacy of an object.

```
  data PrivacyAndSeverityAnnotated a
    = PSA
      {psaSeverity :: !Severity
      , psaPrivacy :: !PrivacyAnnotation
      , psaPayload :: a
      }
      deriving (Show)
```

1.6.16   Cardano.BM.Data.Observable

ObservableInstance

```
  data ObservableInstance = MonotonicClock
    | MemoryStats
    | ProcessStats
    | NetStats
```

```
        | IOStats
        | GhcRtsStats
          deriving (Generic, Eq, Show, FromJSON, ToJSON, Read)
```

1.6.17 Cardano.BM.Data.Output

OutputKind

```
    data OutputKind a = TVarList (STM.TVar [LogObject a])
        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
```

1.6.18   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)
```

1.6.19   Cardano.BM.Data.Severity

Severity

The intended meaning of severity codes:

Debug *detailled information about values and decision flow* Info general information of events; progressing properly Notice *needs attention; something ¬ progressing properly* Warning may continue into an error condition if continued Error *unexpected set* **of** *event or condition occured* Critical error condition causing degrade of operation Alert *a subsystem is no longer operating correctly, likely requires man* 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
```

1.6.20 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)
```

1.6.21 Cardano.BM.Data.Trace

Trace

A Trace consists of a TraceContext and a Tracer *m* (LogObject *a*).

```
type Trace m a = (TraceContext, Tracer m (LogObject a))
```

TraceContext

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

```
data TraceContext = TraceContext
  {configuration :: Configuration
  }
```

1.6.22 Cardano.BM.Data.Tracer

This module extends the basic Tracer with one that keeps a list of

LogNamed

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

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


renderNamedItemTracing :: Show a ⇒ Tracer m String → Tracer m (LogNamed a)
renderNamedItemTracing = contramap $ λitem →
  unpack (lnName item) ++ ":  " ++ show (lnItem item)
```

```
renderNamedItemTracing' :: Show a ⇒ Tracer m String → Tracer m (LogObject a)
renderNamedItemTracing' = contramap $ λitem →
    unpack (loName item) ++ ": " ++ show (loContent item) ++ ", (meta): " ++ show (loMeta item)


named :: Tracer m (LogNamed a) → Tracer m a
named = contramap (LogNamed mempty)
```

Add a new name to the logging context

```
appendNamed :: LoggerName → Tracer m (LogNamed a) → Tracer m (LogNamed a)
appendNamed name = contramap $ (λ(LogNamed oldName item) →
    LogNamed (name <> "." <> oldName) item)
```

Add a new name to the logging context

```
appendNamed' :: LoggerName → Tracer m (LogObject a) → Tracer m (LogObject a)
appendNamed' name = contramap $ (λ(LogObject oldName meta item) →
    if oldName ≡ ""
    then LogObject name meta item
    else LogObject (name <> "." <> oldName) meta item)
```

The function *toLogObject* can be specialized for various environments

```
class Monad m ⇒ ToLogObject m where
    toLogObject :: Tracer m (LogObject a) → Tracer m a
instance ToLogObject IO where
    toLogObject :: Tracer IO (LogObject a) → Tracer IO a
    toLogObject tr = Tracer $ Op $ λa → do
        lo ← LogObject <$> pure ""
            <*> (mkLOMeta Debug Public)
            <*> pure (LogMessage a)
        tracingWith tr lo


To be placed in ouroboros − network ∘
instance (MonadFork m, MonadTimer m) ⇒ ToLogObject m where
    toLogObject (Tracer (Op tr) = Tracer $ Op $ λa → do
        lo ← LogObject <$> pure ""
            <*> (LOMeta <$> getMonotonicTime-- must be evaluated at the calling site
                <*> (pack ∘ show <$> myThreadId)
                <*> pure Debug
                <*> pure Public)
            <*> pure (LogMessage a)
        tr lo


tracingNamed :: Show a ⇒ Tracer IO (LogObject a) → Tracer IO a
tracingNamed = toLogObject
example2 :: IO ()
example2 = do
    let logTrace = appendNamed' "example2" (renderNamedItemTracing' stdoutTracer)
    void $ callFun2 logTrace
```

```
callFun2 :: Tracer IO (LogObject Text) → IO Int
callFun2 logTrace = do
    let logTrace' = appendNamed' "fun2" logTrace
    tracingWith (tracingNamed logTrace') "in function 2"
    callFun3 logTrace'

callFun3 :: Tracer IO (LogObject Text) → IO Int
callFun3 logTrace = do
    tracingWith (tracingNamed (appendNamed' "fun3" logTrace)) "in function 3"
    return 42
```

A Tracer transformer creating a LogObject from *PrivacyAndSeverityAnnotated*.

```
logObjectFromAnnotated :: Show a
    ⇒ Tracer IO (LogObject a)
    → Tracer IO (PrivacyAndSeverityAnnotated a)
logObjectFromAnnotated (Tracer (Op tr)) = Tracer $ Op $ λ(PSA sev priv a) → do
    lometa ← mkLOMeta sev priv
    tr $ LogObject "" lometa (LogMessage a)


example3 :: IO ()
example3 = do
    let logTrace =
        logObjectFromAnnotated $ appendNamed' "example3" $ renderNamedItemTracing' stdoutTracer
    tracingWith logTrace $ PSA Info Confidential ("Hello" :: String)
    tracingWith logTrace $ PSA Warning Public "World"


filterAppendNameTracing :: Monad m
        ⇒ m (LogNamed a → Bool)
        → LoggerName
        → Tracer m (LogNamed a)
        → Tracer m (LogNamed a)
filterAppendNameTracing test name = (appendNamed name) ∘ (condTracingM test)

example4 :: IO ()
example4 = do
    let appendF = filterAppendNameTracing oracle
        logTrace = appendF "example4" (renderNamedItemTracing stdoutTracer)
    tracingWith (named logTrace) ("Hello" :: String)

    let logTrace' = appendF "inner" logTrace
    tracingWith (named logTrace') "World"

    let logTrace'' = appendF "innest" logTrace'
    tracingWith (named logTrace'') "!!"
    where
        oracle :: Monad m ⇒ m (LogNamed a → Bool)
        oracle = return $ ((≢) "example4.inner.") ∘ lnName


-- severity anotated
example5 :: IO ()
example5 = do
    let logTrace =
```

```
        condTracingM oracle $
          logObjectFromAnnotated $
            appendNamed' "test5" $ renderNamedItemTracing' stdoutTracer
      tracingWith logTrace $ PSA Debug Confidential ("Hello" :: String)
      tracingWith logTrace $ PSA Warning Public "World"
    where
      oracle :: Monad m ⇒ m (PrivacyAndSeverityAnnotated a → Bool)
      oracle = return $ λ(PSA sev _priv _) → (sev > Debug)
-- test for combined name and severity
example6 :: IO ()
example6 = do
    let logTrace0 = -- the basis, will output using the local renderer to stdout
        appendNamed' "test6" $ renderNamedItemTracing' stdoutTracer
      logTrace1 = -- the trace from Privacy...Annotated to LogObject
        condTracingM oracleSev $ logObjectFromAnnotated $ logTrace0
      logTrace2 =
        appendNamed' "row" $ condTracingM oracleName $ logTrace0
      logTrace3 = -- oracle should eliminate messages from this trace
        appendNamed' "raw" $ condTracingM oracleName $ logTrace0
    tracingWith logTrace1 $ PSA Debug Confidential ("Hello" :: String)
    tracingWith logTrace1 $ PSA Warning Public "World"
    lometa ← mkLOMeta Info Public
    tracingWith logTrace2 $ LogObject "" lometa (LogMessage ", RoW!")
    tracingWith logTrace3 $ LogObject "" lometa (LogMessage ", RoW!")
  where
    oracleSev :: Monad m ⇒ m (PrivacyAndSeverityAnnotated a → Bool)
    oracleSev = return $ λ(PSA sev _priv _) → (sev > Debug)
    oracleName :: Monad m ⇒ m (LogObject a → Bool)
    oracleName = return $ λ(LogObject name _ _) → (name ≡ "row")-- we only see the names from
```

