Lw and ULw POSIX AEPs for Resource Constrained Processors

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Executive Summary

This specification addresses specification of standard software interfaces applicable between SDR Applications and RTOS available on resource constrained processors such as DSPs.

It has been elaborated by the Wireless Innovation Forum as a contribution to SCA 4.1 elaboration, and aims at providing standard solution for the broadest range of actors of the SDR eco-system.

It defines base AEPs groups of POSIX functions for “Lightweight” / “Lw” and “Ultra-Lightweight” / “ULw” AEPs, in complement to the POSIX AEP defined by SCA 2.2.2.

Both have the same features for threads, semaphores, mutexes, timers and message queues. The Lw profile additionally features condition variables. The ULw brings minor restrictions concerning message queues (limited size and no support of priorities).

By contrast to the SCA AEPs, the AEPs defined in this specification do not address support of C language standard libraries.

In addition to the base AEPs groups, the specification defines two additional groups of POSIX functions, which enable to complement the base AEPs groups with: (i) run-time detection of errors, (ii) release of RTOS resources for SDR Application termination.

As support content, an exhaustive overview of the specification content is provided, by positioning content in front of the entire set of POSIX functions, as done in the SCA 2.2.2 Appendix B tables.

Besides, exhaustive rationale regarding the design choices is provided, on a function-by-function basis.

This specification is a solution that took into account and harmonized two publicly available solutions: the SCA 4.0.1 Lw AEP and the ESSOR Architecture DSP AEP.

It is expected that this specification will be broadly used within the international SDR eco-system structured through usage of SDR standards supporting SDR Applications portability.
Contributors

The direct contributors to this specification were:

- Aeroflex, with Dave Hagood as main contributor.
- Harris Corporation, with Dave Carlson as main contributor,
- Hitachi Kokusai Electric, with Dave Murotake as main contributor,
- Raytheon, with Jimmie Marks as main contributor,
- THALES Communications & Security, with Eric Nicollet as main contributor.

Direct contributions to the specification have been provided by contributors working with JTNC Standards, who provided methodological guidance in order to facilitate later exploitation of the specification in the elaboration process of SCA 4.1.
Lw and ULw POSIX AEPs for Resource Constrained Processors

1 Introduction

1.1 Aim of the specification

1.1.1 Positioning

This specification addresses definition of standard software interfaces between SDR (Software Defined Radio) Applications and RTOS (Real-Time Operating System) capabilities of SDR OEs (Operating Environments), addressing resource constrained processors.

The said software interfaces are defined as POSIX™-compliant (Portable Operating System Interfaces) Application Environment Profiles (AEPs).

This specification defines groups of POSIX functions that can be used by specification users for definition of “Lightweight” / “Lw” and “Ultra-Lightweight” / “ULw” AEPs applicable for their work products, in complement to the POSIX AEP defined by SCA 2.2.2.

By resource constrained processors are meant processors where a single address space is available (implying absence of process concept) and where no file system is implemented.

The SDR Applications running on such environments are considered to be hard-real time applications, implying their execution is constrained by strict execution deadlines.

While DSPs (Digital Signal Processors) are typical examples of what is meant by resource constrained processors, the set of potentially interested processors is broader than only DSPs, while this specification is not relevant for DSPs where not RTOS is available.

The specification supports emergence of portable SDR Applications and open, standard compliant, Operating Environments in resource constrained processors.
The addressed AEPs address a range of processors that were not covered by the SCA 2.2.2 AEP, which was primarily established for GPPs (General Purpose Processors).

By contrast to the AEP defined in SCA 2.2.2, only the relationship between SDR Application and RTOS capabilities of OEs are addressed. Other aspects addressed by POSIX are SCA 2.2.2 AEP, in particular the support of standard C language libraries, is not part of this specification.

1.1.2 Elaboration context and initial objectives

The AEPs addressed in this specification are primarily aimed at supporting elaboration of SCA 4.1. Besides, they are subject to be used by any interested user within the SDR eco-system.

