

Cardano.BM - benchmarking and logging

Alexander Diemand

Andreas Triantafyllos

November 2018

Abstract

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

Contents

| | | |
|----------|---|----------|
| 1 | Cardano BM | 3 |
| 1.1 | Overview | 3 |
| 1.2 | Introduction | 3 |
| 1.2.1 | Logging with <i>Trace</i> | 3 |
| 1.2.2 | Measuring <i>Observables</i> | 3 |
| 1.2.3 | Monitoring | 3 |
| 1.2.4 | Information reduction in <i>Aggregation</i> | 3 |
| 1.2.5 | Output selection | 3 |
| 1.2.6 | Setup procedure | 3 |
| 1.3 | Examples | 3 |
| 1.3.1 | Observing evaluation of a STM action | 3 |
| 1.3.2 | Observing evaluation of a monad action | 3 |
| 1.4 | Code listings | 3 |
| 1.4.1 | Cardano.BM.Observer.STM | 3 |
| 1.4.2 | Cardano.BM.Observer.Monadid | 6 |
| 1.4.3 | BaseTrace | 7 |
| 1.4.4 | Cardano.BM.Trace | 8 |
| 1.4.5 | Cardano.BM.Setup | 11 |
| 1.4.6 | Cardano.BM.Counters | 12 |
| 1.4.7 | Cardano.BM.Counters.Common | 13 |
| 1.4.8 | Cardano.BM.Counters.Dummy | 14 |
| 1.4.9 | Cardano.BM.Counters.Linux | 14 |
| 1.4.10 | Cardano.BM.Data.Backend | 20 |
| 1.4.11 | Cardano.BM.Data.Configuration | 21 |
| 1.4.12 | Cardano.BM.Data.Counter | 22 |
| 1.4.13 | Cardano.BM.Data.LogItem | 23 |
| 1.4.14 | Cardano.BM.Data.Observable | 24 |
| 1.4.15 | Cardano.BM.Data.Output | 24 |
| 1.4.16 | Cardano.BM.Data.Severity | 25 |
| 1.4.17 | Cardano.BM.Data.SubTrace | 26 |
| 1.4.18 | Cardano.BM.Data.Trace | 26 |
| 1.4.19 | Cardano.BM.Configuration | 26 |
| 1.4.20 | Cardano.BM.Configuration.Model | 28 |
| 1.4.21 | Cardano.BM.Aggreated | 31 |
| 1.4.22 | Cardano.BM.Output.Switchboard | 32 |
| 1.4.23 | Cardano.BM.Output.Log | 34 |
| 1.4.24 | Cardano.BM.Output.EKGView | 39 |

| | |
|--|----|
| 1.4.25 Cardano.BM.Output.Aggregation | 41 |
|--|----|

Chapter 1

Cardano BM

1.1 Overview

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

1.2 Introduction

1.2.1 Logging with *Trace*

1.2.2 Measuring *Observables*

1.2.3 Monitoring

1.2.4 Information reduction in *Aggregation*

1.2.5 Output selection

1.2.6 Setup procedure

1.3 Examples

1.3.1 Observing evaluation of a STM action

1.3.2 Observing evaluation of a monad action

1.4 Code listings

1.4.1 Cardano.BM.Observer.STM

$$\begin{aligned} stmWithLog &:: STM.STM(t, [LogObject]) \rightarrow STM.STM(t, [LogObject]) \\ stmWithLog \ action &= action \end{aligned}$$

