Cardano.BM - logging, benchmarking and monitoring

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Abstract

This framework combines logging, benchmarking and monitoring. Complex evaluations of STM or monadic actions can be observed from outside while reading operating system counters before and after, and calculating their differences, thus relating resource usage to such actions.

Through interactive configuration, the runtime behaviour of logging or the measurement of resource usage can be altered.

Further reduction in logging can be achieved by redirecting log messages to an aggregation function which will output the running statistics with less frequency than the original message.

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Chapter 1

Logging, benchmarking and monitoring

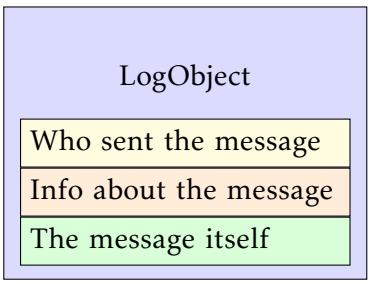
1.1 Main concepts

The main concepts of the framework:

1. LogObject - captures the observable information
2. Trace - transforms and delivers the observables
3. Backend - receives and outputs observables
4. Configuration - defines behaviour of traces, routing of observables

1.1.1 LogObject

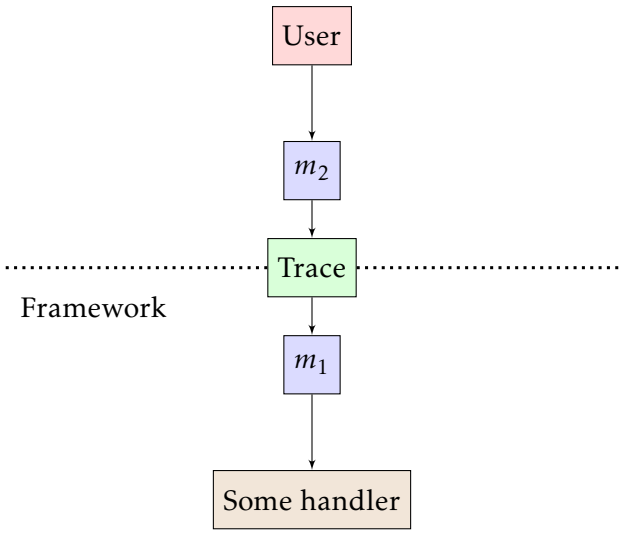
LogObject represents an observation to be logged or otherwise further processed. It is annotated with a logger name, meta information (timestamp and severity level), and some particular message:



Please see Cardano.BM.Data.LogItem for more details.

1.1.2 Trace

You can think of Trace as a pipeline for messages. It is a *consumer* of messages from a user's point of view, but a *source* of messages from the framework's point of view. A user traces an observable to a Trace, which ends in the framework that further processes the message.

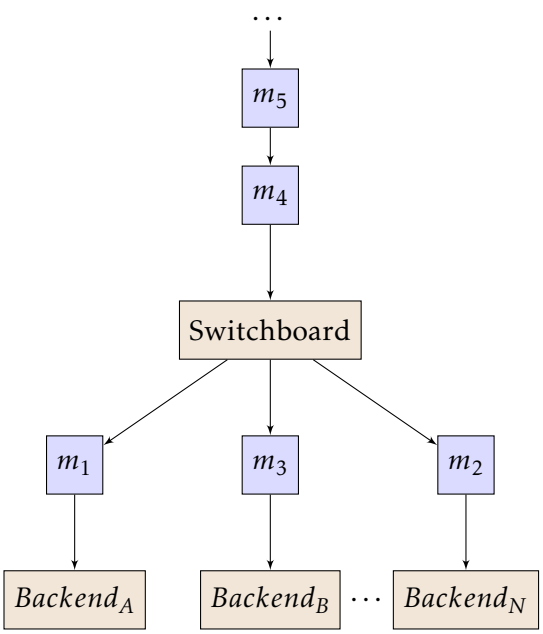


Please see the section 1.4.1 for more details about the ideas behind Trace.

1.1.3 Backend

A Backend must implement functions to process incoming messages of type LogObject. It is an instance of IsEffectuator. Moreover, a backend is also life-cycle managed. The class IsBackend ensures that every backend implements the *realize* and *unrealize* functions.

The central backend in the framework is the Switchboard. It sets up all the other backends and redirects incoming messages to these backends according to configuration:



1.1.4 Configuration

Configuration defines how the message flow in the framework is routed and the behaviour of distinct Traces. It can be parsed from a file in YAML format, or it can explicitly be defined in code.

Please note that Configuration can be changed at runtime using the interactive editor (see *Cardano.BM.*Configuration.Editor for more details).

1.2 Overview

Figure 1.1 displays the relationships among modules in *Cardano.BM*.

1.2.1 Backends

As was mentioned above, the central backend is the Switchboard that redirects incoming log messages to selected backends according to Configuration.

The backend EKGView displays runtime counters and user-defined values in a browser.

The Log backend makes use of the katip package to output log items to files or the console. The format can be chosen to be textual or JSON representation.

The Aggregation backend computes simple statistics over incoming log items (e.g. last, min, max, mean) (see Cardano.BM.Data.Aggregated). Alternatively, Aggregation can also estimate the average of the values passed in using *EWMA*, the exponentially weighted moving average. This works for numerical values, that is if the content of a LogObject is a LogValue.

The backend LogBuffer keeps the latest message per context name and shows these collected messages in the GUI (Editor), or outputs them to the switchboard.

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, *scribe* in *katip* parlance.

Items that are aggregated lead to the creation of an output of their current statistics. To prevent a potential infinite loop these aggregated statistics cannot be routed again back into Aggregation.

1.2.2 Trace

Log items are created in the application's context and passed in via a hierarchy of Traces. Such a hierarchy of named traces can be built with the function appendName. 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:

1. NoTrace which suppresses all log items,
2. SetSeverity which sets a specific severity to all log items,
3. FilterTrace which filters the log items passing through it,
4. ObservableTrace which allows capturing of operating system counters.

(further behaviour types are implemented in Cardano.BM.Data.SubTrace)

1.2.3 Monitoring

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.

1.2.4 IMPORTANT!

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.

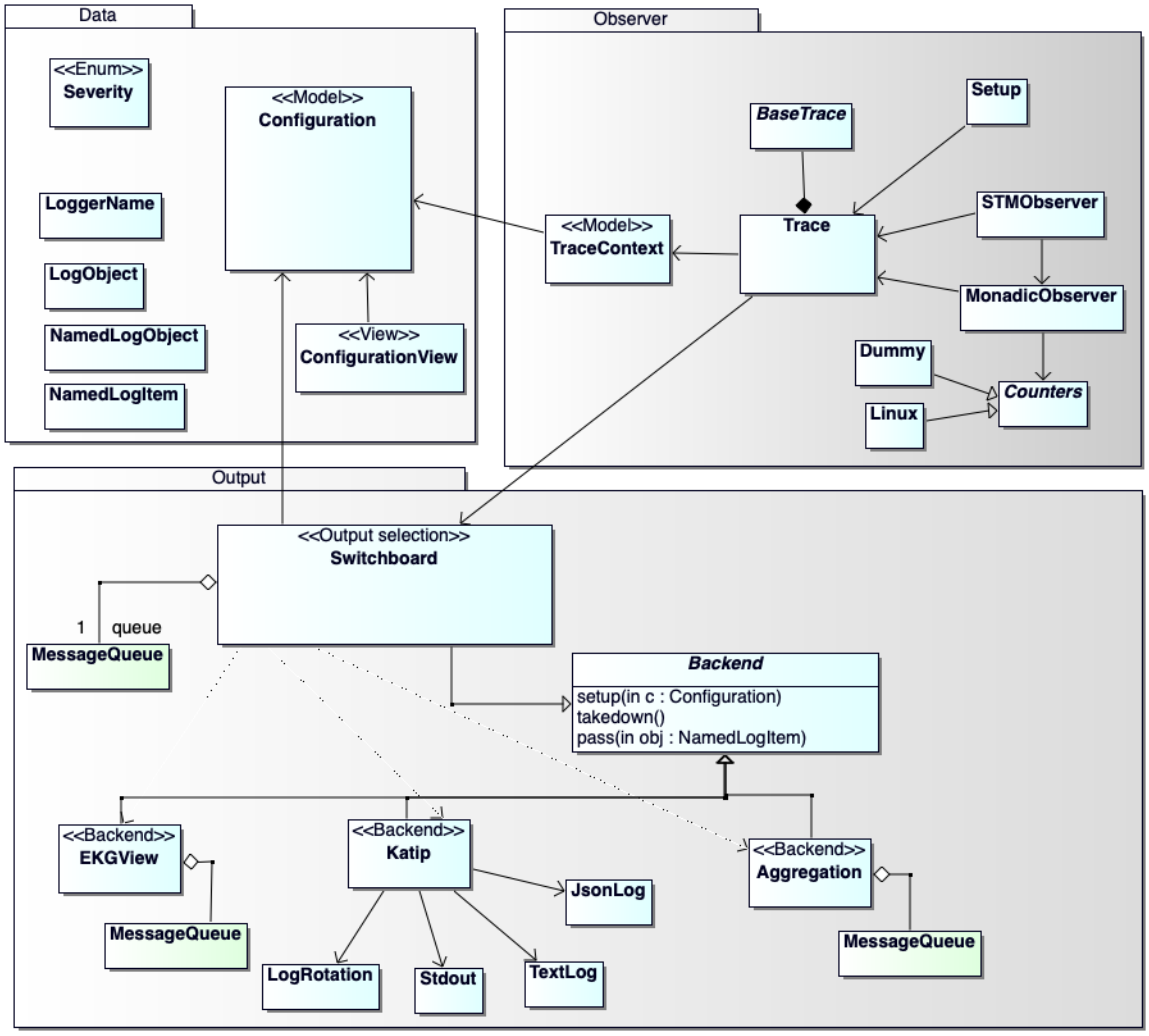


Figure 1.1: Overview of module relationships. The arrows indicate import of a module. The arrows with a triangle at one end would signify "inheritance" in object-oriented programming, but we use it to show that one module replaces the other in the namespace, thus specializes its interface.

1.3 Requirements

1.3.1 Observables

We can observe the passage of the flow of execution through particular points in the code (really the points at which the graph is reduced). Typically observables would be part of an outcome (which has a start and an end). Where the environment permits these outcomes could also gather additional environmental context (e.g read system counters, 'know' the time). The proposed framework would be able to aggregate, filter such outcome measures so as to calculation things (where appropriate) such as:

- min/max/mean/variance of the resource costs of achieving an outcome
- elapsed wall-clock time

- CPU cycles
- memory allocations, etc
- exponentially weighted moving average of outcomes, events
- min/max/mean/variance of inter-arrival times of demand for service (the arrival pattern)
- measuring offered load against the system (e.g rate/distribution of requests against the wallet by an exchange, transactions being forwarded between nodes)

STM evaluation

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

Function evaluation

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

QuickCheck properties *tentatively*

The function

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

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

1.3.2 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.

1.3.3 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

1.3.4 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*?

1.3.5 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.

1.3.6 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`)

1.4 Description

1.4.1 Contravariant Functors Explanation

Tracer's implementations is based on a contravariant package.

Please see the presentation in `docs/pres-20190409/contravariant-idea` to understand the core idea of the contravariant functor.

1.4.2 Logging with Trace

Setup procedure

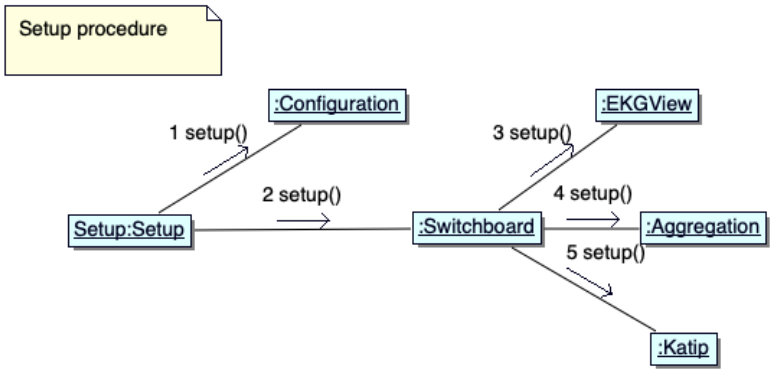


Figure 1.2: Setup procedure

Hierarchy of Traces

1.4.3 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.