The reference POSIX specification taken as basis for elaboration of the specification is POSIX 2013, as publicly available through the Open Group online distribution (see [Ref1]).

The initial elaboration approach was to improve and harmonize into a reference specification the achievements of two pre-existing publicly available AEPs: the Lw AEP defined in Appendix B of SCA 4.0.1 (see [Ref2]) and the DSP AEP of the ESSOR Architecture (see [Ref3]).

1.1.3 OEs implementation possibilities

The terminology “Operating Environment RTOS” is NOT necessarily referring to a COTS RTOS available for RTOS vendors, and is to be understood in a broader sense, only corresponding to the set of specified POSIX capabilities.

The implementation strategies of the said “OE RTOS” are then entirely under platform providers’ responsibility. Some examples of possibilities offered are:

- A COTS RTOS natively supporting the AEPs, integrated “as is” within the complete OE,
- A software implementation of the expected AEPs capability realized on top of a COTS micro-kernel or a proprietary RTOS, and being integrated within the complete OE.

The specification content is therefore written in abstraction of the OE implementation choices, without presupposing that the underlying solution shall be a POSIX-compliant RTOS.

1.2 Specification content

1.2.1 Lw and ULw Base AEPs functions groups

Base AEPs functions groups provide the essential capabilities for RTOS usage.

The two Base AEPs functions groups are defined as:

- The “Base Lightweight / Lw AEP functions group”,
- The “Base Ultra-lightweight / ULw AEP functions group”.

The two Base AEPs functions groups commonly feature Threads, Semaphores, Message queues, Mutexes and Timers capabilities.
The differences between the Base AEPs functions groups are:

- The Lw features *Condition variables* capabilities, while the ULw does not,
- The ULw does not support *Message queues* priorities and restricts the messages size to `sizeof(void*)`.

The Base ULw AEP functions group is therefore as a strict subset of the Base Lw AEP functions group.

The existence of the Base Lw and ULw AEPs functions groups is justified by grounded distinct use cases for conforming to one AEP or the other.

The Base Lw AEP functions group is designed as the natural choice for resource constrained processors featuring lightweight POSIX-certified RTOS.

The Base ULw AEP functions group is designed as a suitable solution for processors with ultra-constrained resources, where the Base Lw AEP functions group features may consume too many resource. Such environments are prone to usage of COTS DSP RTOSes or micro-kernels, completed by the OE integrator so as to expose the Base ULw AEP functions group.

Normative content for Base AEP is in § 2, with associated rationale in § 6.2.

1.2.2 Additional groups

Additional groups of POSIX functions enable users of the specification to extend the selected Base AEP functions group, if and as required.

**Group A**

Group A essentially contains the POSIX functions enabling SDR Applications to get values of RTOS-related attributes (“get” functions). Their usage can typically ease the porting phase in enabling errors detection in the SDR Application code.

Normative content for Group A is in § 3, with associated rationale in § 6.3.

**Group B**

Group B contains the POSIX functions enabling SDR Application to release RTOS resources. Their usage is required for termination of SDR Applications ensuring that no unused RTOS resource remains allocated once the application is inactive.

Normative content for Group B is provided in § 4, with associated rationale in § 6.4.

1.3 Conformance

1.3.1 Applicable AEPs

Users of the specification are using the specification in determining the *applicable AEP* for their conformant work products.
First, one Base AEPs functions group has to be selected among the **Base Lw AEP functions group** and the **Base ULw AEP functions group**. This choice determines if the *applicable AEP* is a Lw or a ULw AEP.

Then, as needed, the selected Base AEPs functions group can be augmented with **Group A** and/or **Group B** functions, thus completing definition of the *applicable AEP*. This choice is not impacting the fundamental design choices of the work products, and is rather influenced by porting assumptions.