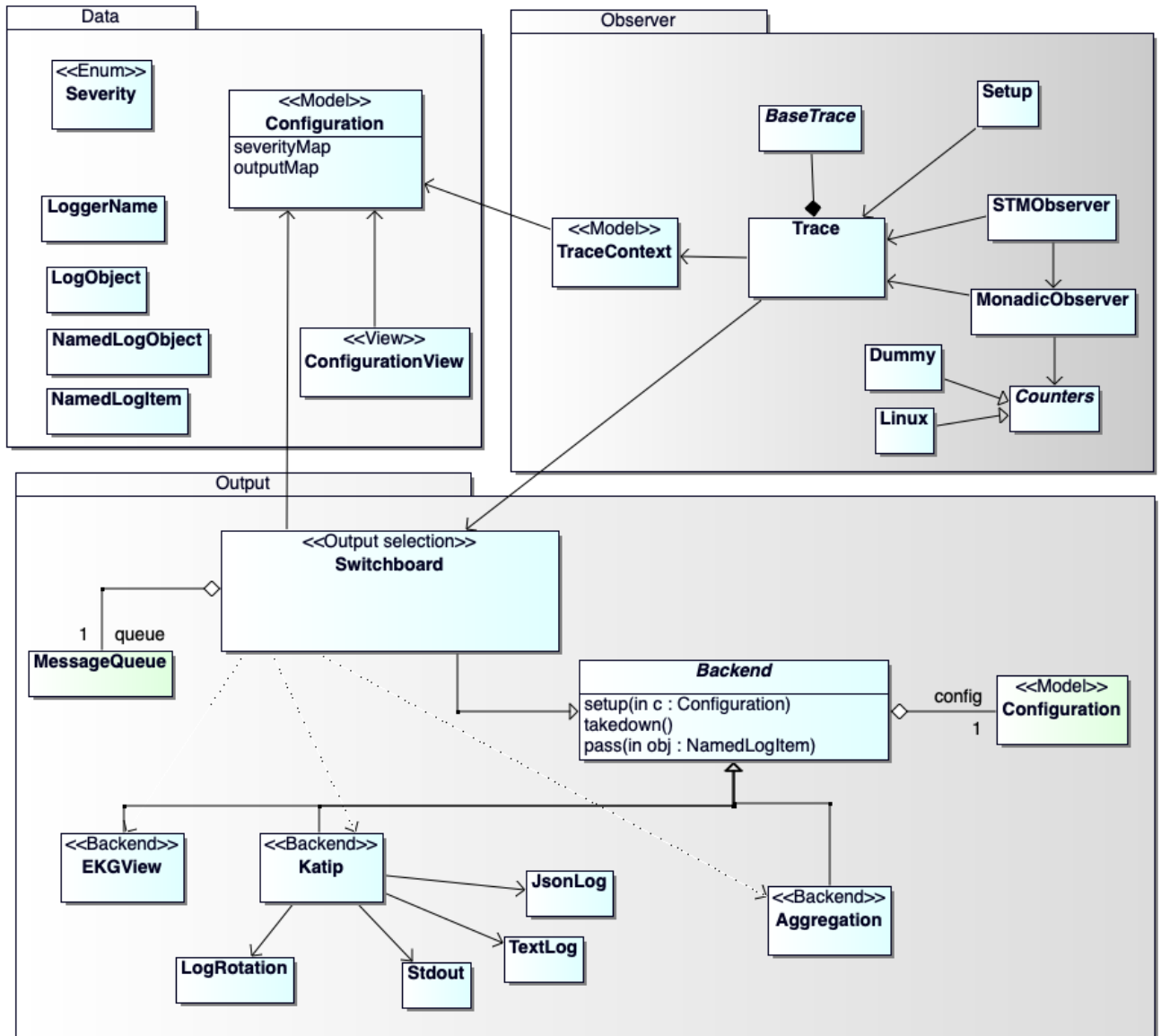


Figure 1.1: Overview of module relationships



Figure 1.2: Setup procedure

Observe STM action in a named context

```

bracketObserveIO :: Trace IO → Text → STM.STM t → IO t
bracketObserveIO logTrace0 name action = do
  (subtrace, logTrace) ← subTrace name logTrace0
  bracketObserveIO' subtrace logTrace action
bracketObserveIO' :: SubTrace → Trace IO → STM.STM t → IO t
bracketObserveIO' NoTrace _ action =
  STM.atomically action
bracketObserveIO' subtrace logTrace action = do
  countersid ← observeOpen subtrace logTrace
  -- run action, returns result only
  t ← STM.atomically action
  observeClose subtrace logTrace countersid [ ]
  pure t
  
```

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

```

bracketObserveLogIO :: Trace IO → Text → STM.STM (t, [LogObject]) → IO t
bracketObserveLogIO logTrace0 name action = do
  (subtrace, logTrace) ← subTrace name logTrace0
  bracketObserveLogIO' subtrace logTrace action
bracketObserveLogIO' :: SubTrace → Trace IO → STM.STM (t, [LogObject]) → IO t
bracketObserveLogIO' NoTrace _ action = do
  (t, _) ← STM.atomically $ stmWithLog action
  pure t
bracketObserveLogIO' subtrace logTrace action = do
  countersid ← observeOpen subtrace logTrace
  -- run action, return result and log items
  (t, as) ← STM.atomically $ stmWithLog action
  
```

```
observeClose subtrace logTrace countersid as
pure t
```

1.4.2 Cardano.BM.Observer.Monad

```
-- Observes an action and adds name given in the logger
-- name of the given Trace. If the empty Text is
-- given as name then the logger name remains untouched.
bracketObserveIO :: Trace IO → Text → IO t → IO t
bracketObserveIO logTrace0 name action = do
  (subtrace, logTrace) ← subTrace name logTrace0
  bracketObserveIO' subtrace logTrace action
bracketObserveIO' :: SubTrace → Trace IO → IO t → IO t
bracketObserveIO' NoTrace _ action = action
bracketObserveIO' subtrace logTrace action = do
  countersid ← observeOpen subtrace logTrace
  -- run action
  t ← action
  observeClose subtrace logTrace countersid [ ]
pure t

observeOpen :: SubTrace → Trace IO → IO CounterState
observeOpen subtrace logTrace = do
  identifier ← newUnique
  logInfo logTrace $ "Opening: " <> pack (show $ hashUnique identifier)
  -- take measurement
  counters ← readCounters subtrace
  let state = CounterState identifier counters
  -- send opening message to Trace
  traceNamedObject logTrace $ ObserveOpen state
  return state

observeClose :: SubTrace → Trace IO → CounterState → [LogObject] → IO ()
observeClose subtrace logTrace (CounterState identifier _) logObjects = do
  logInfo logTrace $ "Closing: " <> pack (show $ hashUnique identifier)
  -- take measurement
  counters ← readCounters subtrace
  -- send closing message to Trace
  traceNamedObject logTrace $ ObserveClose (CounterState identifier counters)
  -- trace the messages gathered from inside the action
  forM_ logObjects $ traceNamedObject logTrace
```


1.4.3 BaseTrace

Contravariant

A covariant is a functor: $F A \rightarrow F B$

A contravariant is a functor: $F B \rightarrow F A$

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

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

contramap

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

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

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

traceWith

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

```
traceWith :: BaseTrace m s  $\rightarrow$  s  $\rightarrow$  m ()
traceWith = getOp o runTrace
```

natTrace

Natural transformation from monad m to monad n .

```
natTrace :: (forall x o m x  $\rightarrow$  n x)  $\rightarrow$  BaseTrace m s  $\rightarrow$  BaseTrace n s
natTrace nat (BaseTrace (Op tr)) = BaseTrace $ Op $ nat o tr
```

noTrace

A *Trace* that discards all inputs.

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

1.4.4 Cardano.BM.Trace

Enter new named context

The context name is created and checked that its size is below a limit (currently 50 chars). The minimum severity that a log message must be labelled with is looked up in the configuration and recalculated.

```

appendName :: MonadIO m => LoggerName -> Trace m -> m (Trace m)
appendName name (ctx, trace) = do
  let prevLoggerName = loggerName ctx
      prevMinSeverity = minSeverity ctx
      newLoggerName   = appendWithDot prevLoggerName name
      globMinSeverity ← liftIO $ Config.minSeverity (configuration ctx)
      namedSeverity ← liftIO $ Config.inspectSeverity (configuration ctx) newLoggerName
  case namedSeverity of
    Nothing -> return (ctx {loggerName = newLoggerName}, trace)
    Just sev -> return (ctx {loggerName = newLoggerName
                          , minSeverity = max (max sev prevMinSeverity) globMinSeverity}
                      , trace)

appendWithDot :: LoggerName -> LoggerName -> LoggerName
appendWithDot "" newName = T.take 50 newName
appendWithDot xs "" = xs
appendWithDot xs newName = T.take 50 $ xs <> " ." <> newName

-- return a BaseTrace from a TraceNamed
named :: BaseTrace m (LogNamed i) -> LoggerName -> BaseTrace m i
named trace name = contramap (LogNamed name) trace

```

TODO remove *locallock*

```

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

```

Trace that forwards to the Switchboard

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

```

mainTrace :: Switchboard.Switchboard -> TraceNamed IO
mainTrace sb = BaseTrace $ Op $ \lognamed -> do
  Switchboard.pass sb lognamed

```

Concrete Trace on stdout

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

```

stdoutTrace :: TraceNamed IO
stdoutTrace = BaseTrace $ Op $ \lognamed ->

```

```

case lnItem lognamed of
  LP (LogMessage logItem) →
    withMVar locallock $ \_ →
      output (lnName lognamed) $ liPayload logItem
  obj →
    withMVar locallock $ \_ →
      output (lnName lognamed) $ toStrict (encodeToLazyText obj)
where
  output nm msg = TIO.putStrLn $ nm <> " :: " <> msg

```

Concrete Trace into a TVar

```

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

```

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

do we need three different *minSeverity* defined?