1.4.4 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)

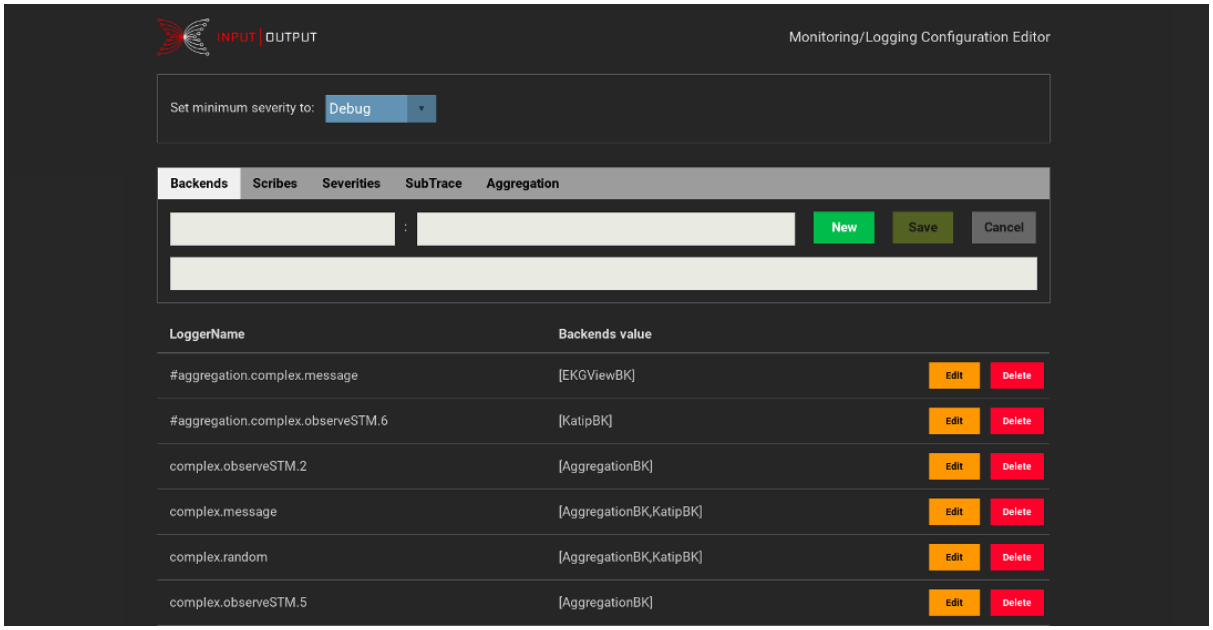


Figure 1.3: The configuration editor is listening on *localhost* and can be accessed through a browser. At the top is the setting for the global minimum severity filter, that drops all messages that have a severity lower than this setting. Below are the settings for various behaviours of the logging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

1.4.5 Information reduction in Aggregation

Statistics

Configuration

1.4.6 Output selection

Configuration

1.4.7 Monitoring

Configuration

Evaluation of monitors

Actions fired

1.5 Examples

1.5.1 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 ()
```

1.5.2 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
#undef RUN_ProcBufferDump
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

import Cardano.BM.Configuration (Configuration)
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`.

```
prepare_configuration :: IO CM.Configuration
prepare_configuration = do
  c ← CM.empty
  CM.setMinSeverity c Debug
  CM.setSetupBackends c [KatipBK
#ifdef ENABLE_AGGREGATION
      ,AggregationBK
#endif
#ifdef ENABLE_EKG
      ,EKGViewBK
#endif
#ifdef ENABLE_GUI
      ,EditorBK
#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"])
    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 "#messagecounters.switchboard" $ Just NoTrace
    CM.setSubTrace c "#messagecounters.katip" $ Just NoTrace
    CM.setSubTrace c "complex.random" (Just $ TeeTrace "ewma")
    CM.setSubTrace c "#ekgview"
      (Just $ FilterTrace [(Drop (StartsWith "#ekgview.#aggregation.complex.random"),
          Unhide [(EndsWith ".count"),
            (EndsWith ".avg"),
            (EndsWith ".mean")]),
        (Drop (StartsWith "#ekgview.#aggregation.complex.observeIO"),
          Unhide [(Contains "diff.RTS.cpuNs.timed.")]),
        (Drop (StartsWith "#ekgview.#aggregation.complex.observeSTM"),
          Unhide [(Contains "diff.RTS.gcNum.timed.")]),
        (Drop (StartsWith "#ekgview.#aggregation.complex.message"),
          Unhide [(Contains ".timed.m")])
        ])
    CM.setSubTrace c "#messagecounters.ekgview" $ Just NoTrace
# 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, KatipBK])
  CM.setBackends c "complex.observeIO" (Just [AggregationBK])
  CM.setSubTrace c "#messagecounters.aggregation" $ Just NoTrace
#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_GUI
  CM.setBackends c "#aggregation.complex.random" (Just [EditorBK])
  CM.setBackends c "#aggregation.complex.random.ewma" (Just [EditorBK])
  CM.setBackends c "#messagecounters.switchboard" (Just [EditorBK, KatipBK])
#endif
#ifdef ENABLE_EKG
  CM.setSubTrace c "#messagecounters.monitoring" $ Just NoTrace
  CM.setBackends c "#aggregation.complex.message" (Just [EKGViewBK])
  CM.setBackends c "#aggregation.complex.observeIO" (Just [EKGViewBK])
  CM.setEKGport c 12789
#endif
#ifdef ENABLE_GUI
  CM.setGUIport c 13789
#endif
  return c
```

Dump the log buffer periodically

```
dumpBuffer :: Switchboard Text → Trace IO Text → IO (Async.Async ())
dumpBuffer sb trace = do
  logInfo trace "starting buffer dump"
  proc ← Async.async (loop trace)
  return proc
  where
```

```
    loop tr = do
      threadDelay 25000000-- 25 seconds
      buf ← readLogBuffer sb
      forM_ buf $ λ(logname, LogObject _ lometa locontent) → do
        tr' ← modifyName (λn → "#buffer." <> n <> logname) tr
        traceNamedObject tr' (lometa, locontent)
      loop tr
```

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 :: Configuration → Trace IO Text → IO (Async.Async ())
observeIO config trace = do
  logInfo trace "starting observer"
  proc ← Async.async (loop trace)
  return proc
  where
    loop tr = do
      threadDelay 5000000-- 5 seconds
      _ ← bracketObserveIO config 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 :: Configuration → Trace IO Text → IO [Async.Async ()]
observeSTM config 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 config 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 :: Configuration → Trace IO Text → IO (Async.Async ())
observeDownload config trace = do
  proc ← Async.async (loop trace)
  return proc
  where
    loop tr = do
      threadDelay 1000000-- 1 second
      tr' ← appendName "observeDownload" tr
      bracketObserveIO config 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 ← prepare_configuration
  -- create initial top-level Trace
  (tr :: Trace IO Text, _sb) ← setupTrace_ 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_ProcBufferDump
  procDump ← dumpBuffer sb tr
#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 c tr
#endif
#endif
#ifdef RUN_ProcObseverSTM
  -- start threads endlessly observing STM actions operating on the same TVar
#ifdef ENABLE_OBSERVABLES
  procObsvSTMs ← observeSTM c 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 c 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
# ifdef RUN_ProcBufferDump
  _ ← Async.waitCatch procDump
# endif
  return ()
```

1.6 Code listings - contra-tracer package

1.6.1 Examples

Tracing using the contravariant Tracer naturally reads:

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

1.6.2 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 a = Tracer {runTracer :: a → m ()}
```

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 t) = Tracer (t ∘ f)
```

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.

In principle a Tracer is an instance of *Semigroup* and *Monoid*, by sequential composition of the tracing actions.

```
instance Applicative m ⇒ Semigroup (Tracer m s) where
  Tracer a1 <> Tracer a2 = Tracer $ λs → a1 s *> a2 s
instance Applicative m ⇒ Monoid (Tracer m s) where
  mappend = (<>)
  mempty = nullTracer
```

nullTracer

The simplest tracer - one that suppresses all output.

```
nullTracer :: Applicative m ⇒ Tracer m a
nullTracer = Tracer $ \_ → pure ()
```

traceWith

```
traceWith :: Tracer m a → a → m ()
traceWith = runTracer
```

1.6.3 Transformers

Applying *show* on a Tracer's messages

The Tracer transformer exploiting Show.

```
showTracing :: (Show a) ⇒ Tracer m String → 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) ⇒ (a → Bool) → Tracer m a → Tracer m a
condTracing active tr = Tracer $ λs →
  when (active s) (traceWith 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) ⇒ m (a → Bool) → Tracer m a → Tracer m a
condTracingM activeP tr = Tracer $ λs → do
  active ← activeP
  when (active s) (traceWith tr s)
```

natTrace

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

```
natTracer :: (forall x ∘ m x → n x) → Tracer m s → Tracer n s
natTracer nat (Tracer tr) = Tracer (nat ∘ tr)
```

1.6.4 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 $ 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 Debug.Trace.traceM
```

1.7 Code listings - iohk-monitoring package

1.7.1 Cardano.BM.Observer.STM

```
stmWithLog :: STM.STM (t, [(LOMeta, LOContent a)]) → 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 :: Config.Configuration → Trace IO a → Severity → Text → STM.STM t → IO t
bracketObserveIO config trace severity name action = do
    trace' ← appendName name trace
    subTrace ← fromMaybe Neutral <$> Config.findSubTrace config name
    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 bracketObserveIO.

```
bracketObserveLogIO :: Config.Configuration → Trace IO a → Severity → Text → STM.STM (t, [(LOMeta
bracketObserveLogIO config trace severity name action = do
    trace' ← appendName name trace
    subTrace ← fromMaybe Neutral <$> Config.findSubTrace config 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
```

1.7.2 Cardano.BM.Observer.Monadic

Monadic.bracketObserverIO

Observes an *IO* action and adds a name to the logger name of the passed in Trace. The subtrace type is found in the configuration with the passed-in name.

Microbenchmarking steps:

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

```
import qualified Cardano.BM.Configuration.Model as CM
ooo
c ← config
trace ← 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
    config
    "submit-tx"
    (Just $ ObservableTrace observablesSet)
  where
    observablesSet = [MonotonicClock, MemoryStats]
```

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

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

and use bracketObserveIO. e.g.:

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

```
bracketObserveIO :: Config.Configuration → Trace IO a → Severity → Text → IO t → IO t
bracketObserveIO config trace severity name action = do
    trace' ← appendName name trace
    subTrace ← fromMaybe Neutral <$> Config.findSubTrace config 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.

```
bracketObserveM :: (MonadCatch m, MonadIO m) ⇒ Config.Configuration → Trace m a → Severity → Text
bracketObserveM config trace severity name action = do
    trace' ← appendName name trace
    subTrace ← liftIO $ fromMaybe Neutral <$> Config.findSubTrace config name
    bracketObserveM' subTrace severity trace' action
  where
    bracketObserveM' :: (MonadCatch m, MonadIO m) ⇒ SubTrace → Severity → Trace m a → m t → m t
    bracketObserveM' NoTrace _ _ act = act
    bracketObserveM' 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) → 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 ← observeClose subtrace sev logTrace countersid []
          case res of
            Left ex → liftIO (TIO.hPutStrLn stderr ("ObserveClose: " <> pack (show ex)))
            _ → pure ()
      pure t
```

Monadic.bracketObserver

Observes a *MonadIO m* ⇒ *m* action and adds a name to the logger name of the passed in Trace.
This observer bracket does not interfere on exceptions.

