1 Basic Rule Set

1.1 Configuration Objectives

```
/* -- configuration ------------------------------ */
        EvaluationPeriod 0.1
        RewardDelay 2
```

1.2 Set Definitions

```
/* -- app sets ----------------------------------- */

        DefineSet LocalUnhealthyApps :
        App Local Where Health < 0, PeriodTune >= 0
        Note "Local Apps with health value
        below 0 (and not paused)"

        DefineSet LocalUnhealthyTunableApps :
        App Local Where Health < 0, PeriodTune < Limit
        Note "Local Apps with health value
        below 0 that still can be tuned"

        DefineSet GlobalUnhealthyApps :
        App Global Where Health < 0
        Note "Global Apps with health value
        below 0"

        DefineSet LeastImportantTunableApps :
        App Global Where LifeSignAge <= Limit,
        NodeLifeSignAge <= Limit,
        PeriodTune < Limit, Importance Min
        Note "The least important apps in the system which
        still can be tuned (so app and node have also
        to be alive)"

        DefineSet LeastImportantCompressableApps :
        App Global Where CompressFactor < Limit,
```

```
        Importance Min
        Note "The least important apps in the system which
        still can be compressed"

        DefineSet LeastImportantPausableApps :
        App Global Where PeriodTune >= 0,
        Importance Min
        Note "The least important apps in the system
        which still can be paused"

        DefineSet MostImportantLocalCompressedHealthyApps :
        App Local Where CompressFactor > 0, Health >= 0.6,
        Importance Max
        Note "The most important local apps that
        are compressed"

        DefineSet MostImportantLocalTunedHealthyApps :
        App Local Where PeriodTune > 1, Health >= 0.6,
        Importance Max
        Note "The most important local apps that are tuned"

        DefineSet MostImportantLocalPausedApps :
        App Local Where PeriodTune < 0,
        Importance Max
        Note "The most important local apps that
        are paused"

        DefineSet MostImportantDeadApps :
        App System Where LifeSignAge > Limit,
        PeriodTune >= 0, Importance Max
        Note "The most important system apps with expired
        life signs (an which are not paused)"

        DefineSet ForeignOrphans :
        App LocalNonSystem Where SystemLifeSignAge > Limit
        Note "Non-system apps running on our locale node
        where we have lost contact to their systems"

/* -- node sets ------------------------------- */

        DefineSet LocalUnhealthyNode :
        Node Local Where Health <= 0.1
        Note "Local node with health value of
        0.1 and below"
```

```
        DefineSet LocalHealthyNode :
        Node Local Where Health >= 0.36
        Note "Local node with health value of
        0.36 and above"

        DefineSet NonLocalSuitableNode :
        Node NonLocal Where
        Capacity % >= Demand + 0.15 (LocalUnhealthyApps),
        LifeSignAge <= Limit, Health Max
        Note "Non local alive node with enough
        capacity (leave 15% free) to take an unhealthy app"

        DefineSet
        LocalNodeWithFifoAlsoAllowsPriorityScheduling :
        Node Local Where Scheduling = 0, MaxScheduling > 0
        Note "Local node which uses FIFO scheduling,
        but also allows priority scheduling"

        DefineSet
        LocalNodeWithoutPreemptionAlsoAllowsPreemption :
        Node Local Where Preemption = 0, MaxPreemption > 0
        Note "Local node which uses no preemption, but
        also allows preemption"

        DefineSet AliveNodeWithLowestIdIsLocal :
        Node System Where LifeSignAge <= Limit,
        Id Min, HopCount = 0
        Note "Contains the alive node with the lowest
         id in the system if this is the local node"

        DefineSet SuitableNodeForMostImportantDeadApps :
        Node Global Where LifeSignAge <= Limit,
        Capacity >= Demand (MostImportantDeadApps),
        Health Max
        Note "Global alive node with enough capacity
        to take the most important dead app"

/* -- comm sets -------------------------------- */

        DefineSet LocalUnhealthyComm :
        Comm Local Where Health <= 0.15
        Note "Local comm with health value of
        0.15 and below"
```

```
        DefineSet LocalHealthyComm :
        Comm Local Where Health >= 0.5
        Note "Local comm with health value of
        0.5 and above"