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

```

traceConditionally
  :: (MonadIO m)
  ⇒ TraceContext → BaseTrace m LogObject → LogObject
  → m ()
traceConditionally ctx logTrace msg@(LP (LogMessage item)) = do
  globminsev ← liftIO $ Config.minSeverity (configuration ctx)
  globnamesev ← liftIO $ Config.inspectSeverity (configuration ctx) (loggerName ctx)
  let minsev = max (minSeverity ctx) $ max globminsev (fromMaybe Debug globnamesev)
  flag = (liSeverity item) ≥ minsev
  when flag $ traceWith logTrace msg
traceConditionally _ logTrace logObject = traceWith logTrace logObject

```

Enter message into a trace

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

```

traceNamedItem
  :: (MonadIO m)
  ⇒ Trace m
  → LogSelection
  → Severity
  → T.Text
  → m ()

traceNamedItem (ctx, logTrace) p s m =
  let logmsg = LP $ LogMessage $ LogItem {liSelection = p
    ,liSeverity = s
    ,liPayload = m
    }
  in
    traceConditionally ctx (named logTrace (loggerName ctx)) $ logmsg

logDebug, logInfo, logNotice, logWarning, logError
  :: (MonadIO m) ⇒ Trace m → T.Text → m ()
logDebug logTrace = traceNamedItem logTrace Both Debug
logInfo logTrace   = traceNamedItem logTrace Both Info
logNotice logTrace = traceNamedItem logTrace Both Notice
logWarning logTrace = traceNamedItem logTrace Both Warning
logError logTrace  = traceNamedItem logTrace Both Error

logDebugS, logInfoS, logNoticeS, logWarningS, logErrorS
  :: (MonadIO m) ⇒ Trace m → T.Text → m ()
logDebugS logTrace = traceNamedItem logTrace Private Debug
logInfoS logTrace   = traceNamedItem logTrace Private Info
logNoticeS logTrace = traceNamedItem logTrace Private Notice
logWarningS logTrace = traceNamedItem logTrace Private Warning
logErrorS logTrace  = traceNamedItem logTrace Private Error

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

logDebugUnsafeP, logInfoUnsafeP, logNoticeUnsafeP, logWarningUnsafeP, logErrorUnsafeP
  :: (MonadIO m) ⇒ Trace m → T.Text → m ()
logDebugUnsafeP logTrace = traceNamedItem logTrace PublicUnsafe Debug
logInfoUnsafeP logTrace   = traceNamedItem logTrace PublicUnsafe Info
logNoticeUnsafeP logTrace = traceNamedItem logTrace PublicUnsafe Notice
logWarningUnsafeP logTrace = traceNamedItem logTrace PublicUnsafe Warning
logErrorUnsafeP logTrace  = traceNamedItem logTrace PublicUnsafe Error

traceNamedObject
  :: Trace m
  → LogObject

```

```

→ m ()
traceNamedObject (ctx, logTrace) = traceWith (named logTrace (loggerName ctx))

```

subTrace

Transforms the *Trace* according to the *Configuration* using the logger name of the current *Trace* appended with the given name. If the empty *Text* is given as name then the logger name remains untouched.

```

subTrace :: MonadIO m => T.Text → Trace m → m (SubTrace, Trace m)
subTrace name tr@(ctx, _) = do
  let newName = appendWithDot (loggerName ctx) name
  subtrace0 ← liftIO $ Config.findSubTrace (configuration ctx) newName
  let subtrace = case subtrace0 of Nothing → Neutral; Just str → str
  case subtrace of
    Neutral      → do
      tr' ← appendName name tr
      return $ (subtrace, tr')
    UntimedTrace → do
      tr' ← appendName name tr
      return $ (subtrace, tr')
    NoTrace      → return (subtrace, (ctx, BaseTrace $ Op $ \_ → pure ()))
    DropOpening  → return (subtrace, (ctx, BaseTrace $ Op $ \lognamed → do
      case lnItem lognamed of
        ObserveOpen _ → return ()
        obj           → traceNamedObject tr obj))
    ObservableTrace _ → do
      tr' ← appendName name tr
      return $ (subtrace, tr')

```

1.4.5 Cardano.BM.Setup

setupTrace

Setup a new *Trace* (*Trace*) with either a given *Configuration* (*Configuration.Model*) or a *FilePath* to a configuration file.

```

setupTrace :: MonadIO m => Either FilePath Config.Configuration → Text → m (Trace m)
setupTrace (Left cfgFile) name = do
  c ← liftIO $ Config.setup cfgFile
  setupTrace_ c name
setupTrace (Right c) name = setupTrace_ c name
setupTrace_ :: MonadIO m => Config.Configuration → Text → m (Trace m)
setupTrace_ c name = do
  sb ← liftIO $ Cardano.BM.Output ○ Switchboard.setup c
  sev ← liftIO $ Config.minSeverity c
  ctx ← liftIO $ newContext name c sev

```

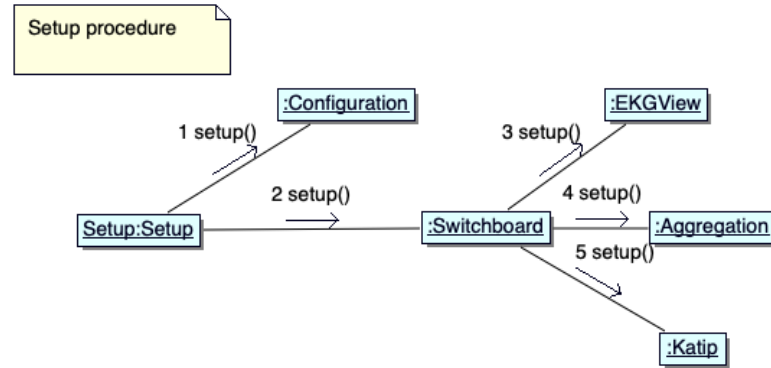


Figure 1.3: Setup procedure

```

let logTrace = (ctx, natTrace liftIO (mainTrace sb))
(⟦, logTrace'⟧) ← subTrace " " logTrace
return logTrace'

```

withTrace

```

withTrace :: MonadIO m ⇒ Config.Configuration → Text → (Trace m → m t) → m t
withTrace cfg name action = do
  logTrace ← setupTrace (Right cfg) name
  action logTrace

```

newContext

```

newContext :: LoggerName → Config.Configuration → Severity → IO TraceContext
newContext name cfg sev = do
  return $ TraceContext {
    loggerName = name
    ,configuration = cfg
    ,minSeverity = sev
  }

```

1.4.6 Cardano.BM.Counters

Here the platform is chosen on which we compile this program.