```
bracketObserveX :: (MonadIO m) ⇒ Config.Configuration → Trace m a → Severity → Text → m t → m t
bracketObserveX config trace severity name action = do
    subTrace ← liftIO $ fromMaybe Neutral < $ > Config.findSubTrace config name
    trace' ← appendName name trace
    bracketObserveX' subTrace severity trace' action
  where
    bracketObserveX' :: (MonadIO m) ⇒ SubTrace → Severity → Trace m a → m t → m t
    bracketObserveX' NoTrace _ _ act = act
    bracketObserveX' subtrace sev logTrace act = do
      countersid ← observeOpen0 subtrace sev logTrace
      -- run action
      t ← act
      observeClose0 subtrace sev logTrace countersid [ ]
      pure t
```

observerOpen

```
observeOpen :: (MonadCatch m, MonadIO m) ⇒ SubTrace → Severity → Trace m a → m (Either SomeExcept
observeOpen subtrace severity logTrace = (do
  state ← observeOpen0 subtrace severity logTrace
  return (Right state)) `catch` (return ∘ Left)
observeOpen0 :: (MonadIO m) ⇒ SubTrace → Severity → Trace m a → m CounterState
observeOpen0 subtrace severity logTrace = do
  identifier ← liftIO newUnique
  -- take measurement
  counters ← liftIO $ readCounters subtrace
  let state = CounterState identifier counters
  if counters ≡ [ ]
  then return ()
  else do
    -- send opening message to Trace
    meta ← mkLOMeta severity Confidential
    traceNamedObject logTrace (meta, ObserveOpen state)
  return state
```

observeClose

```
observeClose
  :: (MonadCatch m, MonadIO m) ⇒ SubTrace → Severity → Trace m a
  → CounterState → [(LOMeta, LOContent a)]
  → m (Either SomeException ())
observeClose subtrace sev logTrace initState logObjects = (do
  observeClose0 subtrace sev logTrace initState logObjects
  return (Right ())) `catch` (return ∘ Left)
```

```
observeClose0 :: (MonadIO m) ⇒ SubTrace → Severity → Trace m a
  → CounterState → [(LOMeta, LOContent a)]
  → m ()
observeClose0 subtrace sev logTrace initState logObjects = do
  let identifier = csIdentifier initState
      initialCounters = csCounters initState
  -- take measurement
  counters ← liftIO $ 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 ()
```

1.7.3 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 basetrace = natTracer nat basetrace
```

Enter new named context

A new context name is added.

```
appendName :: MonadIO m ⇒ LoggerName → Trace m a → m (Trace m a)
appendName name =
  modifyName (λprevLoggerName → 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 overwritten.

```
modifyName :: MonadIO m ⇒ (LoggerName → LoggerName) → Trace m a → m (Trace m a)
modifyName f basetrace = return $ modifyNameBase f 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 =
  traceWith (named logTrace) lo
```

Concrete Trace on stdout

This function returns a trace with an action of type "LogObject $a \rightarrow IO\ ()$" 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 $ 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 $ λa → STM.modifyTVar tvar ((:) a)

traceInTVarIO :: STM.TVar [a] → Tracer IO a
traceInTVarIO tvar = Tracer $ λa →
  STM.atomically $ STM.modifyTVar tvar ((:) a)
```

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 logTrace p s m =
  traceNamedObject logTrace =≪
    (,) <$> liftIO (mkLOMeta s p)
        <*> pure (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
```

1.7.4 Cardano.BM.Setup

setupTrace

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

```
setupTrace :: (MonadIO m, ToObject a) ⇒ Either FilePath Config.Configuration → Text → m (Trace m a)
setupTrace (Left cfgFile) name = do
  c ← liftIO $ Config.setup cfgFile
  fst <$> setupTrace_ c name
```

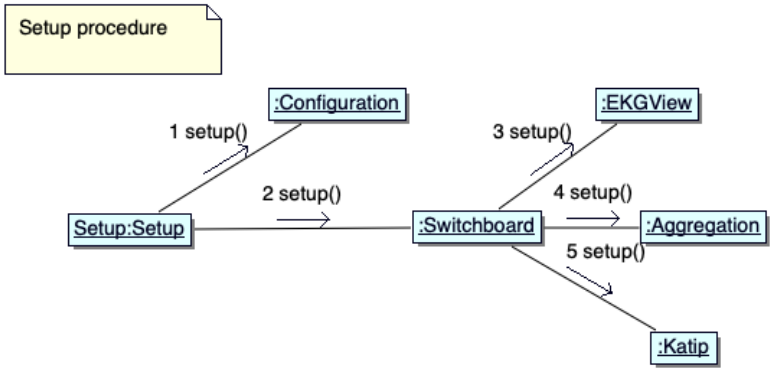


Figure 1.4: Setup procedure

```
setupTrace (Right c) name = fst <$> setupTrace_ c name
setupTrace_ :: (MonadIO m, ToObject a) ⇒ Config.Configuration → Text → m (Trace m a, Switchboard.Switc
setupTrace_ c name = do
  sb ← liftIO $ Switchboard.realize c
  tr ← appendName name $ natTrace liftIO (Switchboard.mainTraceConditionally c sb)
  return (tr, sb)
```

shutdown

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

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

1.7.5 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
```

1.7.6 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)
```

1.7.7 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
```

1.7.8 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 []
readCounters (SetSeverity _) = 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 (setpriority(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 priority).

(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 → IO [Counter]
readProcStats pid = do
    ps0 ← readProcList (pathProcStat pid)
    let ps = zip colnames ps0
      psUseful = filter (("unused" ≢) ∘ fst) ps
    return $ map (λ(n,i) → Counter StatInfo n (PureI i)) psUseful
```

```
      where
        colnames :: [Text]
        colnames = ["pid","unused","unused","ppid","pgrp","session","ttynr","tpgid","flags","mi
          ,"cminflt","majflt","cmajflt","utime","stime","cutime","cstime","priority","nice","n
          ,"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 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 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
```

1.7.9 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 v@(Microseconds a) = show a ++ showUnits v
  show v@(Nanoseconds a) = show a ++ showUnits v
  show v@(Seconds a)     = show a ++ showUnits v
  show v@(Bytes a)       = show a ++ showUnits v
  show v@(PureI a)       = show a ++ showUnits v
  show v@(PureD a)       = show a ++ showUnits v
  show v@(Severity a)    = show a ++ showUnits v
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
```

1.7.10 Cardano.BM.Data.AggregatedKind

AggregatedKind

This identifies the type of Aggregated.

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

1.7.11 Cardano.BM.Data.Backend

Accepts a 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) ⇒ Configuration → Trace IO a → s a → IO (t a)
  default realizefrom :: forall s ∘ (IsEffectuator s a) ⇒ Configuration → Trace IO a → s a → IO (t a)
  realizefrom cfg _ _ = realize cfg
  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 ()
  }
```

1.7.12 Cardano.BM.Data.BackendKind

BackendKind

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

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

1.7.13 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
```

1.7.14 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
  | 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 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}
```

1.7.15 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 :: MonadIO m => Severity -> PrivacyAnnotation -> m LOMeta
mkLOMeta sev priv =
  LOMeta <$> (liftIO getCurrentTime)
    <*> (pack . show <$> (liftIO 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)
  | Command CommandValue
  | KillPill
    deriving (Generic, Show, ToJSON)
```

Backends can enter commands to the trace. Commands will end up in the Switchboard, which will interpret them and take action.

```
data CommandValue = DumpBufferedTo BackendKind
  deriving (Generic, Show, ToJSON)
```

Privacy annotation

```
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)
```

1.7.16 Cardano.BM.Data.Observable

ObservableInstance

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

1.7.17 Cardano.BM.Data.Output

ScribeKind

This identifies katip's scribes by type.

```
data ScribeKind = FileTextSK
  | FileJsonSK
  | StdoutSK
  | StderrSK
  | DevNullSK
  deriving (Generic, Eq, Ord, Show, Read, 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
```

1.7.18 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)
```

1.7.19 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 ma* 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
```

1.7.20 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]
  | SetSeverity Severity
    deriving (Generic, Show, Read, Eq)
instance FromJSON SubTrace where
  parseJSON = withObject "" $ λo → do
                  subtrace :: Text ← o .: "subtrace"
                  case subtrace of
                    "Neutral"       → return $ Neutral
                    "UntimedTrace"  → return $ UntimedTrace
                    "NoTrace"       → return $ NoTrace
                    "TeeTrace"      → TeeTrace    <$> o .: "contents"
                    "FilterTrace"   → FilterTrace <$> o .: "contents"
                    "DropOpening"   → return $ DropOpening
                    "ObservableTrace" → ObservableTrace <$> o .: "contents"
                    "SetSeverity"   → SetSeverity <$> o .: "contents"
                    _               → error "cannot parse such an expression!"
instance ToJSON SubTrace where
  toJSON Neutral          = object ["subtrace" .= String "Neutral"      ]
  toJSON UntimedTrace     = object ["subtrace" .= String "UntimedTrace" ]
  toJSON NoTrace          = object ["subtrace" .= String "NoTrace"      ]
  toJSON (TeeTrace name) = object ["subtrace" .= String "TeeTrace"     ,"contents" .= toJSON name
  toJSON (FilterTrace dus) = object ["subtrace" .= String "FilterTrace" ,"contents" .= toJSON dus]
  toJSON DropOpening      = object ["subtrace" .= String "DropOpening" ]
  toJSON (ObservableTrace os) = object ["subtrace" .= String "ObservableTrace","contents" .= toJSO
  toJSON (SetSeverity sev) = object ["subtrace" .= String "SetSeverity" ,"contents" .= toJSON sev]
```

1.7.21 Cardano.BM.Data.Trace

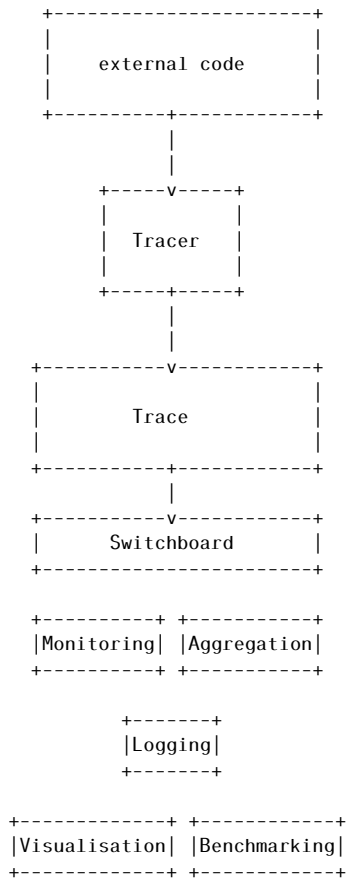
Trace

A Trace *m a* is a Tracer *m* (LogObject *a*).

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

1.7.22 Cardano.BM.Data.Tracer

This module extends the basic Tracer with one that keeps a list of context names to create the basis for Trace which accepts messages from a Tracer and ends in the Switchboard for further processing of the messages.



ToLogObject - transforms a logged item to LogObject

The function toLogObject can be specialized for various environments

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

```
To be placed in ouroboros – network ∘
instance (MonadFork m, MonadTimer m) ⇒ ToLogObject m where
  toLogObject tr = Tracer $ λa → do
```

```
    lo ← LogObject <$> pure ""
      <*> (LOMeta <$> getMonotonicTime-- must be evaluated at the calling site
        <*> (pack ∘ show <$> myThreadId)
        <*> pure Debug
        <*> pure Public)
      <*> pure (LogMessage a)
    traceWith tr lo
```

ToObject - transforms a logged item to JSON

Katip requires JSON objects to be logged as context. This typeclass provides a default instance which uses *ToJSON* and produces an empty object if 'toJSON' results in any type other than *Object*. If you have a type you want to log that produces an Array or Number for example, you'll want to write an explicit instance here. You can trivially add a *ToObject* instance for something with a ToJSON instance like:

```
instance ToObject Foo


class ToJSON a ⇒ ToObject a where
  toObject :: a → Object
  default toObject :: a → Object
  toObject v = case toJSON v of
    Object o → o
    s@(String _) → HM.singleton "string" s
    _ → mempty
instance ToObject () where
  toObject _ = mempty
instance ToObject String
instance ToObject Text
instance ToJSON a ⇒ ToObject (LogObject a)
instance ToJSON a ⇒ ToObject (LOContent a)
```

1.7.23 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
```

Test severities

Test severity of the given LOMeta to be greater or equal to those of the specific LoggerName.

```
testSeverity :: CM.Configuration → LoggerName → LOMeta → IO Bool
testSeverity config loggername meta = do
  globminsev ← CM.minSeverity config
```

```
  globnamesev ← CM.inspectSeverity config loggername
  let minsev = max globminsev $ fromMaybe Debug globnamesev
  return $ (severity meta) ⩾ minsev
```

1.7.24 Cardano.BM.Configuration.Model

Configuration.Model

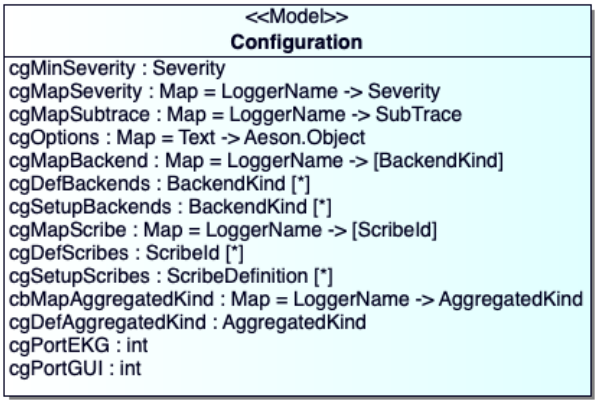


Figure 1.5: Configuration model

```
type ConfigurationMVar = MVar ConfigurationInternal
newtype Configuration = Configuration
  {getCG :: ConfigurationMVar}
-- Our internal state; see -"Configuration model"-
data ConfigurationInternal = ConfigurationInternal
  {cgMinSeverity      :: Severity
  -- minimum severity level of every object that will be output
  ,cgDefRotation      :: Maybe RotationParameters
  -- default rotation parameters
  ,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
  } deriving (Show, Eq)
```

Backends configured in the Switchboard

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

```
getBackends :: Configuration → LoggerName → IO [BackendKind]
getBackends configuration name = do
  cg ← readMVar $ getCG configuration
  let outs = HM.lookup name (cgMapBackend cg)
  case outs of
    Nothing → return (cgDefBackendKs cg)
    Just os → return os

getDefaultBackends :: Configuration → IO [BackendKind]
getDefaultBackends configuration =
  cgDefBackendKs <$> (readMVar $ getCG configuration)

setDefaultBackends :: Configuration → [BackendKind] → IO ()
setDefaultBackends configuration bes =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgDefBackendKs = bes}

setBackends :: Configuration → LoggerName → Maybe [BackendKind] → IO ()
setBackends configuration name be =
  modifyMVar_ (getCG configuration) $ λcg →
    return cg {cgMapBackend = HM.alter (\_ → be) name (cgMapBackend cg)}
```

Backends to be setup by the Switchboard

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

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

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

Scribes configured in the Log backend

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

```
getScribes :: Configuration → LoggerName → IO [ScribeId]
getScribes configuration name = do
    cg ← readMVar (getCG configuration)
    (updateCache, scribes) ← do
      let defs = cgDefScribes cg
      let mapscribes = cgMapScribe cg
      let find_s lname = case HM.lookup lname mapscribes of
        Nothing →
          case dropToDot lname of
            Nothing → defs
            Just lname' → find_s lname'
        Just os → os
      let outs = HM.lookup name (cgMapScribeCache cg)
      -- look if scribes are already cached
      return $ case outs of
        -- if no cached scribes found; search the appropriate scribes that
        -- they must inherit and update the cached map
        Nothing → (True, find_s name)
        Just os → (False, os)
    when updateCache $ setCachedScribes configuration name $ Just scribes
    return scribes
dropToDot :: Text → Maybe Text
dropToDot ts = dropToDot' (T.breakOnEnd "." ts)
  where
    dropToDot' (_, "") = Nothing
    dropToDot' (name', _) = Just $ T.dropWhileEnd (≡ '.') name'
getCachedScribes :: Configuration → LoggerName → IO (Maybe [ScribeId])
getCachedScribes configuration name = do
    cg ← readMVar $ getCG configuration
    return $ HM.lookup name $ cgMapScribeCache cg
setScribes :: Configuration → LoggerName → Maybe [ScribeId] → IO ()
setScribes configuration name scribes =
    modifyMVar_ (getCG configuration) $ λcg →
      return cg {cgMapScribe = HM.alter (\_ → scribes) name (cgMapScribe cg)}
setCachedScribes :: Configuration → LoggerName → Maybe [ScribeId] → IO ()
setCachedScribes configuration name scribes =
    modifyMVar_ (getCG configuration) $ λcg →
      return cg {cgMapScribeCache = HM.alter (\_ → scribes) name (cgMapScribeCache cg)}
setDefaultScribes :: Configuration → [ScribeId] → IO ()
setDefaultScribes configuration scs =
```

```
    modifyMVar_ (getCG configuration) $ λcg →
      return cg {cgDefScribes = scs}
```

Scribes to be setup in the Log backend

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

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

AggregatedKind to define the type of measurement

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

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

Access port numbers of EKG, GUI

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

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

Options

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

Global setting of minimum severity

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

Relation of context name to minimum severity

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

Relation of context name to SubTrace

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

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

Monitors

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

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

Parse configuration from file

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

```
setup :: FilePath → IO Configuration
setup fp = do
    r ← R.parseRepresentation fp
    setupFromRepresentation r
parseMonitors :: Maybe (HM.HashMap Text Value) → HM.HashMap LoggerName (MEvExpr, [MEvAction])
parseMonitors Nothing = HM.empty
parseMonitors (Just hmv) = HM.mapMaybe mkMonitor hmv
    where
    mkMonitor :: Value → Maybe (MEvExpr, [MEvAction])
    mkMonitor = parseMaybe $ λv →
      (withObject "" $ λo →
        (,) <$> o .: "monitor"
            <*> o .: "actions") v
      <|> parseJSON v
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
        defRotation = R.rotation r
    cgref ← newMVar $ ConfigurationInternal
```

```
        {cgMinSeverity      = R.minSeverity r
        ,cgDefRotation      = defRotation
        ,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 defRotation (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 :: Value → Maybe SubTrace
        mkSubtrace = parseMaybe parseJSON
    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 :: Maybe (HM.HashMap Text Value) → HM.HashMap LoggerName AggregatedKi
parseAggregatedKindMap Nothing = HM.empty
parseAggregatedKindMap (Just hmv) = HM.mapMaybe mkAggregatedKind hmv
    where
    mkAggregatedKind :: Value → Maybe AggregatedKind
    mkAggregatedKind (String s) = Just $ read $ unpack s
    mkAggregatedKind v = (parseMaybe parseJSON) v
```

Setup empty configuration

```
empty :: IO Configuration
empty = do
  cgref ← newMVar $ ConfigurationInternal
    {cgMinSeverity     = Debug
    ,cgDefRotation     = Nothing
    ,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
```

toRepresentation

```
toRepresentation :: Configuration → IO R.Representation
toRepresentation (Configuration c) = do
```

```
cfg ← readMVar c
let portEKG = cgPortEKG cfg
    portGUI = cgPortGUI cfg
    otherOptions = cgOptions cfg
    defScribes = cgDefScribes cfg
    splitScribeId :: ScribeId → (ScribeKind, Text)
    splitScribeId x =
      -- "(ScribeId)" = "(ScribeKind) ::  (Filename)"
      let (a, b) = T.breakOn "::" x
      in
        (read $ unpack a, T.drop 2 b)
    createOption name f hashmap = if null hashmap
      then HM.empty
      else HM.singleton name $ HM.map f hashmap
    toString :: Show a ⇒ a → Value
    toString = String ∘ pack ∘ show
    toObject :: (MEvExpr, [MEvAction]) → Value
    toObject (expr, actions) = object ["monitor" .= expr, "actions" .= actions]
    toJSON' :: [ScribeId] → Value
    toJSON' [sid] = toJSON sid
    toJSON' ss    = toJSON ss
    mapSeverities = createOption "mapSeverity" toJSON $ cgMapSeverity cfg
    mapBackends  = createOption "mapBackends" toJSON $ cgMapBackend cfg
    mapAggKinds = createOption "mapAggregatedkinds" toString $ cgMapAggregatedKind cfg
    mapScribes   = createOption "mapScribes"  toJSON' $ cgMapScribe   cfg
    mapSubtrace  = createOption "mapSubtrace" toJSON $ cgMapSubtrace cfg
    mapMonitors  = createOption "mapMonitors" toObject $ cgMonitors    cfg
return $
  R.Representation
    {R.minSeverity     = cgMinSeverity cfg
    ,R.rotation        = cgDefRotation cfg
    ,R.setupScribes    = cgSetupScribes cfg
    ,R.defaultScribes  = map splitScribeId defScribes
    ,R.setupBackends = cgSetupBackends cfg
    ,R.defaultBackends = cgDefBackendKs cfg
    ,R.hasEKG          = if portEKG ≡ 0 then Nothing else Just portEKG
    ,R.hasGUI          = if portGUI ≡ 0 then Nothing else Just portGUI
    ,R.options         = mapSeverities `HM.union`
                         mapBackends  `HM.union`
                         mapAggKinds `HM.union`
                         mapSubtrace  `HM.union`
                         mapScribes   `HM.union`
                         mapMonitors  `HM.union`
                         otherOptions
    }
```

Export Configuration into a file

Converts Configuration into the form of *Representation* and writes it to the given file.

```
exportConfiguration :: Configuration → FilePath → IO ()
exportConfiguration cfg file = do
```

```
    representation ← toRepresentation cfg
    Yaml.encodeFile file representation
```

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*.

```
findRootSubTrace :: Configuration → LoggerName → IO (Maybe SubTrace)
findRootSubTrace config loggername = do
    -- Try to find SubTrace by provided name.
    findSubTrace config loggername >>= λcase
      Just subtrace → return $ Just subtrace-- Ok, found, provide it as it is.
      Nothing →
        -- We didn't find it, so drop the child (from the right side)
        -- and try to find it again.
        case dropToDot loggername of
          Nothing → return Nothing-- Didn't find.
          Just parentName → findRootSubTrace config parentName
testSubTrace :: Configuration → LoggerName → LogObject a → IO (Maybe (LogObject a))
testSubTrace config loggername lo = do
    subtrace ← fromMaybe Neutral <$> findRootSubTrace config loggername
    return $ testSubTrace' lo subtrace
  where
    testSubTrace' :: LogObject a → SubTrace → Maybe (LogObject a)
    testSubTrace' _ NoTrace = Nothing
    testSubTrace' (LogObject _ _ (ObserveOpen _)) DropOpening = Nothing
    testSubTrace' o@(LogObject _ _ (LogValue vname _)) (FilterTrace filters) =
      if evalFilters filters (loggername <> "." <> vname)
      then Just o
      else Nothing
    testSubTrace' o (FilterTrace filters) =
      if evalFilters filters loggername
      then Just o
      else Nothing
    testSubTrace' o (SetSeverity sev) = Just $ o {loMeta = (loMeta o) {severity = sev}}
    testSubTrace' o _ = Just o-- fallback:  all pass
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
```

1.7.25 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 = "nooutput"
    ,scKind = DevNullSK
    ,scPrivacy = ScPublic
    ,scRotation = Nothing
    }
    ]
  CM.setDefaultScribes c ["NullSK::nooutput"]
  return c
```

1.7.26 Cardano.BM.Output.Switchboard

Switchboard

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

```
type SwitchboardMVar a = MVar (SwitchboardInternal a)
newtype Switchboard a = Switchboard
  {getSB :: SwitchboardMVar a}
data SwitchboardInternal a = SwitchboardInternal
  {sbQueue     :: TBQ.TBQueue (LogObject a)
  ,sbDispatch  :: Async.Async ()
  ,sbLogBuffer :: Cardano.BM.Output ∘ LogBuffer.LogBuffer a
  }
```

Trace that forwards to the Switchboard

Every Trace ends in the Switchboard which then takes care of dispatching the messages to the selected backends.
This Tracer will forward all messages unconditionally to the Switchboard. (currently disabled)

```
mainTrace :: IsEffectuator eff a ⇒ eff a → Tracer IO (LogObject a)
mainTrace = Tracer ∘ effectuate
```

This Tracer will apply to every message the severity filter as defined in the Configuration.