1.6.23   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
```

1.6.24   Cardano.BM.Configuration.Model

Configuration.Model

```
    type ConfigurationMVar = MVar ConfigurationInternal
    newtype Configuration = Configuration
      {getCG :: ConfigurationMVar}
    -- Our internal state; see -"Configuration model"-
```

Figure 1.5: 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.

$getBackends :: \text{Configuration} \rightarrow \text{LoggerName} \rightarrow IO\,[\text{BackendKind}]$
$getBackends\ \text{configuration}\ name = \textbf{do}$
   $cg \leftarrow readMVar\,\$\,getCG\ \text{configuration}$
   $\textbf{let}\ outs = HM.lookup\ name\ (cgMapBackend\ cg)$
   $\textbf{case}\ outs\ \textbf{of}$
     $Nothing \rightarrow return\ (cgDefBackendKs\ cg)$
     $Just\ os \rightarrow return\ os$

$getDefaultBackends :: \text{Configuration} \rightarrow IO\,[\text{BackendKind}]$
$getDefaultBackends\ \text{configuration} =$
   $cgDefBackendKs <\$> (readMVar\,\$\,getCG\ \text{configuration})$

$setDefaultBackends :: \text{Configuration} \rightarrow [\text{BackendKind}] \rightarrow IO\,()$
$setDefaultBackends\ \text{configuration}\ bes =$
   $modifyMVar\_\ (getCG\ \text{configuration})\,\$\,\lambda cg \rightarrow$
     $return\ cg\,\{cgDefBackendKs = bes\}$

$setBackends :: \text{Configuration} \rightarrow \text{LoggerName} \rightarrow Maybe\,[\text{BackendKind}] \rightarrow IO\,()$
$setBackends\ \text{configuration}\ name\ be =$
   $modifyMVar\_\ (getCG\ \text{configuration})\,\$\,\lambda cg \rightarrow$
     $return\ cg\,\{cgMapBackend = HM.alter\ (\backslash\_ \rightarrow be)\ name\ (cgMapBackend\ cg)\}$

Backends to be setup by the Switchboard

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

$setSetupBackends :: \text{Configuration} \rightarrow [\text{BackendKind}] \rightarrow IO\,()$
$setSetupBackends\ \text{configuration}\ bes =$
   $modifyMVar\_\ (getCG\ \text{configuration})\,\$\,\lambda cg \rightarrow$
     $return\ cg\,\{cgSetupBackends = bes\}$

$getSetupBackends :: \text{Configuration} \rightarrow IO\,[\text{BackendKind}]$
$getSetupBackends\ \text{configuration} =$
   $cgSetupBackends <\$> (readMVar\,\$\,getCG\ \text{configuration})$

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.

$getScribes :: \text{Configuration} \rightarrow \text{LoggerName} \rightarrow IO\,[\text{ScribeId}]$
$getScribes\ \text{configuration}\ name = \textbf{do}$
    $cg \leftarrow readMVar\ (getCG\ \text{configuration})$
    $(updateCache, scribes) \leftarrow \textbf{do}$

```
        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) $ λcg →
        return cg {cgMapScribe = HM.alter (\_ → scribes) name (cgMapScribe cg)}

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

setDefaultScribes :: Configuration → [ScribeId] → IO ()
setDefaultScribes configuration scs =
    modifyMVar_ (getCG configuration) $ λcg →
        return cg {cgDefScribes = scs}
```

Scribes to be setup in the Log backend

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

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

getSetupScribes :: Configuration → IO [ScribeDefinition]
getSetupScribes configuration =
    cgSetupScribes <$> readMVar (getCG configuration)
```

AggregatedKind to define the type of measurement

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

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

Access port numbers of EKG, GUI

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

setEKGport :: Configuration → Int → IO ()
setEKGport configuration port =
    modifyMVar_ (getCG configuration) $ λcg →
        return cg {cgPortEKG = port}

getGUIport :: Configuration → IO Int
getGUIport configuration =
    cgPortGUI < $ > (readMVar $ getCG configuration)

setGUIport :: Configuration → Int → IO ()
setGUIport configuration port =
    modifyMVar_ (getCG configuration) $ λcg →
        return cg {cgPortGUI = port}
```

Options

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

Global setting of minimum severity

$minSeverity :: Configuration \rightarrow IO\ Severity$
$minSeverity\ configuration =$
   $cgMinSeverity < \$ > (readMVar\ \$\ getCG\ configuration)$

$setMinSeverity :: Configuration \rightarrow Severity \rightarrow IO\ ()$
$setMinSeverity\ configuration\ sev =$
   $modifyMVar\_ (getCG\ configuration)\ \$\ \lambda cg \rightarrow$
     $return\ cg\ \{cgMinSeverity = sev\}$

Relation of context name to minimum severity

$inspectSeverity :: Configuration \rightarrow Text \rightarrow IO\ (Maybe\ Severity)$
$inspectSeverity\ configuration\ name = \mathbf{do}$
   $cg \leftarrow readMVar\ \$\ getCG\ configuration$
   $return\ \$\ HM.lookup\ name\ (cgMapSeverity\ cg)$

$setSeverity :: Configuration \rightarrow Text \rightarrow Maybe\ Severity \rightarrow IO\ ()$
$setSeverity\ configuration\ name\ sev =$
   $modifyMVar\_ (getCG\ configuration)\ \$\ \lambda cg \rightarrow$
     $return\ cg\ \{cgMapSeverity = HM.alter\ (\backslash\_ \rightarrow sev)\ name\ (cgMapSeverity\ cg)\}$

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.

$findSubTrace :: Configuration \rightarrow Text \rightarrow IO\ (Maybe\ SubTrace)$
$findSubTrace\ configuration\ name = \mathbf{do}$
   $cg \leftarrow readMVar\ \$\ getCG\ configuration$
   $return\ \$\ HM.lookup\ name\ (cgMapSubtrace\ cg)$

$setSubTrace :: Configuration \rightarrow Text \rightarrow Maybe\ SubTrace \rightarrow IO\ ()$
$setSubTrace\ configuration\ name\ trafo =$
   $modifyMVar\_ (getCG\ configuration)\ \$\ \lambda cg \rightarrow$
     $return\ cg\ \{cgMapSubtrace = HM.alter\ (\backslash\_ \rightarrow trafo)\ name\ (cgMapSubtrace\ cg)\}$

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 $ aVector.! 0
            as ← mkActions $ aVector.! 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
```

```haskell
      {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
      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)) $ Vec
        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
```