### 1.3.2 Conformance of SDR Applications

The *applicable AEP* for a conformant SDR Application has to be defined in accordance with § 1.3.1.

**Conformity criteria**

| A SDR Application is *conformant* with one *applicable AEP* if the said SDR Application **exclusively uses**, as far as RTOS capabilities are concerned, the capabilities of the said *applicable AEP*. |

**Verification procedure**

Establishment of the *verification procedure* applicable for verification of the conformity criteria is beyond the scope of this specification.

It implies to determine the exact meaning of the "*exclusively uses*" part of the conformity clause, that can go from simple syntactical verification of a source code to exhaustive verification of dependencies, including flagging of forbidden POSIX functions using a black list of functions.

Significant margins of interpretation exist as well concerning the decision to test or not that the SDR Application is making some “forced” calls, such as the attributes setting calls listed by the specification for threads or mutexes creation.

### 1.3.3 Conformance of Operating Environments

**Conformity criteria**

The *applicable AEP* for a conformant OE has to be defined in accordance with § 1.3.1.

| An Operating Environment is *conformant* with one *applicable AEP* if the said OE **at least implements the full set** of capabilities specified in the said *applicable AEP*. |

| An Operating Environment is *compliant* with one *applicable AEP* if the said OE **implements a non-trivial subset** of capabilities of the said *applicable AEP*, the implemented functions being individually complying with the specification. |
Verification procedure

Establishment of the verification procedure applicable for verification of those conformity criteria is beyond the scope of this specification.

It implies to determine if a specific testing procedure is required to declare OE conformance, or if a usage-based validation approach is sufficient.

Besides, a verification procedure could imply to require a formal POSIX conformity certificate, duly established in application of POSIX conformity testing rules.

POSIX conformance

As far as the range of capabilities addressed by this specification is concerned, no difference has been identified by specification developers between the POSIX 2013 [Ref1] version of POSIX, which serves as main reference for this document, and POSIX 2008.1, which is a version of POSIX largely implemented by COTS RTOS vendors. This implies that RTOS complying with POSIX 2008 are assumed conformant with the content of this specification.

1.3.4 Benefits of conformance

For an Operating Environment, conformance to one applicable AEP will ensure capability for the said OE to host SDR Applications conformant with the same applicable AEP, or with narrower AEPs.

For SDR Applications, conformance to one applicable AEP will ensure possibility to port the said SDR Application to OEs conformant with the same applicable AEP, or with broader AEPs.
2 Base Lw and ULw AEPs

2.1 Introduction

This chapter provides the normative content for definition of the Base AEPs functions groups (ULw ad Lw).

It is structured across 6 POSIX capabilities:
- Threads,
- Semaphores,
- Mutexes,
- Message queues (with ULw-specific restrictions),
- Timers,
- Condition variables (Lw only).

2.2 Threads

2.2.1 Overview of Base AEPs Threads

The following table gives the set of POSIX functions of the Base Lw and ULw AEPs for Threads capability.

Table 1 POSIX functions of the Base AEPs for Threads

<table>
<thead>
<tr>
<th>POSIX functions of the Base AEPs</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
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<td>Thread creation</td>
<td>Threads lifecycle</td>
</tr>
<tr>
<td>pthread_self()</td>
<td>Thread ID retrieving</td>
<td>Threads lifecycle</td>
</tr>
<tr>
<td>pthread_attr_init()</td>
<td>Thread attr creation</td>
<td>Threads attr lifecycle</td>
</tr>
<tr>
<td>pthread_attr_destroy()</td>
<td>Thread attr destruction</td>
<td>Threads attr lifecycle</td>
</tr>
<tr>
<td>pthread_attr_setdetachstate()</td>
<td>Setting detachstate</td>
<td>Attribute detachstate</td>
</tr>
<tr>
<td>pthread_attr_setinheritsched()</td>
<td>Setting inheritsched</td>
<td>Attribute inheritsched</td>
</tr>
<tr>
<td>pthread_attr_setschedparam()</td>
<td>Setting schedparam</td>
<td>Attribute schedparam</td>
</tr>
<tr>
<td>pthread_attr_setschedpolicy()</td>
<td>Setting schedpolicy</td>
<td>Attribute schedpolicy</td>
</tr>
<tr>
<td>pthread_attr_setstack()</td>
<td>Setting stack size and address</td>
<td>Stack handling</td>
</tr>
<tr>
<td>pthread_attr_setstacksize()</td>
<td>Setting stack size</td>
<td>Stack handling</td>
</tr>
</tbody>
</table>