Currently, we only 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.Counter
import Data.Time.Units (Microsecond)

```

Calculate difference between clocks

```

diffTimeObserved :: CounterState → CounterState → Microsecond
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
        [(MonotonicClockTime _ micros)] → micros
        _ → error "A time measurement is missing!"
    isMonotonicClockCounter :: Counter → Bool
    isMonotonicClockCounter (MonotonicClockTime _) = True
    isMonotonicClockCounter _ = False

```

1.4.7 Cardano.BM.Counters.Common

Common functions that serve *readCounters* on all platforms.

```

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

getMonoClock :: IO [Counter]
getMonoClock = do
    t ← getMonotonicTimeNSec
    return [MonotonicClockTime "monoclock" $ nominalTimeToMicroseconds t]

```

1.4.8 Cardano.BM.Counters.Dummy

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

The only supported measurement is monotonic clock time for now.

we could well imagine that some day we support all platforms

```
readCounters :: SubTrace → IO [Counter]
readCounters NoTrace      = return []
readCounters Neutral      = return []
readCounters UntimedTrace = return []
readCounters DropOpening  = return []
readCounters (ObservableTrace tts) = foldrM (λ(sel,fun) a →
  if sel 'member' tts
  then (fun >>= λxs → return $ a ++ xs)
  else return a) [] selectors
where
  selectors = [(MonotonicClock, getMonoClock)
    -- , (MemoryStats, readProcStatM)
    -- , (ProcessStats, readProcStats)
    -- , (IOStats, readProcIO)
  ]
```

1.4.9 Cardano.BM.Counters.Linux

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

```
readCounters :: SubTrace → IO [Counter]
readCounters NoTrace      = return []
readCounters Neutral      = return []
readCounters UntimedTrace = return []
readCounters DropOpening  = return []
readCounters (ObservableTrace tts) = foldrM (λ(sel,fun) a →
  if sel 'member' tts
  then (fun >>= λxs → return $ a ++ xs)
  else return a) [] selectors
where
  selectors = [(MonotonicClock, getMonoClock)
    , (MemoryStats, readProcStatM)
    , (ProcessStats, readProcStats)
    , (IOStats, readProcIO)
  ]

pathProc :: FilePath
pathProc = "/proc/"
pathProcStat :: ProcessID → FilePath
```



```

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

```

Reading from a file in /proc/<pid>

```

readProcList :: FilePath → IO [Integer]
readProcList fp = do
  cs ← readFile fp
  return $ map (\s → maybe 0 id $ (readMaybe s :: Maybe Integer)) (words cs)

```

readProcStatM - /proc/<pid>/statm

```

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

```

```

readProcStatM :: IO [Counter]
readProcStatM = do
  pid ← getProcessID
  ps0 ← readProcList (pathProcStatM pid)
  ps ← return $ zip colnames ps0
  forM ps (\(n,i) → return $ MemoryCounter n i)
  where
    colnames :: [Text]
    colnames = ["size", "resident", "shared", "text", "unused", "data", "unused"]

```

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

```

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

```

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

- (1) pid %d
The process ID.
- (2) comm %s

The filename of the executable, in parentheses. This is visible whether or not the executable 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 combination 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, measured 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)`.

```
readProcStats :: IO [Counter]
```

```
readProcStats = do
```

```
    pid ← getProcessID
```

```
    ps0 ← readProcList (pathProcStat pid)
```

```
    ps ← return $ zip colnames ps0
```

```
    forM ps (\(n,i) → return $ StatInfo n i)
```

```
where
```

```
    colnames :: [Text]
```

```
    colnames = [ "pid", "unused", "unused", "ppid", "pgrp", "session", "ttynr", "tpgid", "flags", "minfl",
                  "cminflt", "majflt", "cmajflt", "utime", "stime", "cutime", "cstime", "priority", "nice", "num",
                  "itrealvalue", "starttime", "vsize", "rss", "rsslim", "startcode", "endcode", "startstack",
                  "signal", "blocked", "sigignore", "sigcatch", "wchan", "nswap", "cnsnap", "exitcode", "proc",
                  "policy", "blkio", "guesttime", "cguesttime", "startdata", "enddata", "startbrk", "argstart",
                  "envend", "exitcode"
                ]
```

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

```
/proc/[pid]/io (since kernel 2.6.20)
```

This file contains I/O statistics for the process, for example:

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

The fields are as follows:

rchar: characters read

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

wchar: characters written

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

syscr: read syscalls

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

```

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

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

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

cancelled_write_bytes:
    The big inaccuracy here is truncate. If a process writes 1MB to a file and then deletes the
    file, it will in fact perform no writeout. But it will have been accounted as having caused 1MB
    of write. In other words: this field represents the number of bytes which this process caused
    to not happen, by truncating pagecache. A task can cause "negative" I/O too. If this task
    truncates some dirty pagecache, some I/O which another task has been accounted for (in its
    write_bytes) will not be happening.

```

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

Permission to access this file is governed by a ptrace access mode `PTRACE_MODE_READ_FSCREDS` check; see `ptrace(2)`.

```

readProcIO :: IO [Counter]
readProcIO = do
    pid ← getProcessID
    ps0 ← readProcList (pathProcIO pid)
    ps ← return $ zip colnames ps0
    forM ps (\(n,i) → return $ IOCounter n i)
  where
    colnames :: [Text]
    colnames = ["rchar", "wchar", "syscr", "syscw", "rbytes", "wbytes", "cxwbytes"]

```

1.4.10 Cardano.BM.Data.Backend

BackendKind

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

```

data BackendKind = AggregationBK
    | EKGViewBK
    | KatipBK
deriving (Generic, Eq, Show, ToJSON, FromJSON)

```

Accepts a Type of a logged item

```

class HasPass t where
    pass :: t → NamedLogItem → IO ()

```

Backend

A backend is referenced through the function *pass'* which accepts a Type of a logged item.