        DefineSet LocalVeryHealthyComm :
        Comm Local Where Health >= 0.65
        Note "Local comm with health value of
        0.65 and above"

        DefineSet
        LocalCommWithFifoAlsoAllowsPriorityScheduling :
        Comm Local Where Scheduling = 0, MaxScheduling > 0
        Note "Local comm which uses FIFO scheduling,
        but also allows priority scheduling"

        DefineSet
        LocalCommWithoutPreemptionAlsoAllowsPreemption :
        Comm Local Where Preemption = 0, MaxPreemption > 0
        Note "Local comm which uses no preemption, but
        also allows preemption"
```

1.3 Condition Definitions

```
/* -- the conditions ---------------------------- */
        DefineCondition RelocationMightBeUseful : C
        ardinal (LocalUnhealthyApps) > 0 And
        Cardinal (LocalUnhealthyNode) > 0 And
        Cardinal (LocalUnhealthyComm) = 0 And
        Cardinal (NonLocalSuitableNode) > 0
        Note "If there are unhealthy apps on an
        unhealthy node, but comm is ok and there are
        powerful nodes available, a relocation might
         be useful"

        DefineCondition CompressionMightBeUseful :
        Cardinal (LocalUnhealthyApps) > 0 And
        Cardinal (LocalUnhealthyComm) > 0 And
        Cardinal (LeastImportantCompressableApps) > 0
        Note "If there are unhealthy apps and an unhealthy
        comm and there are still apps that can be
        compressed, compression might be useful"
```

```
DefineCondition TuningMightBeUseful :
Cardinal (LocalUnhealthyApps) > 0 And
Cardinal (LocalUnhealthyComm) > 0 And
Cardinal (LeastImportantCompressableApps) = 0 And
Cardinal (LeastImportantTunableApps) > 0
Note "If there are unhealthy apps and an unhealthy
comm and there are no more apps that can be
compressed but still apps that can be
tuned, tuning might be useful"

DefineCondition TuningUnhealthyAppsMightBeUseful :
Cardinal (LocalUnhealthyTunableApps) > 0 And
Cardinal (LocalUnhealthyComm) = 0
Note "If there are unhealthy apps that still
can be tuned while comm is healthy, tuning
might be useful (also to make room for relocation)"

DefineCondition
TuningRemainingTunableAppsMightBeUseful :
Cardinal (LocalUnhealthyApps) > 0 And
Cardinal (LocalUnhealthyComm) = 0 And
Cardinal (LocalUnhealthyTunableApps) = 0 And
Cardinal (LeastImportantTunableApps) > 0
Note "If there are unhealthy apps while comm is
healthy and there are still tunable apps left,
tuning these apps might be useful
(also to make room for relocation)"

DefineCondition PausingMightBeUseful :
Cardinal (LocalUnhealthyApps) > 0  And
Cardinal (LeastImportantCompressableApps) = 0 And
Cardinal (LeastImportantTunableApps) = 0 And
Cardinal (LeastImportantPausableApps) > 0
Note "If there are unhealthy apps and there
are no more apps that can be compressed or
tuned but still apps that can be paused,
pausing might be useful
(also to make room for relocation) "

DefineCondition
PriorityNodeSchedulingMightBeUseful :
Cardinal (GlobalUnhealthyApps) > 0 And
Cardinal
```

```
        (LocalNodeWithFifoAlsoAllowsPriorityScheduling) > 0
        Note "If there are unhealthy apps in the system
        and our local node is on fifo scheduling but allows
        also priority based scheduling, a switch to
        priority based scheduling might be useful"

        DefineCondition
        PriorityCommSchedulingMightBeUseful :
        Cardinal (GlobalUnhealthyApps) > 0 And
        Cardinal
        (LocalCommWithFifoAlsoAllowsPriorityScheduling) > 0
        Note "If there are unhealthy apps in the system and
        our local comm is on fifo scheduling but allows
        also priority based scheduling, a switch to
        priority based scheduling might be useful"

        DefineCondition NodePreemptionMightBeUseful :
        Cardinal (GlobalUnhealthyApps) > 0 And
        Cardinal
        (LocalNodeWithoutPreemptionAlsoAllowsPreemption)>0
        Note "If there are unhealthy apps in the system
        and our local node allows preemption but preemption
        is not active, a switch to preemption
        might be useful"

        DefineCondition CommPreemptionMightBeUseful :
        Cardinal (GlobalUnhealthyApps) > 0 And
        Cardinal
        (LocalCommWithoutPreemptionAlsoAllowsPreemption)>0
        Note "If there are unhealthy apps in the
        system and our local comm allows preemption but
        preemption is not active, a switch to preemption
        might be useful"