1.6.25 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
```

1.6.26   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
    when (port > 0) $ 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


data Cmd = Backends | Scribes | Severities | SubTrace | Aggregation
    deriving (Enum, Eq, Show, Read)
prepare :: Configuration → Window → UI ()
prepare config window = void $ do
    let commands = [Backends .. Aggregation]

    inputKey   ← UI.input #. "w3-input w3-border" # set UI.size "34"
    inputValue ← UI.input #. "w3-input w3-border" # set UI.size "60"
    outputMsg  ← UI.input #. "w3-input w3-border"

    currentCmd ← UI.p #. "current-cmd"

    let performActionOnId anId action =
          getElementById window anId ≫= λcase
              Nothing          → return ()
              Just anElement → action anElement
    let turn      anElement toState     = void $ element anElement # set UI.enabled toState
    let setValueOf anElement aValue = void $ element anElement # set UI.value aValue
    let setClasses classes anElement = void $ element anElement # set UI.class_   classes

    let setError m = setValueOf outputMsg ("ERROR:  " ++ m)
    let setMessage m = setValueOf outputMsg m

    let enable anElement = turn anElement True
    let disable anElement = turn anElement False
    let clean   anElement = setValueOf anElement ""
    let cleanAndDisable anElement = clean anElement ≫ disable anElement

    let rememberCurrent cmd = setValueOf currentCmd $ show cmd

    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 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'

        disable inputKey
        disable inputValue
        disable outputMsg

        let saveItemButtonId     = "save-item-button"
        let cancelSaveItemButtonId = "cancel-save-item-button"
        let addItemButtonId      = "add-item-button"
        let outputTableId        = "output-table"

        let saveItemButton       = performActionOnId saveItemButtonId
        let cancelSaveItemButton = performActionOnId cancelSaveItemButtonId

        let mkTableRow :: Show t ⇒ Cmd → LoggerName → t → UI Element
            mkTableRow cmd n v = UI.tr #. "itemrow" #+
              [ UI.td #+ [string (unpack n)]
              , UI.td #+ [string (show v)]
              , UI.td #+
                 [do
                    b ← UI.button #. "w3-small w3-btn w3-ripple w3-orange edit-item-button"
                                    #+ [UI.bold #+ [string "Edit"]]
                    on UI.click b $ const $ do
                      saveItemButton enable
                      cancelSaveItemButton enable
                      clean outputMsg
                      enable inputKey
                      enable inputValue
                      setValueOf inputKey (unpack n)
                      setValueOf inputValue (show v)
                      rememberCurrent cmd
                    return b
                 , UI.span # set html "   "
                 , do
                    b ← UI.button #. "w3-small w3-btn w3-ripple w3-red"
                                    #+ [UI.bold #+ [string "Delete"]]
                    on UI.click b $ const $ do
                      liftIO $ removeItem cmd n
```

```
            cleanAndDisable inputKey
            cleanAndDisable inputValue
            -- Initiate a click to current menu to update the items list after deleting
            performActionOnId (show cmd) $ runFunction ∘ ffi "$(%1).click()"
          return b
        ]
    ]
let showCurrentTab cmd = do
    let baseClasses = "w3-bar-item w3-button"
        classesForCurrentTab = baseClasses <> " " <> "w3-light-grey"
    performActionOnId (show cmd) $ setClasses classesForCurrentTab
    let otherTabs = delete cmd commands
    forM_ otherTabs $ λtabName →
        performActionOnId (show tabName) $ setClasses baseClasses
let showCorrespondingItems cmd sel = do
    showCurrentTab cmd
    rememberCurrent cmd
    saveItemButton disable
    cancelSaveItemButton disable
    performActionOnId addItemButtonId enable
    performActionOnId outputTableId $ λt → void $ element t # set children [ ]
    cg ← liftIO $ readMVar (CM.getCG config)
    performActionOnId outputTableId $
        λt → void $ element t #+
            [ UI.tr #+
              [ UI.th #+ [ string "LoggerName" ]
              , UI.th #+ [ string $ show cmd <> " value" ]
              , UI.th #+ [ string "" ]
              ]
            ]
    forM_ (HM.toList $ sel cg) $
        λ(n, v) → performActionOnId outputTableId $
            λt → void $ element t #+ [ mkTableRow cmd n v ]
let switchToTab c@Backends = showCorrespondingItems c CM.cgMapBackend
    switchToTab c@Severities  = showCorrespondingItems c CM.cgMapSeverity
    switchToTab c@Scribes     = showCorrespondingItems c CM.cgMapScribe
    switchToTab c@SubTrace   = showCorrespondingItems c CM.cgMapSubtrace
    switchToTab c@Aggregation = showCorrespondingItems c CM.cgMapAggregatedKind
let mkEditInputs =
    row [ element inputKey
        , UI.span #. "key-value-separator" #+ [ string ":" ]
        , element inputValue
        , UI.span #. "key-value-separator" #+ [ string "" ]
        , do
          b ← UI.button #. "w3-btn w3-ripple w3-green save-item-button"
            # set (UI.attr "id") addItemButtonId
            # set UI.enabled False
            #+ [ UI.bold #+ [ string "New" ] ]
          on UI.click b $ const $ do
            enable inputKey
```

```
                  enable inputValue
                  saveItemButton enable
                  cancelSaveItemButton enable
               return b
            , UI.span #. "key-value-separator" #+ [string ""]
            , do
               b ← UI.button #. "w3-btn w3-ripple w3-lime save-item-button"
                   # set (UI.attr "id") saveItemButtonId
                   # set UI.enabled False
                   #+ [UI.bold #+ [string "Save"]]
               on UI.click b $ const $ do
                  k ← inputKey # get UI.value
                  v ← inputValue # get UI.value
                  m ← currentCmd # get UI.value
                  case (readMay m :: Maybe Cmd) of
                     Nothing → setError "parse error on cmd"
                     Just c → do
                        cleanAndDisable inputKey
                        cleanAndDisable inputValue
                        saveItemButton disable
                        cancelSaveItemButton disable
                        setMessage $ "Setting ′" ++ k ++ "′ to ′" ++ v ++ "′ in " ++ m
                        updateItem c (pack k) v
                        switchToTab c
               return b
            , UI.span #. "key-value-separator" #+ [string ""]
            , do
               b ← UI.button #. "w3-btn w3-ripple w3-white"
                   # set (UI.attr "id") cancelSaveItemButtonId
                   # set UI.enabled False
                   #+ [UI.bold #+ [string "Cancel"]]
               on UI.click b $ const $ do
                  cleanAndDisable inputKey
                  cleanAndDisable inputValue
                  saveItemButton disable
                  cancelSaveItemButton disable
               return b
            ]
    let minimumSeveritySelection = do
        confMinSev ← liftIO $ minSeverity config
        let setMinSev _el Nothing = pure ()
            setMinSev _el (Just sev) = liftIO $
              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)
        on UI.selectionChange minsev $ setMinSev minsev

        row [string "Set minimum severity to:"
```

```
                    , UI.span # set html " "
                    , UI.span #. "severity-dropdown big" #+ [element minsev]
                    ]
        let commandTabs =
            row $ flip map commands $ λcmd → do
                b ← UI.button #. "w3-bar-item w3-button w3-grey"
                                # set (UI.attr "id") (show cmd)
                                #+ [UI.bold #+ [string (show cmd)]]
                    on UI.click b $ const $ do
                      cleanAndDisable inputKey
                      cleanAndDisable inputValue
                      clean outputMsg
                      switchToTab cmd
                      return b
    getElementById window "main-section" ≫ λcase
        Nothing → pure ()
        Just mainSection → void $ element mainSection #+
            [UI.div #. "w3-panel" #+
                [UI.div #. "w3-border w3-border-dark-grey" #+
                  [UI.div #. "w3-panel" #+ [minimumSeveritySelection]]
                , UI.div #. "w3-panel" #+ []
                , UI.div #. "w3-border w3-border-dark-grey" #+
                  [UI.div #. "w3-bar w3-grey" #+ [commandTabs]
                  , UI.div #. "w3-panel" #+ [mkEditInputs]
                  , UI.div #. "w3-panel" #+ [element outputMsg]
                  ]
                ]
            ]
```