```
data Backend = MkBackend {pass' :: NamedLogItem → IO ()}
```

1.4.11 Cardano.BM.Data.Configuration

Representation

```
type Port = Int
data Representation = Representation
  { minSeverity    :: Severity
  , rotation      :: 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 representation we implicitly correct it.

```
implicit_fill_representation :: Representation → Representation
implicit_fill_representation =
  union_setup_and_usage_scribes ∘
  union_setup_and_usage_backends ∘
  filter_duplicates_from_backends ∘
  filter_duplicates_from_scribes ∘
  add_katip_if_any_scribes
where
  union_setup_and_usage_scribes r = r
  union_setup_and_usage_backends r = r
  filter_duplicates_from_backends r = r
  filter_duplicates_from_scribes r = r
  add_katip_if_any_scribes r = r
```

```

test_log_backend_1 :: IO ()
test_log_backend_1 =
  BS.putStrLn $
    encode $ ScribeDefinition {scKind = StdoutSK
                              ,scName = "testlog"
                              ,scRotation = Nothing
                              }
test_log_backend_2 :: IO ()
test_log_backend_2 =
  BS.putStrLn $
    encode $ ScribeDefinition {scKind = StdoutSK
                              ,scName = "testlog"
                              ,scRotation = Just $ RotationParameters 5000000 24 10
                              }
test_conf_representation_1 :: IO ()
test_conf_representation_1 =
  BS.putStrLn $
    encode $ Representation
      { minSeverity = Info
      , rotation = RotationParameters 5000000 24 10
      , setupScribes =
        [ ScribeDefinition {scName = "stdout"
                          ,scKind = StdoutSK
                          ,scRotation = Nothing}
        ]
      , defaultScribes = [(StdoutSK, "stdout")]
      , setupBackends = [EKGVViewBK, KatipBK]
      , defaultBackends = [KatipBK]
      , hasGUI = Just 12789
      , hasEKG = Just 18321
      , options =
        HM.fromList [("test1", (HM.singleton "value" "object1"))
                    , ("test2", (HM.singleton "value" "object2"))]
      }
test_conf_representation_2 :: FilePath → IO ()
test_conf_representation_2 fp = do
  repr :: Representation ← decodeFileThrow fp
  BS.putStrLn $ encode repr

```

1.4.12 Cardano.BM.Data.Counter

Counter

```

data Counter = MonotonicClockTime Text Microsecond
  | MemoryCounter Text Integer
  | StatInfo Text Integer

```



```

    | IOCounter Text Integer
    | CpuCounter Text Integer
    deriving (Eq, Show, Generic, ToJSON)
instance ToJSON Microsecond where
    toJSON = toJSON ◦ toMicroseconds
    toEncoding = toEncoding ◦ toMicroseconds

```

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)

```

1.4.13 Cardano.BM.Data.LogItem

```
type LoggerName = Text
```

Type of a logged item

```
type NamedLogItem = LogNamed LogObject
```

LogItem

TODO *liPayload* :: ToObject

```

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

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

```

LogObject

```

data LogPrims = LogMessage LogItem
  | LogValue Text Integer
  deriving (Generic, Show, ToJSON)
data LogObject = LP LogPrims
  | ObserveOpen CounterState
  | ObserveClose CounterState
  deriving (Generic, Show, ToJSON)

```

LogNamed

A *LogNamed* contains of a list of context names and some log item.

```

data LogNamed item = LogNamed
  { lnName :: LoggerName
  , lnItem :: item
  } deriving (Show)
deriving instance Generic item  $\Rightarrow$  Generic (LogNamed item)
deriving instance (ToJSON item, Generic item)  $\Rightarrow$  ToJSON (LogNamed item)

```

1.4.14 Cardano.BM.Data.Observable**ObservableInstance**

```

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

```

1.4.15 Cardano.BM.Data.Output**OutputKind**

```

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

```

ScribeKind

This identifies katip's scribes by type.

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

ScribeId

A scribe is identified by *ScribeKind x Filename*

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

ScribeDefinition

This identifies katip's scribes by type.

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

1.4.16 Cardano.BM.Data.Severity**Severity**

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

1.4.17 Cardano.BM.Data.SubTrace

SubTrace

```
data SubTrace = Neutral
  | UntimedTrace
  | NoTrace
  | DropOpening
  | ObservableTrace (Set ObservableInstance)
  deriving (Generic, Show, FromJSON, ToJSON)
```

1.4.18 Cardano.BM.Data.Trace

Trace

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

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

TraceNamed

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

```
type TraceNamed m = BaseTrace m (LogNamed LogObject)
```

TraceContext

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

```
data TraceContext = TraceContext {
  loggerName :: LoggerName
  , configuration :: Configuration
  , minSeverity :: Severity
}
```

1.4.19 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
```

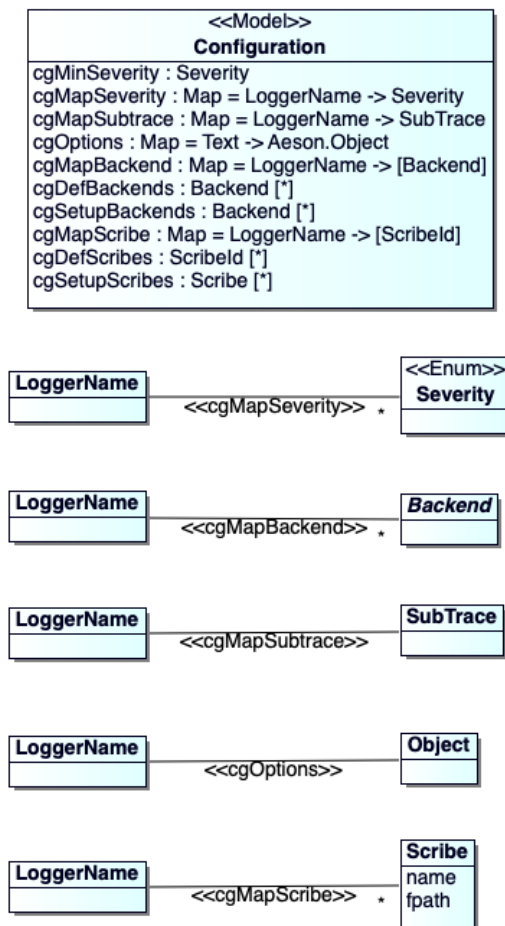


Figure 1.4: Configuration model

1.4.20 Cardano.BM.Configuration.Model

Configuration.Model

```

type ConfigurationMVar = MVar ConfigurationInternal
newtype Configuration = Configuration
    {getCG :: ConfigurationMVar}
-- Our internal state; see -"Configuration model"-
data ConfigurationInternal = ConfigurationInternal
    {cgMinSeverity    :: Severity
    ,cgMapSeverity    :: HM.HashMap LoggerName Severity
    ,cgMapSubtrace    :: HM.HashMap LoggerName SubTrace
    ,cgOptions        :: HM.HashMap Text Object
    ,cgMapBackend     :: HM.HashMap LoggerName [BackendKind]
    ,cgDefBackendKs   :: [BackendKind]
    ,cgSetupBackends :: [BackendKind]
    ,cgMapScribe      :: HM.HashMap LoggerName [ScribeId]
    ,cgDefScribes     :: [ScribeId]
    ,cgSetupScribes   :: [ScribeDefinition]
    }