        DefineCondition UnpausingMightBePossible :
        Cardinal (MostImportantLocalPausedApps) > 0 And
        Cardinal (LocalHealthyNode) > 0 And
        Cardinal (LocalHealthyComm) = MaxSet
        Note "If there are local paused apps and the state
        of the local node and comm is quite good,
        unpausing might be possible"

        DefineCondition UntuningMightBePossible :
        Cardinal (MostImportantLocalTunedHealthyApps) > 0
```

```
And Cardinal (MostImportantLocalPausedApps) = 0
And Cardinal (LocalHealthyNode) > 0 And
Cardinal (LocalHealthyComm) = MaxSet
Note "If there are local tuned healthy apps and
no more local paused apps and the state of the
local node and comm is quite good ,
untuning might be possible"

DefineCondition UncompressingMightBePossible :
Cardinal
(MostImportantLocalCompressedHealthyApps) > 0 And
Cardinal (MostImportantLocalTunedHealthyApps) = 0
And Cardinal (MostImportantLocalPausedApps) = 0
And Cardinal (LocalHealthyNode) > 0 And
Cardinal (LocalVeryHealthyComm) = MaxSet
Note "If there are local compressed healthy apps
and no more local tuned or paused apps and the
state of the local node and comm is good ,
uncompresssing might be possible"

DefineCondition RestartMightBeUseful :
Cardinal (AliveNodeWithLowestIdIsLocal) > 0 And
Cardinal (MostImportantDeadApps) > 0 And
Cardinal (SuitableNodeForMostImportantDeadApps) > 0
Note "If the alive node with the lowest id is the
local node and this node detects important apps
with expired lifesigns and we have node capacity,
a restart of these apps might be a good idea
(so only one node does the restart, no conflicts)"

DefineCondition
TuningToEnableRestartMightBeUseful :
Cardinal (AliveNodeWithLowestIdIsLocal) > 0 And
Cardinal (MostImportantDeadApps) > 0 And
Cardinal (SuitableNodeForMostImportantDeadApps) = 0
And Cardinal (LeastImportantTunableApps) > 0
Note "If the alive node with the lowest id is the
local node and this node detects important apps
with expired lifesigns and we have no node capacity
but still tunable apps, tuning might be
useful to create capacity"

DefineCondition
PausingToEnableRestartMightBeUseful :
```

```
        Cardinal (AliveNodeWithLowestIdIsLocal) > 0 And
        Cardinal (MostImportantDeadApps) > 0 And
        Cardinal (SuitableNodeForMostImportantDeadApps) = 0
        And Cardinal (LeastImportantTunableApps) = 0 And
        Cardinal (LeastImportantPausableApps) > 0
        Note "If the alive node with the lowest id is
        the local node and this node detects important apps
        with expired lifesigns and we have no node capacity
        and no tunable apps but still pausable apps,
        pausing might be useful to create capacity"

        DefineCondition ForeignOrphansExist :
        Cardinal (ForeignOrphans) > 0
        Note "Do foreign orphans exist once a
        foreign CPS gets lost and we still
        have remains running"
```

1.4 Action Definitions

```
/* -- the actions ------------------------------ */

        DefineAction RelocateLocalUnhealthyApp :
        Relocate LocalUnhealthyApps To NonLocalSuitableNode
        Note "Relocate one local unhealthy
        app to a suitable node"

        DefineAction CompressLeastImportantApp :
        Compress LeastImportantCompressableApps To
        Current Limit
        Note "Compress the least important
        compressabe app to its limit"

        DefineAction TuneLeastImportantApp :
        TunePeriodAndPriority LeastImportantTunableApps To
        Current Limit
        Note "Tune the least important tuneable
        app to its limit"

        DefineAction TuneLocalUnhealthyApps :
        TunePeriodAndPriority LocalUnhealthyTunableApps To
        Current Limit
        Note "Tune a local unhealthy app to its limit"
```

```
DefineAction PauseLeastImportantApp :
TunePeriod LeastImportantPausableApps To -1
Note "Pause the least important pausable app"

DefineAction PauseLeastImportantAppFast :
TunePeriod LeastImportantPausableApps To -1
RewardDelay 0.3
Note "Pause the least important pausable app
(short reward delay to quickly make room)"

DefineAction ActivatePriorityNodeScheduling :
SetScheduling
LocalNodeWithFifoAlsoAllowsPriorityScheduling To
1 Adjust
Note "Activate priority based scheduling on local
node which currently is on fifo scheduling and
assign app priorities"

DefineAction ActivatePriorityCommScheduling :
SetScheduling
LocalCommWithFifoAlsoAllowsPriorityScheduling To 1