1.6.27 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 a = MVar (SwitchboardInternal a)
newtype Switchboard a = Switchboard
  {getSB :: SwitchboardMVar a}
data SwitchboardInternal a = SwitchboardInternal
  {sbQueue :: TBQ.TBQueue (LogObject a)
  , 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 a → Tracer IO (LogObject a)
mainTrace sb = Tracer.Tracer $ Op $ effectuate sb
```

```
mainTraceConditionally :: TraceContext → Switchboard a → Tracer IO (LogObject a)
mainTraceConditionally ctx sb = Tracer.Tracer $ Op $ λitem@(LogObject loggername meta _) → do
    globminsev ← liftIO $ Config.minSeverity (configuration ctx)
    globnamesev ← liftIO $ Config.inspectSeverity (configuration ctx) loggername
    let minsev = max globminsev $ fromMaybe Debug globnamesev
    if (severity meta) ⩾ minsev
    then effectuate sb item
    else return ()
```

Process incoming messages

Incoming messages are put into the queue, and then processed by the dispatcher. The switchboard will never block when processing incoming messages ("eager receiver").
The queue is initialized and the message dispatcher launched.

```
instance IsEffectuator Switchboard a where
    effectuate switchboard item = do
        let writequeue :: TBQ.TBQueue (LogObject a) → LogObject a → 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
    -- TODO where to put this error message
    handleOverflow _ = TIO.hPutStrLn stderr "Error: Switchboard's queue full, dropping log item
```

```
instead of 'writequeue ...':
    evalMonitoringAction config item ⨾=
        mapM_ (writequeue (sbQueue sb))
evalMonitoringAction :: Configuration → LogObject a → m [LogObject a]
evalMonitoringAction c item = return [item]
    -- let action = LogObject  loName=(loName item) <> ".action", loContent=LogMessage .
    -- return (action :  item)
```

Switchboard implements Backend functions

Switchboard is an Declaration of a Backend

```
instance (Show a, ToJSON a) ⇒ IsBackend Switchboard a where
    typeof _ = SwitchboardBK

    realize cfg =
        let spawnDispatcher
                :: (Show a)
                ⇒ Configuration
                → [(BackendKind, Backend a)]
                → TBQ.TBQueue (LogObject a)
                → IO (Async.Async ())
            spawnDispatcher config backends queue = do
```

```
        now ← getCurrentTime
        let messageCounters = resetCounters now
        countersMVar ← newMVar messageCounters
        let traceInQueue q =
            Tracer.Tracer $ 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 {configuration = cfg
                }
        _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 (loName nli)
        let selBEs = befilter selectedBackends
        forM_ backends $ λ(bek, be) →
            when (bek ∈ selBEs) (bEffectuate be nli)

      qProc counters = do
        -- read complete queue at once and process items
        nlis ← atomically $ do
          r ← TBQ.flushTBQueue queue
          when (null r) retry
          return r
        let processItem nli@(LogObject loname lometa loitem) = do
          let losev = severity lometa

          -- evaluate minimum severity criteria
          locsev ← fromMaybe Debug < $ > Config.inspectSeverity cfg loname
          globsev ← Config.minSeverity config
          let sevGE = losev ⩾ globsev ∧ losev ⩾ locsev

          -- do not count again messages that contain the results of message counte
          when (loname ≢ "#messagecounters.switchboard") $
            -- increase the counter for the specific severity
            modifyMVar_ counters $
              λcnt → return $ updateMessageCounters cnt nli

          subtrace ← fromMaybe Neutral < $ > Config.findSubTrace (configuration ctx) loname
          case subtrace of
            TeeTrace secName →
              atomically $ TBQ.writeTBQueue queue $ nli {loName = secName}
            _ → return ()

          let doOutput = case subtrace of
                FilterTrace filters →
                  case loitem of
                    LogValue name _ →
                        evalFilters filters (loname <> "." <> name)
                    _ →
```

```
                              evalFilters filters loname
                  DropOpening → case loitem of
                     ObserveOpen _ → False
                      _ → True
                  NoTrace  → False
                  _             → True
              case loitem of
                KillPill → do
                  forM_ backends (λ(_, be) → bUnrealize be)
                  return False
# ifdef ENABLE_AGGREGATION
                (AggregatedMessage _) → do
                  when (sevGE ∧ doOutput) $
                    sendMessage nli (filter (≢ AggregationBK))
                  return True
# endif
# ifdef ENABLE_MONITORING
                (MonitoringEffect inner) → do
                  when (sevGE ∧ doOutput) $
                    sendMessage (inner {loName = loname}) (filter (≢ MonitoringBK))
                  return True
# endif
                _ → do
                  when (sevGE ∧ doOutput) $
                    sendMessage nli id
                  return True
          res ← mapM processItem nlis
          when (and res) $ qProc counters
      Async.async $ qProc countersMVar
    in do
    q ← atomically $ TBQ.newTBQueue 2048
    sbref ← newEmptyMVar
    let sb :: Switchboard a = 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 some → IO ()
      clearMVar = void ∘ tryTakeMVar

    (dispatcher, queue) ← withMVar (getSB switchboard) (λsb → return (sbDispatch sb, sbQueue sb))
    -- send terminating item to the queue
    lo ← LogObject < $ > pure "kill.switchboard"
            < ∗ > (mkLOMeta Warning Confidential)
            < ∗ > pure KillPill
```