```

```

TODO listOutput ← o .:? "output_map" .!= []

```

```

TODO defaultBackendKinds ← o .:? "default_backend_kinds" .!= []

```

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 =
    withMVar (getCG configuration) $ λcg → do
        let outs = HM.lookup name (cgMapBackend cg)
        case outs of
            Nothing → do
                return (cgDefBackendKs cg)
            Just os → return $ os -- TODO in (cgDefBackendKs cg)
getDefaultBackends :: Configuration → IO [BackendKind]
getDefaultBackends configuration =
    withMVar (getCG configuration) $ λcg → do
        return (cgDefBackendKs cg)
setDefaultBackends :: Configuration → [BackendKind] → IO ()
setDefaultBackends configuration bes = do
    cg ← takeMVar (getCG configuration)
    putMVar (getCG configuration) $ cg {cgDefBackendKs = bes}
setBackend :: Configuration → LoggerName → Maybe [BackendKind] → IO ()

```

```

setBackend configuration name be = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ 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 = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ cg {cgSetupBackends = bes}

```

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 =
  withMVar (getCG configuration) $ λcg → do
    let outs = HM.lookup name (cgMapScribe cg)
    case outs of
      Nothing → do
        return (cgDefScribes cg)
      Just os → return $ os
setDefaultScribes :: Configuration → [ScribeId] → IO ()
setDefaultScribes configuration scs = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ cg {cgDefScribes = scs}

```

Scribes to be setup in the Log backend

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

```

setSetupScribes :: Configuration → [ScribeDefinition] → IO ()
setSetupScribes configuration sds = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ cg {cgSetupScribes = sds}
getSetupScribes :: Configuration → IO [ScribeDefinition]
getSetupScribes configuration =
  withMVar (getCG configuration) $ λcg → do
    return $ cgSetupScribes cg

```

Options

```
getOption :: Configuration → Text → IO (Maybe Text)
getOption configuration name = do
  withMVar (getCG configuration) $ \cg →
    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 = withMVar (getCG configuration) $ \cg →
  return $ cgMinSeverity cg

setMinSeverity :: Configuration → Severity → IO ()
setMinSeverity configuration sev = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ cg {cgMinSeverity = sev}
```

Relation of context name to minimum severity

```
inspectSeverity :: Configuration → Text → IO (Maybe Severity)
inspectSeverity configuration name = do
  withMVar (getCG configuration) $ \cg →
    return $ HM.lookup name (cgMapSeverity cg)

setSeverity :: Configuration → Text → Maybe Severity → IO ()
setSeverity configuration name sev = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ cg {cgMapSeverity = HM.alter (\_ → sev) name (cgMapSeverity cg)}
```

Relation of context name to SubTrace

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

```
findSubTrace :: Configuration → Text → IO (Maybe SubTrace)
findSubTrace configuration name = do
  withMVar (getCG configuration) $ \cg →
    return $ HM.lookup name (cgMapSubtrace cg)

setSubTrace :: Configuration → Text → Maybe SubTrace → IO ()
setSubTrace configuration name trafo = do
  cg ← takeMVar (getCG configuration)
  putMVar (getCG configuration) $ cg {cgMapSubtrace = HM.alter (\_ → trafo) name (cgMapSubtrace cg)}
```


Configuration.Model.setup

```

setup :: FilePath → IO Configuration
setup fp = do
  c ← empty
  -- r <- parseRepresentation
  return c

empty :: IO Configuration
empty = do
  cgref ← newEmptyMVar
  putMVar cgref $ ConfigurationInternal Debug HM.empty HM.empty HM.empty HM.empty [] [] HM.empty []
  return $ Configuration cgref

```

1.4.21 Cardano.BM.Aggregated

```

module Cardano.BM.Aggregated
(
  Aggregated (..)
, Stats (..)
, updateAggregation
) where

data Stats = Stats {
  fmin :: Integer,
  fmax :: Integer,
  fcount :: Integer,
  fsum_A :: Integer,
  fsum_B :: Integer
} deriving (Show, Eq)

data Aggregated = Aggregated {
  fstats :: Stats,
  flast :: Integer,
  fdelta :: Stats
} deriving (Show, Eq)

```

Update aggregation

We distinguish an uninitialized from an already initialized aggregation:

```

updateAggregation :: Integer → Maybe Aggregated → Maybe Aggregated
updateAggregation v Nothing =
  Just $
    Aggregated {fstats = Stats {
      fmin = v, fmax = v, fcount = 1
      , fsum_A = v, fsum_B = v * v}

```

```

    ,flast = v
    ,fdelta = Stats {
      fmin = 0, fmax = 0, fcount = 0
      ,fsum_A = 0, fsum_B = 0}
  }
updateAggregation v (Just (Aggregated (Stats _min _max _count _sumA _sumB)
  _last
  (Stats _dmin _dmax _dcount _dsumA _dsumB)
  )) =
  let delta = v - _last
  in
  Just $
    Aggregated {fstats = Stats {
      fmin = (min _min v)
      ,fmax = (max _max v)
      ,fcount = (_count + 1)
      ,fsum_A = (_sumA + v)
      ,fsum_B = (_sumB + v * v)
    }
    ,flast = v
    ,fdelta = Stats {
      fmin = (min _dmin delta)
      ,fmax = (max _dmax delta)
      ,fcount = (_dcount + 1)
      ,fsum_A = (_dsumA + delta)
      ,fsum_B = (_dsumB + delta * delta)
    }
  }
}

```

1.4.22 Cardano.BM.Output.Switchboard

Switchboard

The switchboard is a singleton.

```

type SwitchboardMVar = MVar SwitchboardInternal
newtype Switchboard = Switchboard
  {getSB :: SwitchboardMVar}
-- Our internal state
data SwitchboardInternal = SwitchboardInternal
  {sbQueue    :: TBQ.TBQueue (Maybe NamedLogItem)
  ,sbDispatch :: Async.Async ()
  ,sbBackends :: [(BackendKind, Backend)]
  ,configuration :: Configuration
  }