```
mainTraceConditionally :: IsEffectuator eff a ⇒ Configuration → eff a → Tracer IO (LogObject a)
mainTraceConditionally config eff = Tracer $ λitem → do
  mayItem ← Config.testSubTrace config (loName item) item
  case mayItem of
    Just itemF@(LogObject loggername meta _) → do
      passSevFilter ← Config.testSeverity config loggername meta
      when passSevFilter $
        effectuate eff itemF
    Nothing → pure ()
```

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
  handleOverflow _ = TIO.hPutStrLn stderr "Error: Switchboard's queue full, dropping log ite

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 IsBackend

```
instance ToObject a => IsBackend Switchboard a where
  typeof _ = SwitchboardBK
  realize cfg = do
    -- we setup LogBuffer explicitly so we can access it as a Backend and as LogBuffer
    logbuf :: Cardano.BM.Output o LogBuffer.LogBuffer a <- Cardano.BM.Output o LogBuffer.realize cfg
    let spawnDispatcher
          :: [(BackendKind, Backend a)]
          -> TBQ.TBQueue (LogObject a)
          -> IO (Async.Async ())
        spawnDispatcher backends queue = do
          now <- getCurrentTime
          let messageCounters = resetCounters now
          countersMVar <- newMVar messageCounters
          let traceInQueue q =
                Tracer $ \lognamed -> do
                  item' <- Config.testSubTrace cfg (loName lognamed) lognamed
                  case item' of
                    Just obj@(LogObject loggername meta _) -> do
                      passSevFilter <- Config.testSeverity cfg loggername meta
                      when passSevFilter $ do
                        nocapacity <- atomically $ TBQ.isFullTBQueue q
                        if nocapacity
                        then putStrLn "Error: Switchboard's queue full, dropping log items!"
                        else atomically $ TBQ.writeTBQueue q obj
                    Nothing -> pure ()
          _timer <- Async.async $ sendAndResetAfter
            (traceInQueue queue)
            "#messagecounters.switchboard"
            countersMVar
            60000 -- 60000 ms = 1 min
            Warning-- Debug
          let sendMessage nli befilter = do
                selectedBackends <- getBackends cfg (loName nli)
                let selBEs = befilter selectedBackends
                forM_ backends $ \(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 _ loitem) = do
                when (loname ≢ "#messagecounters.switchboard") $
                  modifyMVar_ counters $
                    λcnt → return $ updateMessageCounters cnt nli
                Config.findSubTrace cfg loname >>= λcase
                  Just (TeeTrace sndName) →
                    atomically $ TBQ.writeTBQueue queue $ nli {loName = loname <> "." <> sndName}
                  _ → return ()
                case loitem of
                  KillPill → do
                    forM_ backends (λ(_, be) → bUnrealize be)
                    return False
                  (AggregatedMessage _) → do
                    sendMessage nli (filter (≢ AggregationBK))
                    return True
                  (MonitoringEffect inner) → do
                    sendMessage (inner {loName = loname}) (filter (≢ MonitoringBK))
                    return True
                  (Command (DumpBufferedTo bk)) → do
                    msgs ← Cardano.BM.Output ∘ LogBuffer.readBuffer logbuf
                    forM_ msgs (λ(lonm, lobj) → sendMessage (lobj {loName = lonm}) (const [bk]))
                    return True
                  _ → do
                    sendMessage nli id
                    return True
          res ← mapM processItem nlis
          when (and res) $ qProc counters
      Async.async $ qProc countersMVar
    q ← atomically $ TBQ.newTBQueue 2048
    sbref ← newEmptyMVar
    let sb :: Switchboard a = Switchboard sbref
    backends ← getSetupBackends cfg
    bs0 ← setupBackends backends cfg sb
    bs1 ← return (LogBufferBK, MkBackend
                    {bEffectuate = Cardano.BM.Output ∘ LogBuffer.effectuate logbuf
                    , bUnrealize = Cardano.BM.Output ∘ LogBuffer.unrealize logbuf
                    })
    let bs = bs1 : bs0
    dispatcher ← spawnDispatcher 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, sbLogBuffer = logbuf}
    return sb
  unrealize switchboard = do
    let clearMVar :: MVar some -> IO ()
        clearMVar = void . tryTakeMVar
    (dispatcher, queue) <- withMVar (getSB switchboard) (\sb -> 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
```

Reading the buffered log messages

```
readLogBuffer :: Switchboard a -> IO [(LoggerName, LogObject a)]
readLogBuffer switchboard = do
  sb <- readMVar (getSB switchboard)
  Cardano.BM.Output . LogBuffer.readBuffer (sbLogBuffer sb)
```

Realizing the backends according to configuration

```
setupBackends :: ToObject a
  => [BackendKind]
  -> Configuration
  -> Switchboard a
  -> IO [(BackendKind, Backend a)]
setupBackends bes c sb = catMaybes <$>
  forM bes (\bk -> do {setupBackend' bk c sb >>= \case Nothing -> return Nothing
    Just be -> return $ Just (bk, be)})
setupBackend' :: ToObject a => BackendKind -> Configuration -> Switchboard a -> IO (Maybe (Backend a)
setupBackend' SwitchboardBK _ _ = error "cannot instantiate a further Switchboard"
#ifdef ENABLE_MONITORING
setupBackend' MonitoringBK c sb = do
  let basetrace = mainTraceConditionally c sb
  be :: Cardano.BM.Output . Monitoring.Monitor a <- Cardano.BM.Output . Monitoring.realizefrom c baset
  return $ Just MkBackend
    {bEffectuate = Cardano.BM.Output . Monitoring.effectuate be
    ,bUnrealize = Cardano.BM.Output . Monitoring.unrealize be
    }
#else
setupBackend' MonitoringBK _ _ = do
  TIO.hPutStrLn stderr "disabled! will not setup backend 'Monitoring'"
  return Nothing
```

```
#endif
#ifdef ENABLE_EKG
setupBackend' EKGViewBK c sb = do
  let basetrace = mainTraceConditionally c sb
  be :: Cardano.BM.Output ∘ EKGView.EKGView a ← Cardano.BM.Output ∘ EKGView.realizefrom c basetr
  return $ Just MkBackend
    {bEffectuate = Cardano.BM.Output ∘ EKGView.effectuate be
    ,bUnrealize = Cardano.BM.Output ∘ EKGView.unrealize be
    }
#else
setupBackend' EKGViewBK _ _ = do
  TIO.hPutStrLn stderr "disabled! will not setup backend 'EKGView'"
  return Nothing
#endif
#ifdef ENABLE_AGGREGATION
setupBackend' AggregationBK c sb = do
  let basetrace = mainTraceConditionally c sb
  be :: Cardano.BM.Output ∘ Aggregation.Aggregation a ← Cardano.BM.Output ∘ Aggregation.realizefrom
  return $ Just MkBackend
    {bEffectuate = Cardano.BM.Output ∘ Aggregation.effectuate be
    ,bUnrealize = Cardano.BM.Output ∘ Aggregation.unrealize be
    }
#else
setupBackend' AggregationBK _ _ = do
  TIO.hPutStrLn stderr "disabled! will not setup backend 'Aggregation'"
  return Nothing
#endif
#ifdef ENABLE_GUI
setupBackend' EditorBK c sb = do
  port ← Config.getGUIport c
  if port > 0
  then do
    let trace = mainTraceConditionally c sb
    be :: Cardano.BM.Output ∘ Editor.Editor a ← Cardano.BM.Output ∘ Editor.realizefrom c trace sb
    return $ Just MkBackend
      {bEffectuate = Cardano.BM.Output ∘ Editor.effectuate be
      ,bUnrealize = Cardano.BM.Output ∘ Editor.unrealize be
      }
  else
    return Nothing
#else
setupBackend' EditorBK _ _ = do
  TIO.hPutStrLn stderr "disabled! will not setup backend 'Editor'"
  return Nothing
#endif
setupBackend' KatipBK c _ = do
  be :: Cardano.BM.Output ∘ Log.Log a ← Cardano.BM.Output ∘ Log.realize c
  return $ Just MkBackend
    {bEffectuate = Cardano.BM.Output ∘ Log.effectuate be
    ,bUnrealize = Cardano.BM.Output ∘ Log.unrealize be
    }
```

```
setupBackend' LogBufferBK _ _ = return Nothing
```

MockSwitchboard

MockSwitchboard is useful for tests since it keeps the LogObjects to be output in a list.

```
newtype MockSwitchboard a = MockSB (TVar [LogObject a])
instance IsEffectuator MockSwitchboard a where
  effectuate (MockSB tvar) item = atomically $ modifyTVar tvar ((:) item)
  handleOverflow _ = pure ()
```

traceMock

A Tracer which forwards LogObjects to MockSwitchboard simulating functionality of mainTraceConditionally

```
traceMock :: MockSwitchboard a → Config.Configuration → Tracer IO (LogObject a)
traceMock ms config =
    Tracer $ λitem@(LogObject loggername _ _) → do
      traceWith mainTrace item
      subTrace ← fromMaybe Neutral <$> Config.findSubTrace config loggername
      case subTrace of
        TeeTrace secName →
          traceWith mainTrace item {loName = secName}
        _ → return ()
  where
    mainTrace = mainTraceConditionally config ms
```

1.7.27 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 ToObject 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
      modifyMVar_ logMVar $ λli → return $
        li {msgCounters = updateMessageCounters (msgCounters li) item}
      -- reset message counters afer 60 sec = 1 min
      resetMessageCounters logMVar c 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 cfg 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
        let counterName = "#messagecounters.katip"
        countersObjects ← forM (HM.toList $ mcCountersMap counters) $ λ(key, count) →
            LogObject
              <$> pure counterName
              <*> (mkLOMeta sev Confidential)
              <*> pure (LogValue key (PureI $ toInteger count))
        intervalObject ←
          LogObject
            <$> pure counterName
            <*> (mkLOMeta sev Confidential)
            <*> pure (LogValue "time_interval_(s)" (PureI diffTime))
        let namedCounters = countersObjects ++ [intervalObject]
        namedCountersFiltered ← catMaybes <$> (forM namedCounters $ λobj → do
          mayObj ← Config.testSubTrace cfg counterName obj
          case mayObj of
            Just o → do
              passSevFilter ← Config.testSeverity cfg counterName $ loMeta o
              if passSevFilter
              then return $ Just o
              else return Nothing
            Nothing → return Nothing)
        forM_ scribes $ λsc →
          forM_ namedCountersFiltered $ 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

```
instance ToObject 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
        createScribe DevNullSK _ _ = mkDevNullScribe
    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 :: ToObject 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, TL.toStrict (encodeToLazyText (toObject logItem)), Nothing)
              (ObserveDiff _) →
```