```
     atomically $ TBQ.writeTBQueue queue 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 :: (Show a, ToJSON a)
          ⇒ [BackendKind]
          → Configuration
          → Switchboard a
          → [(BackendKind, Backend a)]
          → IO [(BackendKind, Backend a)]
setupBackends [ ] _ _ acc = return acc
setupBackends (bk : bes) c sb acc = do
   be' ← setupBackend' bk c sb
   setupBackends bes c sb ((bk, be') : acc)
setupBackend' :: (Show a, ToJSON a) ⇒ BackendKind → Configuration → Switchboard a → IO (Backend a
setupBackend' SwitchboardBK _ _ = error "cannot instantiate a further Switchboard"
# ifdef ENABLE_MONITORING
setupBackend' MonitoringBK c sb = do
   let ctx = TraceContext {configuration = c
           }
      trace = mainTraceConditionally ctx sb

   be :: Cardano.BM.Output ∘ Monitoring.Monitor a ← Cardano.BM.Output ∘ Monitoring.realizefrom (ctx, tra
   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 _ _ =
   TIO.hPutStrLn stderr "disabled! will not setup backend 'Monitoring'"
# endif
# ifdef ENABLE_EKG
setupBackend' EKGViewBK c sb = do
   let ctx = TraceContext {configuration = c
           }
      trace = mainTraceConditionally ctx sb

   be :: Cardano.BM.Output ∘ EKGView.EKGView a ← Cardano.BM.Output ∘ EKGView.realizefrom (ctx, tra
   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 _ _ =
   TIO.hPutStrLn stderr "disabled! will not setup backend 'EKGView'"
# endif
```

```
# ifdef ENABLE_AGGREGATION
setupBackend' AggregationBK c sb = do
  let ctx = TraceContext {configuration = c
            }
     trace = mainTraceConditionally ctx sb
  be :: Cardano.BM.Output ∘ Aggregation.Aggregation a ← Cardano.BM.Output ∘ Aggregation.realizefrom
  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 _ _ =
  TIO.hPutStrLn stderr "disabled! will not setup backend 'Aggregation'"
# endif
setupBackend' KatipBK c _ = do
  be :: Cardano.BM.Output ∘ Log.Log a ← Cardano.BM.Output ∘ Log.realize c
  return MkBackend
    {bEffectuate = Cardano.BM.Output ∘ Log.effectuate be
    ,bUnrealize = Cardano.BM.Output ∘ Log.unrealize be
    }
```

1.6.28   Cardano.BM.Output.Log

Internal representation

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

Log implements *effectuate*

```
instance (ToJSON a, Show a) ⇒ IsEffectuator Log a where
  effectuate katip item = do
      let logMVar = getK katip
      c ← configuration < $ > readMVar logMVar
      setupScribes ← getSetupScribes c
      selscribes ← getScribes c (loName item)
      let selscribesFiltered =
          case item of
            LogObject _ (LOMeta _ _ _ Confidential) (LogMessage _)
                → removePublicScribes setupScribes selscribes
            _ → selscribes
      forM_ selscribesFiltered $ λsc → passN sc katip item
      -- increase the counter for the specific severity and message type
```

```haskell
        modifyMVar_ logMVar $ λli → return $
          li {msgCounters = updateMessageCounters (msgCounters li) 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 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
                < $ > pure "#messagecounters.katip"
                < * > (mkLOMeta sev Confidential)
                < * > pure (LogValue (pack key) (PureI $ toInteger count))
            intervalObject ←
              LogObject
                < $ > pure "#messagecounters.katip"
                < * > (mkLOMeta sev Confidential)
                < * > pure (LogValue "time_interval_(s)" (PureI diffTime))
            let namedCounters = countersObjects ++ [intervalObject]
            forM_ scribes $ λsc →
              forM_ namedCounters $ λnamedCounter →
                passN sc katip namedCounter
            modifyMVar_ logMVar $ λli → return $
              li {msgCounters = resetCounters now}
      handleOverflow _ = TIO.hPutStrLn stderr "Notice: Katip's queue full, dropping log items!"
```

Log implements backend functions

```haskell
    instance (ToJSON a, Show a) ⇒ IsBackend Log a 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
  meta ← mkLOMeta Info Public
  passN (pack (show StdoutSK)) k $ LogObject
    {loName = "test"
    ,loMeta = meta
    ,loContent = LogMessage "Hello!"
    }
  meta' ← mkLOMeta Info Public
  passN (pack (show StdoutSK)) k $ LogObject
```

```
{loName = "test"
,loMeta = meta'
,loContent = LogValue "cpu-no" 1
}
```

Needed instances for *katip*:

deriving instance *ToJSON a* ⇒ *K.ToObject* (**LogObject** *a*)
deriving instance *K.ToObject Text*
deriving instance *ToJSON a* ⇒ *K.ToObject* (*Maybe* (**LOContent** *a*))

instance *ToJSON a* ⇒ *KC.LogItem* (**LogObject** *a*) **where**
    payloadKeys _ _ = *KC.AllKeys*
instance *KC.LogItem Text* **where**
    payloadKeys _ _ = *KC.AllKeys*
instance *ToJSON a* ⇒ *KC.LogItem* (*Maybe* (**LOContent** *a*)) **where**
    payloadKeys _ _ = *KC.AllKeys*

Log.passN

The following function copies the **LogObject** 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 :: (ToJSON a, Show a) ⇒ ScribeId → Log a → LogObject a → IO ()
passN backend katip (LogObject loname lometa loitem) = 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 (sev, msg, payload) = case loitem of
                (LogMessage logItem) →
                   (severity lometa, pack $ show 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)
                          (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 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 [loname])
                           , _itemLoc      = Nothing
                           }
                        void $ atomically $ KC.tryWriteTBQueue shChan (KC.NewItem itemKatip)
                     else return ()
```

Scribes

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

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

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

mkFileScribeH
    :: Handle
```

```haskell
  → (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 = 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
```

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


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

1.6.29 Cardano.BM.Output.EKGView

Structure of EKGView