```

Starting the switchboard from configuration

The queue is initialized and the message dispatcher launched. TODO: the backends should be connected according to configuration.

```

setup :: Configuration → IO Switchboard
setup cfg = do
  backends ← getDefaultBackends cfg
  bs ← setupBackends cfg [] backends
  sbref ← newEmptyMVar
  q ← atomically $ TBQ.newTBQueue 2048
  d ← spawnDispatcher sbref q
  putMVar sbref $ SwitchboardInternal q d bs cfg
  return $ Switchboard sbref
where
  spawnDispatcher :: SwitchboardMVar → TBQ.TBQueue (Maybe NamedLogItem) → IO (Async.Async ())
  spawnDispatcher switchboard queue = Async.async qProc
    where
      qProc = do
        nli' ← atomically $ TBQ.readTBQueue queue
        case nli' of
          Just nli → do
            withMVar switchboard $ \sb → do
              selbes ← getBackends (configuration sb) (lnName nli)
              forM_ (sbBackends sb) (λ(bek, be) →
                when (bek ∈ selbes) (dispatch nli be))
            qProc
          Nothing → return () -- end dispatcher
      dispatch :: NamedLogItem → Backend → IO ()
      dispatch nli backend = (pass' backend) nli

  setupBackends :: Configuration → [(BackendKind, Backend)] → [BackendKind] → IO [(BackendKind, Backend)]
  setupBackends _ acc [] = return acc
  setupBackends c acc (bk : bes) = do
    be' ← setupBackend' bk c
    setupBackends c ((bk, be') : acc) bes

  setupBackend' :: BackendKind → Configuration → IO Backend
  setupBackend' EKGViewBK c = do
    be ← Cardano.BM.Output ∘ EKGView.setup c
    return $ MkBackend {pass' = Cardano.BM.Output ∘ EKGView.pass be}

  setupBackend' AggregationBK c = do
    be ← Cardano.BM.Output ∘ Aggregation.setup c
    return $ MkBackend {pass' = Cardano.BM.Output ∘ Aggregation.pass be}

  setupBackend' KatipBK c = do
    be ← Cardano.BM.Output ∘ Log.setup c
    return $ MkBackend {pass' = Cardano.BM.Output ∘ Log.pass be}

```

Process incoming messages

Incoming messages are put into the queue, and then processed by the dispatcher.

```
instance HasPass Switchboard where
  pass switchboard item = do
    let writequeue :: TBQ.TBQueue (Maybe NamedLogItem) → NamedLogItem → STM ()
    writequeue q i = do
      nocapacity ← TBQ.isFullTBQueue q
      if ¬ nocapacity
      then TBQ.writeTBQueue q (Just i)
      else return ()
    withMVar (getSB switchboard) $ λsb →
      atomically $ writequeue (sbQueue sb) item
```

Halting the switchboard

The queue is flushed before the dispatcher terminates.

```
takedown :: Switchboard → IO ()
takedown switchboard = do
  (q,d) ← withMVar (getSB switchboard) $ λsb →
    return (sbQueue sb, sbDispatch sb)
  -- send terminating item to the queue
  atomically $ TBQ.writeTBQueue q Nothing
  -- wait for the dispatcher to exit
  _ ← Async.waitCatch d
  return ()
```

1.4.23 Cardano.BM.Output.Log

Log is a singleton.

```
type KatipMVar = MVar KatipInternal
newtype Log = Log
  {getK :: KatipMVar}
-- Our internal state
data KatipInternal = KatipInternal
  {kLogEnv :: K.LogEnv
   ,configuration :: Config.Configuration}

instance HasPass Log where
  pass katip item = do
    c ← withMVar (getK katip) $ λk → return (configuration k)
    selscribes ← getScribes c (lnName item)
    forM_ selscribes $ λsc → passN sc katip item
```

Setup *katip* and its scribes according to the configuration

```

setup :: Config.Configuration → IO Log
setup config = do
  cfoKey ← Config.getOptionOrDefault config (pack "cfokey") (pack "<unknown>")
  -- TODO setup katip
  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
    -- stdoutScribe <- mkStdoutScribeJson K.V0
    -- le <- register [(StdoutSK, "stdout", stdoutScribe)] le1
  kref ← newEmptyMVar
  putMVar kref $ KatipInternal le config
  return $ Log kref
where
  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
    name' = pack (show kind) <> ":" <> name
    scr ← createScribe kind name
    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 = mkTextFileScribe (FileDescription $ unpack name) False
  createScribe FileJsonSK name = mkJsonFileScribe (FileDescription $ unpack name) False
  createScribe StdoutSK _ = mkStdoutScribe
  createScribe StderrSK _ = mkStderrScribe

example :: IO ()
example = do
  config ← Config.setup "from_some_path.yaml"
  k ← setup config
  passN (pack (show StdoutSK)) k $ LogNamed
    {lnName = "test"}

```

```

    ,lnItem = LP $ LogMessage $ LogItem
      { liSelection = Both
      , liSeverity = Info
      , liPayload = "Hello!"
      }
  }
passN (pack (show StdoutSK)) k $ LogNamed
  { lnName = "test"
  , lnItem = LP $ LogValue "cpu-no" 1
  }

-- useful instances for katip
deriving instance K.ToObject LogObject
deriving instance K.ToObject LogItem
deriving instance K.ToObject (Maybe LogObject)
instance KC.LogItem LogObject where
  payloadKeys _ = KC.AllKeys
instance KC.LogItem LogItem where
  payloadKeys _ = KC.AllKeys
instance KC.LogItem (Maybe LogObject) where
  payloadKeys _ = KC.AllKeys

```

Log.passN

The following function copies the *NamedLogItem* to the queues of all scribes that match on their name. This function is non-blocking.

```

passN :: Text → Log → NamedLogItem → IO ()
passN backend katip namedLogItem = do
  env ← withMVar (getK katip) $ λk → return (kLogEnv k)
  -- TODO go through list of registered scribes
  -- and put into queue of scribe if backend kind matches
  -- compare start of name of scribe to (show backend <> "::")
  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 item = lnItem namedLogItem
        let (sev, msg, payload) = case item of
          (LP (LogMessage logItem)) →
            (liSeverity logItem, liPayload logItem, Nothing)
          _ → (Info, "", Just item)
        threadIdText ← KC.mkThreadIdText < $ > myThreadId
        let ns = lnName namedLogItem
        itemTime ← env ^. KC.logEnvTimer
        let itemKatip = K.Item {