```
                let text = TL.toStrict (encodeToLazyText (toObject loitem))
                in
                (severity lometa, text, Just loitem)
              (ObserveOpen _) →
                let text = TL.toStrict (encodeToLazyText (toObject loitem))
                in
                (severity lometa, text, Just loitem)
              (ObserveClose _) →
                let text = TL.toStrict (encodeToLazyText (toObject 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 (toObject logitem))
                in
                (severity lometa, text, Just loitem)
              KillPill →
                (severity lometa, "Kill pill received!", Nothing)
              Command _ →
                (severity lometa, "Command 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 ^. KC.logEnvApp
            , _itemEnv       = env ^. KC.logEnvEnv
            , _itemSeverity  = sev2klog sev
            , _itemThread    = threadIdText
            , _itemHost      = env ^. KC.logEnvHost
            , _itemProcess   = env ^. KC.logEnvPid
            , _itemPayload   = payload
            , _itemMessage   = K.logStr msg
            , _itemTime      = itemTime
            , _itemNamespace = (env ^. KC.logEnvApp) <> (K.Namespace [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

mkDevNullScribe :: IO K.Scribe
mkDevNullScribe = do
    let logger _ = pure ()
    pure $ K.Scribe logger (pure ())

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

mkFileScribeH
    :: Handle
    → (forall a ∘ K.LogItem a ⇒ Handle → Bool → K.Verbosity → K.Item a → IO ())
    → Bool
    → IO K.Scribe
mkFileScribeH h formatter colorize = do
    hSetBuffering h LineBuffering
    locklocal ← newMVar ()
    let logger :: forall a ∘ K.LogItem a ⇒ K.Item a → IO ()
        logger item = withMVar locklocal $ \_ →
                formatter h colorize K.V0 item
    pure $ K.Scribe logger (hClose h)

mkTextFileScribe :: Maybe RotationParameters → FileDescription → Bool → IO K.Scribe
mkTextFileScribe rotParams fdesc colorize = do
    mkFileScribe rotParams fdesc formatter colorize
  where
    formatter :: Handle → Bool → K.Verbosity → K.Item a → IO Int
    formatter hdl colorize' v' item =
      case KC._itemMessage item of
          K.LogStr "" →
            -- if message is empty do not output it
            return 0
          _ → do
            let tmsg = toLazyText $ formatItem colorize' v' item
            TIO.hPutStrLn hdl tmsg
            return $ fromIntegral $ TL.length tmsg

mkJsonFileScribe :: Maybe RotationParameters → FileDescription → Bool → IO K.Scribe
mkJsonFileScribe rotParams fdesc colorize = do
    mkFileScribe rotParams fdesc formatter colorize
  where
```

```
    formatter :: (K.LogItem a) ⇒ Handle → Bool → K.Verbosity → K.Item a → IO Int
    formatter h _ verbosity item = do
      let jmsg = case KC._itemMessage item of
            -- if a message is contained in item then only the
            -- message is printed and not the data
            K.LogStr "" → K.itemJson verbosity item
            K.LogStr msg → K.itemJson verbosity $
              item {KC._itemMessage = K.logStr ("" :: Text)
                ,KC._itemPayload = 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) $
                 \e -> 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 $ \handler ->
            void $ formatter handler colorize K.V0 item
    return $ K.Scribe logger finalizer


formatItem :: Bool -> K.Verbosity -> K.Item a -> Builder
formatItem withColor _verb K.Item{..} =
    fromText header <>
    fromText "  " <>
    brackets (fromText timestamp) <>
    fromText "  " <>
    KC.unLogStr _itemMessage
  where
    header = colorBySeverity _itemSeverity $
      "[" <> mconcat namedcontext <> ":" <> severity <> ":" <> threadid <> "]"
    namedcontext = KC.intercalateNs _itemNamespace
    severity = KC.renderSeverity _itemSeverity
    threadid = KC.getThreadIdText _itemThread
    timestamp = pack $ formatTime defaultTimeLocale tsformat _itemTime
    tsformat :: String
    tsformat = "%F %T%2Q %Z"
    colorBySeverity s m = case s of
      K.EmergencyS -> red m
      K.AlertS     -> red m
      K.CriticalS  -> red m
      K.ErrorS     -> red m
      K.NoticeS    -> magenta m
      K.WarningS   -> yellow m
      K.InfoS      -> blue m
      _ -> m
    red = colorize "31"
    yellow = colorize "33"
    magenta = colorize "35"
    blue = colorize "34"
```

```
    colorize c m
      | withColor = "\ESC[" <> c <> "m" <> m <> "\ESC[0m"
      | otherwise = m
-- translate Severity to Log.Severity
sev2klog :: Severity → K.Severity
sev2klog = λcase
    Debug    → K.DebugS
    Info     → K.InfoS
    Notice   → K.NoticeS
    Warning  → K.WarningS
    Error    → K.ErrorS
    Critical → K.CriticalS
    Alert    → K.AlertS
    Emergency → K.EmergencyS


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

1.7.28 Cardano.BM.Output.LogBuffer

Structure of LogBuffer

```
newtype LogBuffer a = LogBuffer
  {getLogBuf :: LogBufferMVar a}
type LogBufferMVar a = MVar (LogBufferInternal a)
data LogBufferInternal a = LogBufferInternal
  {logBuffer :: LogBufferMap a
  }
```

Relation from log context name to log item

We keep the latest LogObject from a log context in a *HashMap*.

```
type LogBufferMap a = HM.HashMap LoggerName (LogObject a)
```

Read out the latest LogObjects

```
readBuffer :: LogBuffer a → IO [(LoggerName, LogObject a)]
readBuffer buffer =
  withMVar (getLogBuf buffer) $ λcurrentBuffer →
    return $ HM.toList $ logBuffer currentBuffer
```

LogBuffer is an effectuator

Function *effectuate* is called to pass in a LogObject for log buffering.

```
instance IsEffectuator LogBuffer a where
  effectuate buffer lo@(LogObject logname _lometa (LogValue lvname _lvalue)) = do
    modifyMVar_ (getLogBuf buffer) $ λcurrentBuffer →
      return $ LogBufferInternal $ HM.insert ("#buffered." <> logname <> "." <> lvname) lo $ logBuffer c
  effectuate buffer lo@(LogObject logname _lometa _logitem) = do
    modifyMVar_ (getLogBuf buffer) $ λcurrentBuffer →
      return $ LogBufferInternal $ HM.insert ("#buffered." <> logname) lo $ logBuffer currentBuffer
  handleOverflow _ = TIO.hPutStrLn stderr "Notice: overflow in LogBuffer, dropping log items
```

LogBuffer implements Backend functions

LogBuffer is an IsBackend

```
instance IsBackend LogBuffer a where
  typeof _ = LogBufferBK
  realize _ = do
    let emptyBuffer = LogBufferInternal HM.empty
    LogBuffer <$> newMVar emptyBuffer
  unrealize _ = return ()
```

1.7.29 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 :: ToObject a ⇒ EKGView a → Configuration → IO (Trace IO a)
ekgTrace ekg _c = do
```

```
    let basetrace = ekgTrace' ekg
    Trace.appendName "#ekgview" basetrace
  where
    ekgTrace' :: ToObject a ⇒ EKGView a → Tracer IO (LogObject a)
    ekgTrace' ekgview = Tracer $ 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 :: ToObject a ⇒ LogObject a → EKGViewInternal a → IO (Maybe (EKGViewInternal a))
          update (LogObject logname _ (LogMessage logitem)) ekg_i =
            setlabel logname (pack $ show $ toObject 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 ToObject a ⇒ IsBackend EKGView a where
    typeof _ = EKGViewBK
    realize _ = error "EKGView cannot be instantiated by 'realize'"
    realizefrom config sbtrace _ = do
      evref ← newEmptyMVar
      let ekgview = EKGView evref
      evport ← getEKGport config
      ehdl ← forkServer "127.0.0.1" evport
      ekghdl ← getLabel "iohk-monitoring version" ehdl
      Label.set ekghdl $ pack (showVersion version)
      ekgtrace ← ekgTrace ekgview config
      queue ← atomically $ TBQ.newTBQueue 25120
      dispatcher ← spawnDispatcher config 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 :: Configuration
                → TBQ.TBQueue (Maybe (LogObject a))
                → Trace.Trace IO a
                → Trace.Trace IO a
                → IO (Async.Async ())
spawnDispatcher config evqueue sbtrace ekgtrace = 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 _ _) → do
          obj' ← testSubTrace config ("#ekgview." <> logname) obj
          case obj' of
            Just lo@(LogObject logname' meta content) → do
              trace ← Trace.appendName logname' ekgtrace
              Trace.traceNamedObject trace (meta,content)
              -- increase the counter for the type of message
              modifyMVar_ counters $ λcnt → return $ updateMessageCounters cnt lo
            Nothing → pure ()
          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
```

1.7.30 Cardano.BM.Output.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).

Structure of Editor

```
type EditorMVar a = MVar (EditorInternal a)
newtype Editor a = Editor
  {getEd :: EditorMVar a}
data ToObject a ⇒ EditorInternal a = EditorInternal
  {edSBtrace :: Trace IO a
  ,edThread :: Async.Async ()
  ,edBuffer  :: LogBuffer a
  }
```

Editor implements Backend functions

Editor is an IsBackend

```
instance ToObject a ⇒ IsBackend Editor a where
  typeof _ = EditorBK
  realize _ = error "Editor cannot be instantiated by 'realize'"
  realizefrom config sbtrace _ = do
    gref ← newEmptyMVar
    let gui = Editor gref
    port ← getGUIport config
    when (port ⩽ 0) $ error "cannot create GUI"
    -- local LogBuffer
    logbuf :: Cardano.BM.Output ∘ LogBuffer.LogBuffer a ← Cardano.BM.Output ∘ LogBuffer.realize confi
    thd ← Async.async $
      startGUI defaultConfig {jsPort = Just port
        ,jsAddr                      = Just "127.0.0.1"
        ,jsStatic                    = Just "iohk-monitoring/static"
        ,jsCustomHTML = Just "configuration-editor.html"
        } $ prepare gui config
    Async.link thd
    putMVar gref $ EditorInternal
      {edSBtrace = sbtrace
      ,edThread = thd
      ,edBuffer = logbuf
      }
    return gui
```

```
  unrealize editor =
    withMVar (getEd editor) $ λed →
      Async.cancel $ edThread ed
```

Editor is an effectuator

Function *effectuate* is called to pass in a LogObject for display in the GUI.