```
type EKGViewMVar a = MVar (EKGViewInternal a)
newtype EKGView a = EKGView
  {getEV :: EKGViewMVar a}
data EKGViewInternal a = EKGViewInternal
  {evQueue :: TBQ.TBQueue (Maybe (LogObject a))
  ,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 :: Show a ⇒ EKGView a → Configuration → IO (Trace IO a)
ekgTrace ekg c = do
    let trace = ekgTrace' ekg
        ctx = TraceContext {configuration = c
             }
    Trace.appendName "#ekgview" (ctx, trace)
  where
    ekgTrace' :: Show a ⇒ EKGView a → Tracer IO (LogObject a)
    ekgTrace' ekgview = Tracer $ Op $ λlo@(LogObject loname _ _) → do
      let setlabel :: Text → Text → EKGViewInternal a → IO (Maybe (EKGViewInternal a))
          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 :: Show a ⇒ LogObject a → EKGViewInternal a → IO (Maybe (EKGViewInternal a))
          update (LogObject logname _ (LogMessage logitem)) ekg_i =
            setlabel logname (pack $ show logitem) ekg_i
          update (LogObject logname _ (LogValue iname value)) 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." loname of
        Nothing → loname
        Just ln' → ln'
    logname = case stripPrefix "#ekgview." lognam1 of
        Nothing → lognam1
        Just ln' → ln'
  upd ← update lo {loName = 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 LogObject 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 a 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 item of
      (LogObject logname lometa (AggregatedMessage ags)) → liftIO $ do
        let traceAgg :: [(Text, Aggregated)] → IO ()
            traceAgg [] = return ()
            traceAgg ((n, AggregatedEWMA ewma) : r) = do
              enqueue $ LogObject (logname <> "." <> n) lometa (LogValue "avg" $ avg ewma)
              traceAgg r
            traceAgg ((n, AggregatedStats stats) : r) = do
              let statsname = logname <> "." <> n
                  qbasestats s' nm = do
                    enqueue $ LogObject nm lometa (LogValue "mean" (PureD $ meanOfStats s'))
                    enqueue $ LogObject nm lometa (LogValue "min" $ fmin s')
                    enqueue $ LogObject nm lometa (LogValue "max" $ fmax s')
                    enqueue $ LogObject nm lometa (LogValue "count" $ PureI $ fromIntegral $ fcount s')
                    enqueue $ LogObject nm lometa (LogValue "stdev" (PureD $ stdevOfStats s'))
              enqueue $ LogObject statsname 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 _ = TIO.hPutStrLn stderr "Notice: EKGViews's queue full, dropping log items"
```

EKGView implements Backend functions

EKGView is an IsBackend

```
instance Show a ⇒ IsBackend EKGView a 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 :: (Show a)
            ⇒ TBQ.TBQueue (Maybe (LogObject a))
            → Trace.Trace IO a
            → Trace.Trace IO a
            → 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 obj@(LogObject logname meta content) → do
          trace' ← Trace.appendName logname trace
          Trace.traceNamedObject trace' (meta, content)
          -- increase the counter for the type of message
          modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt obj
          qProc counters
        Nothing → return () -- stop here
```

Interactive testing EKGView

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

1.6.30 Cardano.BM.Output.Aggregation

Internal representation

```
type AggregationMVar a = MVar (AggregationInternal a)
newtype Aggregation a = Aggregation
  { getAg :: AggregationMVar a }
data AggregationInternal a = AggregationInternal
  { agQueue :: TBQ.TBQueue (Maybe (LogObject a))
  , 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 a where
  effectuate agg item = do
    ag ← readMVar (getAg agg)
    nocapacity ← atomically $ TBQ.isFullTBQueue (agQueue ag)
    if nocapacity
    then handleOverflow agg
    else atomically $ TBQ.writeTBQueue (agQueue ag) $! Just item

  handleOverflow _ = TIO.hPutStrLn stderr "Notice: Aggregation's queue full, dropping log ite
```

Aggregation implements Backend functions

Aggregation is an IsBackend

```
instance Show a ⇒ IsBackend Aggregation a where
  typeof _ = AggregationBK
  realize _ = error "Aggregation cannot be instantiated by 'realize'"
  realizefrom trace@(ctx, _) _ = do
    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 :: (Show a)
              ⇒ Configuration
              → AggregationMap
              → TBQ.TBQueue (Maybe (LogObject a))
              → Trace.Trace IO a
              → IO (Async.Async ())
spawnDispatcher conf aggMap aggregationQueue trace0 = do
    now ← getCurrentTime
    trace ← Trace.appendName "#aggregation" trace0
    let messageCounters = resetCounters now
    countersMVar ← newMVar messageCounters
    _timer ← Async.async $ sendAndResetAfter
        trace0
        "#messagecounters.aggregation"
        countersMVar
        60000 -- 60000 ms = 1 min
        Warning-- Debug

    Async.async $ qProc trace countersMVar aggMap
  where
    qProc trace counters aggregatedMap = do
        maybeItem ← atomically $ TBQ.readTBQueue aggregationQueue
        case maybeItem of
          Just (lo@(LogObject logname lm _)) → do
            (updatedMap, aggregations) ← update lo aggregatedMap
            unless (null aggregations) $
                sendAggregated trace (LogObject logname lm (AggregatedMessage aggregations))
            -- increase the counter for the specific severity and message type
            modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt lo
            qProc trace 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 a
        → AggregationMap
        → IO (AggregationMap, [(Text, Aggregated)])
    update (LogObject logname lme (LogValue iname value)) 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 logname lme (ObserveDiff counterState)) agmap =
      updateCounters (csCounters counterState) lme (logname, "diff") agmap []
  update (LogObject logname lme (ObserveOpen counterState)) agmap =
      updateCounters (csCounters counterState) lme (logname, "open") agmap []
  update (LogObject logname lme (ObserveClose counterState)) agmap =
      updateCounters (csCounters counterState) lme (logname, "close") agmap []

  update (LogObject logname lme (LogMessage _)) 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 :: Trace.Trace IO a → LogObject a → IO ()
sendAggregated trace (LogObject logname meta v@(AggregatedMessage _)) = do
    -- enter the aggregated message into the Trace
    trace' ← Trace.appendName logname trace
    liftIO $ Trace.traceNamedObject trace' (meta, v)
-- 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_`

```
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"
```

1.6.31   Cardano.BM.Output.Monitoring

Structure of Monitoring

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

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 LogObject for monitoring.

```
     instance IsEffectuator Monitor a 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 _ = TIO.hPutStrLn stderr "Notice: Monitor's queue full, dropping log items!"
```

Monitor implements Backend functions

Monitor is an IsBackend

```
     instance Show a ⇒ IsBackend Monitor a 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 :: (Show a)
                 ⇒ TBQ.TBQueue (Maybe (LogObject a))
                 → Configuration
                 → Trace.Trace IO a
                 → 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 (logvalue@(LogObject _ _ _)) → do
            state' ← evalMonitoringAction state 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 → LogObject a → IO MonitorMap
    evalMonitoringAction mmap logObj@(LogObject logname _ _) =
      case HM.lookup logname mmap of
        Nothing → return mmap
        Just mon@(MonitorState expr acts env0) → do
          let env' = updateEnv env0 logObj
          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 en
            return $ HM.insert logname mon {_environment = env''} mmap
          else return mmap
    where
      utc2ns (UTCTime days secs) =
        let yearsecs :: Rational
            yearsecs = 365 * 24 * 3600
            rdays, rsecs :: Rational
            rdays = toRational $ toModifiedJulianDay days
            rsecs = toRational secs
            s2ns = 1000000000
        in
```

```
        Nanoseconds $ round $ (fromRational $ s2ns * rsecs + rdays * yearsecs :: Double)
updateEnv env (LogObject _ _ (ObserveOpen _)) = env
updateEnv env (LogObject _ _ (ObserveDiff _)) = env
updateEnv env (LogObject _ _ (ObserveClose _)) = env
updateEnv env (LogObject _ lometa (LogValue vn val)) =
    let addenv = HM.fromList [(vn, val)
        ,("timestamp", utc2ns (tstamp lometa))
        ]
    in
    HM.union addenv env
updateEnv env (LogObject _ lometa (LogMessage _logitem)) =
    let addenv = HM.fromList [("severity", (Severity (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 ev
    aggs2measurables ((n, AggregatedStats s) : r) acc = aggs2measurables r $
      (n <> ".mean", PureD ∘ meanOfStats $ fbasic s)
      :(n <> ".flast", flast s)
      :(n <> ".fcount", PureI ∘ fromIntegral ∘ fcount $ fbasic s)
      : acc
-- catch all
updateEnv env _ = env
```