Note "Activate priority based scheduling on local
comms which are currently on fifo scheduling"

DefineAction ActivateNodePreemption :
SetPreemption
LocalNodeWithoutPreemptionAlsoAllowsPreemption To 2
Note "Activate preemption on local node
which currently does not use preemption"

DefineAction ActivateCommPreemption :
SetPreemption
LocalCommWithoutPreemptionAlsoAllowsPreemption To 2
Note "Activate preemption on local comms
which currently do not use preemption"

DefineAction UnpauseMostImportantLocalApp :
TunePeriodAndPriority MostImportantLocalPausedApps
To Current Limit
Note "Unpause the most important local app that
is paused"

DefineAction UntuneMostImportantLocalApp :
TunePeriodAndPriority
```

```
        MostImportantLocalTunedHealthyApps To
        Current -0.5 ExpLimitDown 1
        Note "Untune the most important local app
        that is tuned down by 0.5, don't go below 1"

        DefineAction UncompressMostImportantLocalApp :
        Compress MostImportantLocalCompressedHealthyApps To
        Current -0.1 ExpLimitDown 0
        Note "Uncompress the most important local app
        that is compressed down by 0.1, don't go below 0"

        DefineAction RestartDeadApp :
        Restart MostImportantDeadApps On
        SuitableNodeForMostImportantDeadApps
        RewardDelay 0.3
        Note "Restart the most important dead app
        on a suitable alive node"

        DefineAction KillForeignOrphans :
        Remove All ForeignOrphans
        Note "Kill all foreign orphans"
```

1.5 Rule Definitions

```
/* -- the rules ---------------------------------- */

        /* -- group 1: rules for crashes -- */

        If RestartMightBeUseful Then RestartDeadApp
        Note "Rule for restarting dead apps"

        /* rules to make room for restarting crashed
        apps in overload situations */

        If TuningToEnableRestartMightBeUseful
        Then TuneLeastImportantApp
        Note "Rule to tune the least important app in case
        there is no capacity to restart a crashed app"

        If PausingToEnableRestartMightBeUseful
        Then PauseLeastImportantAppFast
        Note "Rule to pause the least important app in
        case there is no capacity to restart a crashed
```

```
        app (this also includes crashed apps => the most
        important apps will run)"

        /* -- group 2: general rules for
        overload situations -- */

        If RelocationMightBeUseful
        Then RelocateLocalUnhealthyApp
        Note "Rule for relocation"

        If CompressionMightBeUseful
        Then CompressLeastImportantApp
        Note "Rule for compression"

        If TuningMightBeUseful Then TuneLeastImportantApp
        Note "Rule for tuning"

        If TuningUnhealthyAppsMightBeUseful
        Then TuneLocalUnhealthyApps Lag 2
        Note "Rule if we have unhealthy tunable
        apps but comm is ok, lag due to race conditions"

        If TuningRemainingTunableAppsMightBeUseful
        Then TuneLeastImportantApp Lag 2
        Note "Rule if we have unhealthy apps but comm
        is ok and there are still tunable apps left,
        lag due to race conditions"

        If PausingMightBeUseful Then PauseLeastImportantApp
        Note "Rule for pausing"

        /* -- group 3: rules for scheduling issues -- */

        If PriorityNodeSchedulingMightBeUseful
        Then ActivatePriorityNodeScheduling
        Note "Rule to fix scheduling issues on nodes"

        If PriorityCommSchedulingMightBeUseful
        Then ActivatePriorityCommScheduling
        Note "Rule to fix scheduling issues on comms"

        If NodePreemptionMightBeUseful
        Then ActivateNodePreemption
        Note "Rule to fix preemption issues on nodes"
```

```
If CommPreemptionMightBeUseful
Then ActivateCommPreemption
Note "Rule to fix preemption issues on comms"

/* -- group 4: rules for undoing
overload measures -- */

If UnpausingMightBePossible
Then UnpauseMostImportantLocalApp
Note "Rule for undo pausing if the
situation gets better"

If UntuningMightBePossible
Then UntuneMostImportantLocalApp
Note "Rule for undo tuning if the
situation gets better"

If UncompressingMightBePossible
Then UncompressMostImportantLocalApp
Note "Rule for undo compression if the
situation gets better"

/* -- group 5: rules to kill foreign orphans -- */

If ForeignOrphansExist Then KillForeignOrphans
Note "Rule for killing foreign orphans once a
foreign CPS gets lost and we still have
remains running"
```