```
instance ToObject a ⇒ IsEffectuator Editor a where
  effectuate editor item =
    withMVar (getEd editor) $ λed →
      effectuate (edBuffer ed) item
  handleOverflow _ = TIO.hPutStrLn stderr "Notice: overflow in Editor!"
```

Prepare the view

```
data Cmd = Backends | Scribes | Severities | SubTrace | Aggregation | Buffer | ExportConfiguration
  deriving (Enum, Eq, Show, Read)
prepare :: ToObject a ⇒ Editor a → Configuration → Window → UI ()
prepare editor config window = void $ do
  let commands = [Backends ..]
  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
      removeItem _           _ = pure ()
  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'
    updateItem _            _ _ = pure ()
  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 addItemButton          = performActionOnId addItemButtonId
  let saveItemButton         = performActionOnId saveItemButtonId
  let cancelSaveItemButton   = performActionOnId cancelSaveItemButtonId
  let cleanOutputTable       = performActionOnId outputTableId $ λt → void $ element t # set children [ ]
  let mkLinkToFile :: String → FilePath → UI Element
      mkLinkToFile str file = UI.anchor # set (attr "href") file
                                        # set (attr "target") "_blank"
                                        #+ [string str]
  let mkSimpleRow :: ToObject a ⇒ LoggerName → LogObject a → UI Element
      mkSimpleRow n lo@(LogObject _lonm _lometa _lov) = UI.tr #. "itemrow" #+
        [UI.td #+ [string (unpack n)]
        ,UI.td #+ [string $ unpack $ TL.toStrict (encodeToLazyText (toObject lo))]
        ]
  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 displayItems cmd sel = do
    showCurrentTab cmd
    rememberCurrent cmd
    saveItemButton disable
    cancelSaveItemButton disable
    addItemButton enable
    cleanOutputTable
    performActionOnId outputTableId $
        λt → void $ element t #+
          [UI.tr #+
            [UI.th #+ [string "LoggerName"]
            , UI.th #+ [string $ show cmd <> " value"]
            , UI.th #+ [string ""]
            ]
          ]
    cg ← liftIO $ readMVar (CM.getCG config)
    forM_ (HM.toList $ sel cg) $
        λ(n, v) → performActionOnId outputTableId $
          λt → void $ element t #+ [mkTableRow cmd n v]
let displayBuffer :: ToObject a ⇒ Cmd → [(LoggerName, LogObject a)] → UI ()
  displayBuffer cmd sel = do
    showCurrentTab cmd
    rememberCurrent cmd
    saveItemButton disable
    cancelSaveItemButton disable
    addItemButton disable
    cleanOutputTable
    performActionOnId outputTableId $
        λt → void $ element t #+
          [UI.tr #+
```

```
                [UI.th #+ [string "LoggerName"]
                ,UI.th #+ [string $ show cmd <> " value"]
                ,UI.th #+ [string ""]
                ]
              ]
        forM_ (sel) $
            λ(n,v) → performActionOnId outputTableId $
              λt → void $ element t #+ [mkSimpleRow n v]
    let accessBufferMap = do
        ed ← liftIO $ readMVar (getEd editor)
        liftIO $ readBuffer $ edBuffer ed
    let exportConfiguration = do
        currentDir ← liftIO getCurrentDirectory
        let dir = currentDir </> "iohk-monitoring/static/conf"
        liftIO $ createDirectoryIfMissing True dir
        tsnow ← formatTime defaultTimeLocale tsformat <$> liftIO getCurrentTime
        let filename = "config.yaml" ++ "-" ++ tsnow
            filepath = dir </> filename
        res ← liftIO $ catch
            (CM.exportConfiguration config filepath ≫
              return ("Configuration was exported to the file: " ++ filepath))
            (λ(e :: SomeException) → return $ show e)
        setMessage res
        performActionOnId outputTableId $
            λt → void $ element t #+ [mkLinkToFile
              "Link to configuration file"
              ("/static/conf" </> filename)
              ]
    let displayExport cmd = do
        showCurrentTab cmd
        rememberCurrent cmd
        saveItemButton disable
        cancelSaveItemButton disable
        addItemButton disable
        cleanOutputTable
        exportConfiguration
    let switchToTab c@Backends      = displayItems c $ CM.cgMapBackend
      switchToTab c@Severities      = displayItems c $ CM.cgMapSeverity
      switchToTab c@Scribes         = displayItems c $ CM.cgMapScribe
      switchToTab c@SubTrace        = displayItems c $ CM.cgMapSubtrace
      switchToTab c@Aggregation     = displayItems c $ CM.cgMapAggregatedKind
      switchToTab c@Buffer          = accessBufferMap ≫= displayBuffer c
      switchToTab c@ExportConfiguration = displayExport c
    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]
              ]
            ]
        ]
```

1.7.31 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 it
```

Aggregation implements Backend functions

Aggregation is an IsBackend

```
instance IsBackend Aggregation a where
  typeof _ = AggregationBK
  realize _ = error "Aggregation cannot be instantiated by 'realize'"
  realizefrom config trace _ = do
    aggref ← newEmptyMVar
    aggregationQueue ← atomically $ TBQ.newTBQueue 2048
    dispatcher ← spawnDispatcher config HM.empty aggregationQueue trace
    -- link the given Async to the current thread, such that if the Async
    -- raises an exception, that exception will be re-thrown in the current
    -- thread, wrapped in ExceptionInLinkedThread.
    Async.link dispatcher
    putMVar aggref $ AggregationInternal aggregationQueue dispatcher
    return $ Aggregation aggref
  unrealize aggregation = do
    let clearMVar :: MVar a → IO ()
        clearMVar = void ∘ tryTakeMVar
    (dispatcher,queue) ← withMVar (getAg aggregation) (λag →
      return (agDispatch ag,agQueue ag))
```

```
    -- send terminating item to the queue
    atomically $ TBQ.writeTBQueue queue Nothing
    -- wait for the dispatcher to exit
    -- TODO add a timeout to waitCatch in order
    -- to be sure that it will finish
    res ← Async.waitCatch dispatcher
    either throwM return res
    (clearMVar ∘ getAg) aggregation
```

Asynchronously reading log items from the queue and their processing

```
spawnDispatcher :: Configuration
                → AggregationMap
                → TBQ.TBQueue (Maybe (LogObject a))
                → Trace.Trace IO a
                → IO (Async.Async ())
spawnDispatcher conf aggMap aggregationQueue basetrace = do
    now ← getCurrentTime
    trace ← Trace.appendName "#aggregation" basetrace
    let messageCounters = resetCounters now
    countersMVar ← newMVar messageCounters
    _timer ← Async.async $ sendAndResetAfter
      basetrace
      "#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)
  -- ignore 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"
```

1.7.32 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 IsBackend Monitor a where
  typeof _ = MonitoringBK
  realize _ = error "Monitoring cannot be instantiated by 'realize'"
  realizefrom config sbtrace _ = do
    monref ← newEmptyMVar
    let monitor = Monitor monref
    queue ← atomically $ TBQ.newTBQueue 512
    dispatcher ← spawnDispatcher queue config sbtrace
    -- link the given Async to the current thread, such that if the Async
    -- raises an exception, that exception will be re-thrown in the current
    -- thread, wrapped in ExceptionInLinkedThread.
    Async.link dispatcher
    putMVar monref $ MonitorInternal
      {monQueue = queue
      -- , monState = mempty
      }
    return monitor
  unrealize _ = return ()
```

Asynchrouniously reading log items from the queue and their processing

```
spawnDispatcher :: TBQ.TBQueue (Maybe (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 $ \cnt -> return $ updateMessageCounters cnt logvalue
          qProc counters state'
        Nothing -> return ()-- stop here
    initMap = do
      ls <- getMonitors config
      return $ HM.fromList $ map (\(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 ew
        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

```
{-# 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)
import qualified Cardano.BM.Test.Structured (tests)
import qualified Cardano.BM.Test.Tracer (tests)
#ifdef ENABLE_MONITORING
import qualified Cardano.BM.Test.Monitoring (tests)
#endif
main :: IO ()
main = defaultMain tests
tests :: TestTree
tests =
```

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'

```
  testGroup "iohk-monitoring"
  [
# ifdef ENABLE_AGGREGATION
    Cardano.BM.Test ∘ Aggregated.tests
  ,
# endif
    Cardano.BM.Test ∘ STM.tests
  ,Cardano.BM.Test ∘ Trace.tests
  ,Cardano.BM.Test ∘ Configuration.tests
  ,Cardano.BM.Test ∘ Rotator.tests
  ,Cardano.BM.Test ∘ Routing.tests
  ,Cardano.BM.Test ∘ Structured.tests
  ,Cardano.BM.Test ∘ Tracer.tests
# ifdef ENABLE_MONITORING
  ,Cardano.BM.Test ∘ Monitoring.tests
# endif
  ]
```

2.3 Test case generation

2.3.1 instance Arbitrary Aggregated

We define an instance of *Arbitrary* for an Aggregated which lets *QuickCheck* generate arbitrary instances of Aggregated. For this an arbitrary list of *Integer* is 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
  {tcConfig      :: Configuration
  ,tcOutputKind :: MockSwitchboard Text
  ,tcName        :: LoggerName
  ,tcSubTrace    :: SubTrace
  }
setupTrace :: TraceConfiguration → IO (Trace IO Text)
setupTrace (TraceConfiguration cfg mockSB name subTr) = do
  let logTrace = traceMock mockSB cfg
  setSubTrace cfg name (Just subTr)
  appendName name logTrace
```

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 cfg logTrace0 "0"
      logTrace1 ← appendName "complex-work-1" logTrace
      work1 ← complexWork1 cfg 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 cfg tr msg = Async.async $ do
      logInfo tr ("let's see (1): " `append` msg)
      trInner ← appendName "inner-work-1" tr
      let observablesSet = [MonotonicClock]
      setSubTrace cfg "test.complex-work-1.inner-work-1.STM-action" $
        Just $ ObservableTrace observablesSet
# ifdef ENABLE_OBSERVABLES
      _ ← STMObserver.bracketObserveIO cfg trInner Debug "STM-action" setVar_
# endif
      logInfo trInner "let's see: done."
```

Show effect of turning off observables

```
# ifdef ENABLE_OBSERVABLES
runTimedAction :: Configuration → Trace IO Text → LoggerName → Int → IO Measurable
runTimedAction cfg logTrace name 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 cfg trace Debug name action
      return ()
    action = return $ forM [1 :: Int .. 100] $ λx → [x] ++ (init $ reverse [1 :: Int .. 10000])

timingObservableVsUntimed :: Assertion
timingObservableVsUntimed = do
    cfg1 ← defaultConfigTesting
    msgs1 ← STM.newTVarIO []
    traceObservable ← setupTrace $ TraceConfiguration cfg1
      (MockSB msgs1)
      "observables"
      (ObservableTrace observablesSet)
    cfg2 ← defaultConfigTesting
    msgs2 ← STM.newTVarIO []
    traceUntimed ← setupTrace $ TraceConfiguration cfg2
      (MockSB msgs2)
      "no timing"
      UntimedTrace
    cfg3 ← defaultConfigTesting
    msgs3 ← STM.newTVarIO []
    traceNoTrace ← setupTrace $ TraceConfiguration cfg3
      (MockSB msgs3)
      "no trace"
      NoTrace
    t_observable ← runTimedAction cfg1 traceObservable "observables" 100
    t_untimed ← runTimedAction cfg2 traceUntimed "no timing" 100
    t_notrace  ← runTimedAction cfg3 traceNoTrace  "no trace"  100
    ms ← STM.readTVarIO msgs1
    assertBool
      ("Untimed consumed more time than ObservableTrace " ++ (show [t_untimed, t_observable]) ++
      (t_observable > t_untimed ∧ ¬ (null ms))
    assertBool
      ("NoTrace consumed more time than ObservableTrace" ++ (show [t_notrace, t_observable]))
      (t_observable > t_notrace)
    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
  cfg ← defaultConfigTesting
  msgs ← STM.newTVarIO [ ]
  basetrace ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test" Neutral
  logInfo basetrace "This should have been displayed!"
  -- subtrace of trace which traces nothing
  setSubTrace cfg "test.inner" (Just NoTrace)
  trace1 ← appendName "inner" basetrace
  logInfo trace1 "This should NOT have been displayed!"
  setSubTrace cfg "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
  cfg ← defaultConfigTesting
  msgs ← STM.newTVarIO [ ]
  trace ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test min severity" Neutral
  logInfo trace "Message #1"
  -- raise the minimum severity to Warning
  setMinSeverity cfg Warning
  msev ← Cardano.BM.Configuration.minSeverity cfg
  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 cfg 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
  cfg ← defaultConfigTesting
  msgs ← STM.newTVarIO [ ]
  basetrace ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test-duplicate" Neutral
  logInfo basetrace "Message #1"
  -- create a subtrace which duplicates all messages
  setSubTrace cfg "test-duplicate.orig" $ Just (TeeTrace "test-duplicate.dup")
  trace ← appendName "orig" basetrace
  -- 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
  cfg ← defaultConfigTesting
  msgs ← STM.newTVarIO [ ]
  basetrace ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test-named-severity" Neutral
  trace ← appendName "sev-change" basetrace
  logInfo trace "Message #1"
  -- raise the minimum severity to Warning
  setSeverity cfg "test-named-severity.sev-change" (Just Warning)
  msev ← Cardano.BM.Configuration.inspectSeverity cfg "test-named-severity.sev-change"
  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 cfg "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
  cfg ← liftIO Cardano.BM.Configuration ∘ Model.empty
  let (t1 : t2 : t3 : _) = cycle subtraces
  msgs ← STM.newTVarIO [ ]
  -- create trace of type 1
  trace1 ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test" t1
  logInfo trace1 "Message from level 1."
  -- subtrace of type 2
  setSubTrace cfg "test.inner" (Just t2)
  trace2 ← appendName "inner" trace1
  logInfo trace2 "Message from level 2."
  -- subsubtrace of type 3
  setSubTrace cfg "test.inner.innermost" (Just t3)
#ifdef ENABLE_OBSERVABLES
  _ ← STMObserver.bracketObserveIO cfg trace2 Debug "innermost" setVar_
#endif
  logInfo trace2 "Message from level 3."
  -- acquire the traced objects
  res ← STM.readTVarIO msgs
  -- only the first message should have been traced
  assertBool
    ("Found more or less messages than expected: " ++ show res)
    (f res)
```