Chapter 2

Testing

2.1 Test coverage

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

```
cabal new-test
```

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

2.2 Test main entry point

```haskell
{-# 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

tests :: TestTree
tests =
  testGroup "iohk-monitoring"
  [
```

Cardano.BM.Counters.Dummy	100%
Cardano.BM.Setup	100%
Cardano.BM.Data.Trace	100%
Cardano.BM.Configuration.Static	100%
Cardano.BM.Configuration	100%
Cardano.BM.Configuration.Model	94%
Cardano.BM.Data.MessageCounter	85%
Cardano.BM.Data.Configuration	83%
Cardano.BM.Data.MonitoringEval	81%
Cardano.BM.BaseTrace	80%
Cardano.BM.Observer.Monadic	75%
Cardano.BM.Output.Switchboard	75%
Cardano.BM.Output.Aggregation	68%
Cardano.BM.Output.Log	68%
Cardano.BM.Trace	63%
Cardano.BM.Data.Aggregated	63%
Cardano.BM.Rotator	50%
Cardano.BM.Data.BackendKind	50%
Cardano.BM.Data.Backend	50%
Cardano.BM.Counters.Common	50%
Cardano.BM.Data.Output	48%
Cardano.BM.Data.Severity	47%
Cardano.BM.Data.LogItem	41%
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%
Cardano.BM.Output.EKGView	0%
Cardano.BM.Data.Counter	0%
Cardano.BM.Counters	0%
Paths_iohk_monitoring	0%
	54%

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

```
#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* gener-
ate arbitrary instances of `Aggregated`. For this an arbitrary list of *Integer* is
generated and this list is aggregated into a structure of `Aggregated`.

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

```
    mkDeltaStats
    mkTimedStats)
```

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

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

2.4 Tests

2.4.1 Testing aggregation

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

Property tests

prop_Aggregation_minimal :: *Bool*
prop_Aggregation_minimal = *True*

lometa :: `LOMeta`
lometa = *unsafePerformIO* $ *mkLOMeta* `Debug Public`

prop_Aggregation_comm :: *Integer* → *Integer* → `Aggregated` → *Property*
prop_Aggregation_comm v1 v2 ag =
   let *AggregatedStats stats1* = `updateAggregation` (*PureI v1*) (`updateAggregation` (*PureI v2*) *ag lometa N*
     AggregatedStats stats2 = `updateAggregation` (*PureI v2*) (`updateAggregation` (*PureI v1*) *ag lometa No*
   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
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) (B
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) (BaseS
unitAggregationInitialPlus1Minus1 :: *Assertion*
unitAggregationInitialPlus1Minus1 = **do**
   let *AggregatedStats stats1* = `updateAggregation` (*PureI* (−1)) (`updateAggregation` (*PureI* 1) *firstState*
   (*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 Public
        stats1 ← pure $ updateAggregation (Bytes 5000) stats0 t1 Nothing
        -- putStrLn (show stats1)
        -- showTimedMean stats1
        threadDelay 50000-- 0.05 s
        t2 ← mkLOMeta Debug Public
        stats2 ← pure $ updateAggregation (Bytes 1000) stats1 t2 Nothing
        -- putStrLn (show stats2)
        -- showTimedMean stats2
        checkTimedMean stats2
        threadDelay 50000-- 0.05 s
        t3 ← mkLOMeta Debug Public
        stats3 ← pure $ updateAggregation (Bytes 3000) stats2 t3 Nothing
        -- putStrLn (show stats3)
        -- showTimedMean stats3
        checkTimedMean stats3
        threadDelay 50000-- 0.05 s
        t4 ← mkLOMeta Debug Public
        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


    firstStateAggregatedStats :: Aggregated
    firstStateAggregatedStats = AggregatedStats (Stats z z (BaseStats z z 1 0 0) (BaseStats z z 0 0 0) (BaseStats z z
      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"` `unitAppendName`
    , *testCase* `"create 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" unitLoggingPriva
            ]
        where
            observablesSet = [MonotonicClock, MemoryStats]
            notObserveOpen :: [LogObject a] → Bool
            notObserveOpen = all (λcase {LogObject _ _ (ObserveOpen _) → False; _ → True})
            notObserveClose :: [LogObject a] → Bool
            notObserveClose = all (λcase {LogObject _ _ (ObserveClose _) → False; _ → True})
            notObserveDiff :: [LogObject a] → Bool
            notObserveDiff = all (λcase {LogObject _ _ (ObserveDiff _) → False; _ → True})
            onlyLevelOneMessage :: [LogObject Text] → Bool
            onlyLevelOneMessage = λcase
                [LogObject _ _ (LogMessage "Message from level 1.")] → True
                _ → False
            observeNoMeasures :: [LogObject a] → Bool
            observeNoMeasures obs = notObserveOpen obs ∧ notObserveClose obs ∧ notObserveDiff obs
```

Helper routines

```
    data TraceConfiguration = TraceConfiguration
        {tcOutputKind :: OutputKind Text
        ,tcName       :: LoggerName
        ,tcSubTrace   :: SubTrace
        }
    setupTrace :: TraceConfiguration → IO (Trace IO Text)
    setupTrace (TraceConfiguration outk name subTr) = do
        c ← liftIO $ Cardano.BM.Configuration ∘ Model.empty
        ctx ← liftIO $ newContext c
        let logTrace0 = case outk of
            TVarList tvar → TracerT.natTrace liftIO $ traceInTVarIOConditionally tvar ctx

        setSubTrace (configuration ctx) name (Just subTr)
        let logTrace' = (ctx, logTrace0)
        appendName name logTrace'

    setTransformer_ :: Trace IO Text → LoggerName → Maybe SubTrace → IO ()
    setTransformer_ (ctx, _) name subtr = do
        let c = configuration ctx
        setSubTrace c name subtr
```

Simple demo of logging.

```
    simpleDemo :: IO String
    simpleDemo = do
        cfg ← defaultConfigTesting
        logTrace :: Trace IO String ← Setup.setupTrace (Right cfg) "test"
        putStrLn "\n"
```

```
logDebug     logTrace "This is how a Debug message looks like."
logInfo      logTrace "This is how an Info message looks like."
logNotice    logTrace "This is how a Notice message looks like."
logWarning   logTrace "This is how a Warning message looks like."
logError     logTrace "This is how an Error message looks like."
logCritical  logTrace "This is how a Critical message looks like."
logAlert     logTrace "This is how an Alert message looks like."
logEmergency logTrace "This is how an Emergency message looks like."
```
return ""