```

```

    _itemApp      = env ^. KC.logEnvApp
    , _itemEnv    = env ^. KC.logEnvEnv
    , _itemSeverity = sev2klog sev
    , _itemThread = threadIdText
    , _itemHost   = env ^. KC.logEnvHost
    , _itemProcess = env ^. KC.logEnvPid
    , _itemPayload = payload
    , _itemMessage = K.logStr msg
    , _itemTime   = itemTime
    , _itemNamespace = (env ^. KC.logEnvApp) <> (K.Namespace [ ns ])
    , _itemLoc    = Nothing
  }
  atomically $ KC.tryWriteTBQueue shChan (KC.NewItem itemKatip)
else return False

```

Scribes

```

mkStdoutScribe :: IO K.Scribe
mkStdoutScribe = mkTextFileScribeH stdout True

mkStderrScribe :: IO K.Scribe
mkStderrScribe = mkTextFileScribeH stderr True

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

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

mkTextFileScribe :: FileDescription → Bool → IO K.Scribe
mkTextFileScribe fdesc colorize = do
  mkFileScribe fdesc formatter colorize
where
  formatter :: Handle → Bool → K.Verbosity → K.Item a → IO ()
  formatter hdl colorize' v' item = do
    let tmsg = toLazyText $ formatItem colorize' v' item

```

```

TIO.hPutStrLn hdl tmsg
mkJsonFileScribe :: FileDescription → Bool → IO K.Scribe
mkJsonFileScribe fdesc colorize = do
  mkFileScribe fdesc formatter colorize
where
  formatter :: (K.LogItem a) ⇒ Handle → Bool → K.Verbosity → K.Item a → IO ()
  formatter h _ verbosity item = do
    let tmsg = case KC._itemMessage item of
      K.LogStr " " → K.itemJson verbosity item
      K.LogStr msg → K.itemJson verbosity $
        item { KC._itemMessage = K.logStr (" " :: Text)
              , KC._itemPayload = LogItem Both Info $ toStrict $ toLazyText msg
              }
    TIO.hPutStrLn h (encodeToLazyText tmsg)
mkFileScribe
  :: FileDescription
  → (forall a ◦ K.LogItem a ⇒ Handle → Bool → K.Verbosity → K.Item a → IO ())
  → Bool
  → IO K.Scribe
mkFileScribe fdesc formatter colorize = do
  let prefixDir = prefixPath fdesc
  (createDirectoryIfMissing True prefixDir)
  'catchIO' (prtoutException ("cannot log prefix directory: " ++ prefixDir))
  let fpath = filePath fdesc
  h ← catchIO (openFile fpath WriteMode) $
    λe → do
      prtoutException ("error while opening log: " ++ fpath) e
      -- fallback to standard output in case of exception
      return stdout
  hSetBuffering h LineBuffering
  scribestate ← newMVar h
  let finalizer :: IO ()
  finalizer = withMVar scribestate hClose
  let logger :: forall a ◦ K.LogItem a ⇒ K.Item a → IO ()
  logger item =
    withMVar scribestate $ λhandler →
      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

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

-- display message and stack trace of exception on stdout
prtoutException :: Exception e ⇒ String → e → IO ()
prtoutException msg e = do
  putStrLn msg
  putStrLn ("exception: " ++ displayException e)

```

1.4.24 Cardano.BM.Output.EKGView

The ekgview is a singleton.

```

type EKGViewMVar = MVar EKGViewInternal
newtype EKGView = EKGView
    {getEV :: EKGViewMVar}
-- Our internal state
data EKGViewInternal = EKGViewInternal
    {evGauges :: HM.HashMap Text Gauge.Gauge
    ,evLabels  :: HM.HashMap Text Label.Label
    ,ekgServer :: Server
    }

setup :: Configuration → IO EKGView
setup _ = do
    evref ← newEmptyMVar
    ehdl ← forkServer "127.0.0.1" 16543
    putMVar evref $ EKGViewInternal HM.empty HM.empty ehdl
    return $ EKGView evref

instance HasPass EKGView where
    pass ekgtview item =
        let update :: LogObject → LoggerName → EKGViewInternal → IO (Maybe EKGViewInternal)
            update (LP (LogMessage logitem)) logname ekg@(EKGViewInternal _ labels server) =
                case HM.lookup logname labels of
                    Nothing → do
                        ekghdl ← getLabel logname server
                        Label.set ekghdl (liPayload logitem)
                        return $ Just $ ekg {evLabels = HM.insert logname ekghdl labels}
                    Just ekghdl → do
                        Label.set ekghdl (liPayload logitem)
                        return Nothing
            update (LP (LogValue iname value)) logname ekg@(EKGViewInternal gauges _ server) =
                let name = logname <> "." <> iname
                in
                case HM.lookup name gauges of
                    Nothing → do
                        ekghdl ← getGauge name server
                        Gauge.set ekghdl (fromInteger value)
                        return $ Just $ ekg {evGauges = HM.insert name ekghdl gauges}
                    Just ekghdl → do
                        Gauge.set ekghdl (fromInteger value)
                        return Nothing
            update _ _ _ = return Nothing
        in do
            ekg ← takeMVar (getEV ekgtview)
            upd ← update (lnItem item) (lnName item) ekg
            case upd of
                Nothing → putMVar (getEV ekgtview) ekg
                Just ekg' → putMVar (getEV ekgtview) ekg'

```

1.4.25 Cardano.BM.Output.Aggregation

The aggregation is a singleton.

```

type AggregationMVar = MVar AggregationInternal
newtype Aggregation = Aggregation
    {getAg :: AggregationMVar}
-- Our internal state
data AggregationInternal = AggregationInternal
    {agMap :: HM.HashMap Text Aggregated
    ,agSome :: [Int]-- TODO
    }

inspect :: Aggregation → Text → IO (Maybe Aggregated)
inspect agg name =
    withMVar (getAg agg) $ \ag →
        return $ HM.lookup name (agMap ag)

setup :: Configuration → IO Aggregation
setup _ = do
    aggref ← newEmptyMVar
    -- TODO create thread which will periodically output
    -- aggregated values to the switchboard
    putMVar aggref $ AggregationInternal HM.empty []
    return $ Aggregation aggref

pass :: Aggregation → NamedLogItem → IO ()
pass agg item = do
    ag ← takeMVar (getAg agg)
    putMVar (getAg agg) $ AggregationInternal (updated $ agMap ag) (agSome ag)
where
    updated agmap = pass' (lnItem item) (lnName item) agmap
    pass' :: LogObject → LoggerName → HM.HashMap Text Aggregated → HM.HashMap Text Aggregated
    pass' (LP (LogValue iname value)) logname agmap =
        let name = logname <> "." <> iname
        in
            HM.alter (λm → updateAggregation value m) name agmap
    -- TODO for text messages aggregate on delta of timestamps
    pass' _ _ agmap = agmap

```