Logging in parallel

```
unitTraceInFork :: Assertion
unitTraceInFork = do
    cfg ← defaultConfigTesting
    msgs ← STM.newTVarIO [ ]
```

```
    trace ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test" Neutral
    trace0 ← appendName "work0" trace
    trace1 ← appendName "work1" trace
    work0 ← work trace0
    threadDelay 5000
    work1 ← work trace1
    Async.wait $ work0
    Async.wait $ work1
    res ← STM.readTVarIO msgs
    let names@(_ : namesTail) = map 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

```
stressTraceInFork :: Assertion
stressTraceInFork = do
    cfg ← defaultConfigTesting
    msgs ← STM.newTVarIO [ ]
    trace ← setupTrace $ TraceConfiguration cfg (MockSB 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

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

Assert maximum length of log context name

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

```
unitAppendName :: Assertion
unitAppendName = do
    cfg ← defaultConfigTesting
    msgs ← STM.newTVarIO [ ]
    basetrace ← setupTrace $ TraceConfiguration cfg (MockSB msgs) "test" Neutral
    trace1 ← appendName bigName basetrace
    trace2 ← appendName bigName trace1
    forM_ [basetrace, 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 filter6a = [(Drop (StartsWith "test."),
    Unhide [(EndsWith ".sum"),
      (EndsWith ".other")])]
  assertBool ("Dropping all and unhiding some names, the LogObject should pass the filter
    (True ≡ evalFilters filter6a (contextName <> "." <> loname))
  assertBool ("Dropping all and unhiding some names, another LogObject should not pass th
    (False ≡ evalFilters filter6a (contextName <> ".value"))
  let filter6b = [(Drop (Contains "test."),
    Unhide [(Contains ".sum"),
      (Contains ".other")])]
  assertBool ("Dropping all and unhiding some names, the LogObject should pass the filter
    (True ≡ evalFilters filter6b (contextName <> "." <> loname))
  assertBool ("Dropping all and unhiding some names, another LogObject should not pass th
    (False ≡ evalFilters filter6b (contextName <> ".value"))
  assertBool ("Dropping others and unhiding some names, something different should still
    (True ≡ evalFilters filter6b "some.other.value")
  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. Lazy evaluation is really happening! This test fails if run with a configuration *defaultConfigTesting*, because this one will ignore all traced messages.

```
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 ← defaultConfigStdout
      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
      basetrace ← Setup.setupTrace (Right cfg) "test"
      setSubTrace cfg "test.work" (Just NoTrace)
      trace ← appendName "work" basetrace
      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 "export configuration" unitConfigurationExport
  ,testCase "include EKG if defined" unitConfigurationCheckEKGpositive
  ,testCase "not include EKG if not def" unitConfigurationCheckEKGnegative
  ,testCase "check scribe caching" unitConfigurationCheckScribeCache
  ,testCase "test ops on Configuration" unitConfigurationOps
  ]
```

Property tests

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

Unit tests

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

```
unitConfigurationCheckEKGpositive :: Assertion
unitConfigurationCheckEKGpositive = do
#ifndef ENABLE_EKG
  return ()
#else
  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:"
      ,"      contents:"
      ,"      - GhcRtsStats"
      ,"      - MonotonicClock"
      ,"      subtrace: ObservableTrace"
      ,"    iohk.deadend:"
      ,"      subtrace: 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:"
      ,"      actions:"
      ,"      - AlterMinSeverity \"chain.creation\" Debug"
      ,"      monitor: ((time > (23 s)) Or (time < (17 s)))"
      ,"    '#aggregation.critproc.observable':"
      ,"      actions:"
      ,"      - CreateMessage \"exceeded\" \"the observable has been too long too high!
```

```
      ,"      - AlterGlobalMinSeverity Info"
      ,"      monitor: (mean >= (42))"
      ,"  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
    ,cgDefRotation     = Just $ RotationParameters
                         {rpLogLimitBytes = 5000000
                         ,rpMaxAgeHours  = 24
                         ,rpKeepFilesNum = 10
                         }
    ,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 [("subtrace",String "ObservableTrace")
```

```
                    ,("contents",Array $ V.fromList
                                   [String "GhcRtsStats"
                                   ,String "MonotonicClock"])]))
        ,("iohk.deadend",
                  Object (HM.fromList [("subtrace",String "NoTrace")]))])
  ,("mapMonitors",HM.fromList [("chain.creation.block",Object (HM.fromList
                    [("monitor",String "((time > (23 s)) Or (time < (17 s)))")
                    ,("actions",Array $ V.fromList
                        [String "AlterMinSeverity \"chain.creation\" Debug"])]))
    ,("#aggregation.critproc.observable",Object (HM.fromList
                    [("monitor",String "(mean >= (42))")
                    ,("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" (GT,(Agg.Sec
                           ,["AlterMinSeverity \"chain.creation\" Debug"]
                           )
                             )
                           ,("#aggregation.critproc.observable",(Compare "mean" (GE,(Agg.PureI 4
                             ,["CreateMessage \"exceeded\" \"the observable has been too long
                             ,"AlterGlobalMinSeverity Info"]
                             )
                             )
                           ]
      ,cgPortEKG         = 12789
      ,cgPortGUI         = 0
      }
  unitConfigurationExport :: Assertion
  unitConfigurationExport = do
    cfg <- setup "test/config.yaml"
    cfg' <- withSystemTempFile "config.yaml-1213" $ λfile _ -> do
          exportConfiguration cfg file
          setup file
    cfgInternal <- readMVar $ getCG cfg
    cfgInternal' <- readMVar $ getCG cfg'
    cfgInternal' @?= cfgInternal

Test caching and inheritance of Scribes.

  unitConfigurationCheckScribeCache :: Assertion
  unitConfigurationCheckScribeCache = do
    configuration <- empty
    let defScribes = ["FileTextSK::node.log"]
```

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

Test operations on Configuration.

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

2.4.5 Rotator

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

```
property_tests :: TestTree
property_tests = testGroup "Property tests" [
  testProperty "rotator: 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
```

2.4.6 Cardano.BM.Test.Structured

```
tests :: TestTree
tests = testGroup "Testing Structured Logging" [
  testCase "logging simple text" logText
```

```
    -- , testCase "logging data structures" logStructures
      ]
```

Simple logging of text.

```
logText :: Assertion
logText = do
  cfg ← defaultConfigTesting
  baseTrace :: Trace IO Text ← Setup.setupTrace (Right cfg) "logText"
  let logTrace = toLogObject $ baseTrace
  traceWith logTrace "This is a simple message."
  traceWith logTrace ".. and another!"
  assertBool "OK" True
```

2.4.7 Cardano.BM.Test.Tracer

```
tests :: TestTree
tests = testGroup "Testing Extensions to Tracer" [
  testCase "simple tracing of messages in a named context" tracingInNamedContext,
  testCase "tracing with privacy and severity annotation" tracingWithPrivacyAndSeverityAnnota
  testCase "tracing with a predicate filter" tracingWithPredicateFilter,
  testCase "tracing with a filter that is evaluated in a monad" tracingWithMonadicFilter,
  testCase "tracing with filtering for both severity and privacy" tracingWithComplexFilterin
  ]
```

Utilities

```
data LogNamed item = LogNamed
  {lnName :: LoggerName
  ,lnItem :: item
  } deriving (Show)
named :: Tracer m (LogNamed a) → Tracer m a
named = contramap (LogNamed mempty)
appendNamed :: LoggerName → Tracer m (LogNamed a) → Tracer m (LogNamed a)
appendNamed name = contramap $ (λ(LogNamed oldName item) →
  LogNamed (name <> "." <> oldName) item)
renderNamedItemTracing :: Show a ⇒ Tracer m String → Tracer m (LogNamed a)
renderNamedItemTracing = contramap $ λitem →
  unpack (lnName item) ++ ":  " ++ show (lnItem item)

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

Tracing messages in a named context

```
tracingInNamedContext :: Assertion
tracingInNamedContext = do
  let logTrace = appendNamed' "named" $ renderNamedItemTracing' $ stdoutTracer
  void $ callFun2 logTrace
  assertBool "OK" True
callFun2 :: Tracer IO (LogObject Text) → IO Int
callFun2 logTrace = do
  let logTrace' = appendNamed' "fun2" logTrace
  traceWith (toLogObject logTrace') "in function 2"
  callFun3 logTrace'
callFun3 :: Tracer IO (LogObject Text) → IO Int
callFun3 logTrace = do
  traceWith (toLogObject $ appendNamed' "fun3" $ logTrace) "in function 3"
  return 42
```

Tracing messages with pricacy and severity annotation

A `Tracer` transformer creating a `LogObject` from *PrivacyAndSeverityAnnotated*.

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


tracingWithPrivacyAndSeverityAnnotation :: Assertion
tracingWithPrivacyAndSeverityAnnotation = do
  let logTrace =
    logObjectFromAnnotated $ appendNamed' "example3" $ renderNamedItemTracing' stdoutTracer
  traceWith logTrace $ PSA Info Confidential ("Hello" :: String)
  traceWith logTrace $ PSA Warning Public "World"
  assertBool "OK" True
```

Filter Tracer

```
filterAppendNameTracing :: Monad m
      ⇒ m (LogObject a → Bool)
      → LoggerName
      → Tracer m (LogObject a)
      → Tracer m (LogObject a)
filterAppendNameTracing test name = (appendNamed' name) ∘ (condTracingM test)
tracingWithPredicateFilter :: Assertion
tracingWithPredicateFilter = do
    let appendF = filterAppendNameTracing oracle
        logTrace = appendF "example4" (renderNamedItemTracing' stdoutTracer)
```

```
    traceWith (toLogObject logTrace) ("Hello" :: String)
    let logTrace' = appendF "inner" logTrace
    traceWith (toLogObject logTrace') "World"
    let logTrace'' = appendF "innest" logTrace'
    traceWith (toLogObject logTrace'') "!!"
    assertBool "OK" True
  where
    oracle :: Monad m => m (LogObject a -> Bool)
    oracle = return $ ((/=) "example4.inner.") . loName


-- severity anotated
tracingWithMonadicFilter :: Assertion
tracingWithMonadicFilter = do
    let logTrace =
      condTracingM oracle $
        logObjectFromAnnotated $
          appendNamed' "test5" $ renderNamedItemTracing' stdoutTracer
    traceWith logTrace $ PSA Debug Confidential ("Hello" :: String)
    traceWith logTrace $ PSA Warning Public "World"
    assertBool "OK" True
  where
    oracle :: Monad m => m (PrivacyAndSeverityAnnotated a -> Bool)
    oracle = return $ λ(PSA sev _priv _) -> (sev > Debug)

tracing with combined filtering for name and severity

tracingWithComplexFiltering :: Assertion
tracingWithComplexFiltering = 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
    traceWith logTrace1 $ PSA Debug Confidential ("Hello" :: String)
    traceWith logTrace1 $ PSA Warning Public "World"
    lometa ← mkLOMeta Info Public
    traceWith logTrace2 $ LogObject "" lometa (LogMessage ", RoW!")
    traceWith logTrace3 $ LogObject "" lometa (LogMessage ", RoW!")
    assertBool "OK" True
  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
```

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