Example of using named contexts with Trace

exampleWithNamedContexts :: *IO String*
exampleWithNamedContexts = **do**
    cfg ← *defaultConfigTesting*
    Setup.`withTrace` *cfg* "test" $ *λ*(*logTrace* :: `Trace` *IO Text*) → **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 Text* → *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]))
      True
    assertBool
      ("NoTrace consumed more time than ObservableTrace" ++ (show [t_notrace, t_observable]))
      True
    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 "test.inner" (Just NoTrace)

  trace1 ← appendName "inner" trace0
  logInfo trace1 "This should NOT have been displayed!"

  setTransformer_ trace1 "test.inner.innermost" (Just Neutral)
  trace2 ← appendName "innermost" trace1
  logInfo trace2 "This should NOT have been displayed also due to the trace one level ab

  -- acquire the traced objects
  res ← STM.readTVarIO msgs

  -- only the first message should have been traced
  assertBool
    ("Found more or less messages than expected: " ++ show res)
    (length res ≡ 1)
```

Change a trace's minimum severity

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

```
unitTraceMinSeverity :: Assertion
unitTraceMinSeverity = do
  msgs ← STM.newTVarIO [ ]
  trace@(ctx, _) ← setupTrace $ TraceConfiguration (TVarList msgs) "test min severity" Neutral
  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 "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 "test-duplicate.dup"
      trace ← appendName "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) "test-named-severity.sev-change" (Just Warning)
      msev ← Cardano.BM.Configuration.inspectSeverity (configuration ctx) "test-named-severity.sev
      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) "test-named-severity.sev-change" (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 "Message #2") → False
            _ → True)
          res)


unitHierarchy' :: [SubTrace] → ([LogObject Text] → 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 "test.inner" (Just t2)
  trace2 ← appendName "inner" trace1
  logInfo trace2 "Message from level 2."

  -- subsubtrace of type 3
  setTransformer_ trace2 "test.inner.innermost" (Just t3)
#ifdef ENABLE_OBSERVABLES
  _ ← STMObserver.bracketObserveIO trace2 Debug "test.inner.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 (TVarList msgs) "test" Neutral
    trace0 ← appendName "work0" trace
    trace1 ← appendName "work1" trace
    work0 ← work trace0
    threadDelay 5000
    work1 ← work trace1
```

```haskell
        Async.wait $ work0
        Async.wait $ work1
        res ← STM.readTVarIO msgs
        let names@(_ : namesTail) = map loName 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 Text → IO (Async.Async ())
      work trace = Async.async $ do
        logInfoDelay trace "1"
        logInfoDelay trace "2"
        logInfoDelay trace "3"
      logInfoDelay :: Trace IO Text → Text → IO ()
      logInfoDelay trace msg =
        logInfo trace msg ≫
        threadDelay 10000
```

Stress testing parallel logging

```haskell
stressTraceInFork :: Assertion
stressTraceInFork = do
    msgs ← STM.newTVarIO [ ]
    trace ← setupTrace $ TraceConfiguration (TVarList 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 loName 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 Text → IO (Async.Async ())
    work trace = Async.async $ forM_ [1 .. totalMessages] $ (logInfo trace) ∘ pack ∘ show
    totalMessages :: Int
    totalMessages = 10
```

Dropping ObserveOpen messages in a subtrace

```haskell
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, cur-
rently the limit is set to 80.

```
unitAppendName :: Assertion
unitAppendName = do
    msgs ← STM.newTVarIO [ ]
    trace0 ← setupTrace $ TraceConfiguration (TVarList msgs) "test" Neutral
    trace1 ← appendName bigName trace0
    trace2 ← appendName bigName trace1
    forM_ [trace0, trace1, trace2] $ (flip logInfo msg)
    res ← reverse < $ > STM.readTVarIO msgs
    let loggernames = map loName res
    assertBool
      ("AppendName did not work properly. The loggernames for the messages are: " ++
        show loggernames)
      (loggernames ≡ ["test"
        , "test." <> bigName
        , "test." <> bigName <> "." <> bigName
        ])
  where
    bigName = T.replicate 30 "abcdefghijklmnopqrstuvwxyz"
    msg = "Hello!"


# 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
    (*False* ≡ **evalFilters** *filter2 contextName*)
let *filter3* = [(*Drop* (*StartsWith* "test."), *Unhide* [ ])]
assertBool ("Dropping a name starting with a specific text should filter out the contex
    (*False* ≡ **evalFilters** *filter3 contextName*)
let *filter4* = [(*Drop* (*Contains* ".sub."), *Unhide* [ ])]
assertBool ("Dropping a name starting containing a specific text should filter out the
    (*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 pa
    (*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
    (*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 ← appendName "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
      ("Confidential file should contain 2 lines and it contains " ⧺ show countPrivate ⧺ "
         "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. In-
fer that *EKGViewBK* needs to be started as a backend.

> *unitConfigurationCheckEKGpositive* :: *Assertion*
> *unitConfigurationCheckEKGpositive* = **do**
> *# ifndef ENABLE_EKG*
>   *return* ()
> *#* **else**
>   *tmp* ← *getTemporaryDirectory*
>   **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
  tmp ← getTemporaryDirectory
  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 < (`
               ,*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 t`
                ,*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.Sec
                        ,["AlterMinSeverity \"chain.creation\" Debug"]
                        )
                          )
```

```
                                ,("#aggregation.critproc.observable",(Compare "mean" ((⩾),(Agg.PureI 4
                                  ,["CreateMessage \"exceeded\" \"the observable has been too long
                                  ,"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"` $
```

$$defAggregatedKind \equiv \text{EwmaAK } 0.01$$
$$assertBool \text{ "Specific name aggregated kind"} \$$$
$$name1AggregatedKind \equiv \text{StatsAK}$$
$$assertBool \text{ "Set EKG port"} \$$$
$$ekgPort \equiv 11223$$
$$assertBool \text{ "Set GUI port"} \$$$
$$guiPort \equiv 1080$$

## 2.4.5 Rotator

```
tests :: TestTree
tests = testGroup "testing Trace" [
  property_tests
  ]
property_tests :: TestTree
property_tests = testGroup "Property tests" [
  testProperty "rotator: file naming" propNaming
# ifdef POSIX
  , testProperty "rotator: cleanup" $ propCleanup $ rot n
# endif
  ]
# ifdef POSIX
  where
    n = 5
    rot num = RotationParameters
      { rpLogLimitBytes = 10000000 -- 10 MB
      , rpMaxAgeHours  = 24
      , rpKeepFilesNum = num
      }
# endif
```

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

```
propNaming :: FilePath → Property
propNaming 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.

```
# ifdef POSIX
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
          ]
      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 _ = [ ]
data NumFiles = NF Int deriving (Show)
instance Arbitrary NumFiles where
    arbitrary = QC.oneof [return (NF 0), return (NF 1), return (NF 5), return (NF 7)]
propCleanup :: RotationParameters → LocalFilePath → NumFiles → SmallAndLargeInt → Property
propCleanup rotationParams (Dir filename) (NF nFiles) (SL maxDev) = QC.withMaxSuccess 20 $ ioProperty
    tmpDir0 ← getTemporaryDirectory
    let tmpDir = tmpDir0 </> "rotatorTest.base"
    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
    removeDirectoryRecursive tmpDir
    return $ kept === toBeKept
# endif
```

Index