2.2.2 Normative content for Base AEPs Threads

2.2.2.1 Threads lifecycle

**POSIX functions:** pthread_create() and pthread_self().

POSIX standard is fully applicable.

The created threads only support the specific values indicated in following chapters for attributes detachstate, inheritsched and schedpolicy.
The related destructor `pthread_exit()` is member of Group B of functions, see § 4.2.

2.2.2.2 Threads attributes lifecycle

**POSIX functions:** `pthread_attr_init()` and `pthread_attr_destroy()`.

POSIX standard is fully applicable.

2.2.2.3 Attribute `detachstate`

**POSIX functions:** `pthread_attr_setdetachstate()`.

The `detachstate` attribute of threads is always equal to `PTHREAD_CREATE_DETACHED`. Other values, including POSIX default `PTHREAD_CREATE_JOINABLE`, are not part of the required capabilities.

POSIX standard is otherwise fully applicable.

The POSIX function `pthread_attr_setdetachstate()` is in the Base AEPs, to explicitly set attribute `detachstate` to `PTHREAD_CREATE_DETACHED`.

The related accessor `pthread_attr_getdetachstate()` is member of Group A of functions, see § 3.2.

**Implications on conformant products:**
- A conformant SDR Application has to explicitly call `pthread_attr_setdetachstate(PTHREAD_CREATED_DETACHED)`,
- A conformant OE has to implement `pthread_attr_setdetachstate()`, even if only supporting `PTHREAD_CREATE_DETACHED` value.

2.2.2.4 Attribute `inheritsched`

**POSIX functions:** `pthread_attr_setinheritsched()`.

The `inheritsched` attribute of threads is always equal to `PTHREAD_EXPLICIT_SCHED`. Other values are not part of the required capabilities.

POSIX standard is otherwise fully applicable.

The POSIX function `pthread_attr_setinheritsched()` is in the Base AEPs, to explicitly set attribute `inheritsched` to `PTHREAD_EXPLICIT_SCHED`.

The related accessor `pthread_attr_getinheritsched()` is member of Group A of functions, see § 3.2.

**Implications on conformant products:**
- A conformant SDR Application has to explicitly call `pthread_attr_setinheritsched(PTHREAD_EXPLICIT_SCHED)`,
- A conformant OE has to implement `pthread_attr_setinheritsched()`, even if only supporting `PTHREAD_EXPLICIT_SCHED` value.
2.2.2.5  Attribute schedparam

**POSIX functions:** `pthread_attr_setschedparam()`.

POSIX standard is fully applicable.

The related accessor `pthread_attr_getschedparam()` is member of Group A of functions, see § 3.2.

2.2.2.6  Attribute schedpolicy

**POSIX functions:** `pthread_attr_setschedpolicy()`.

The `schedpolicy` attribute of threads is always equal to SCHED_FIFO. Other values are not part of the required capabilities.

POSIX standard is otherwise fully applicable.

The POSIX function `pthread_attr_setschedpolicy()` is in the Base AEPs, to explicitly set attribute `schedpolicy` to SCHED_FIFO.

The related accessor `pthread_attr_getschedpolicy()` is member of Group A of functions, see § 3.2.

**Implications on conformant products:**
- A conformant SDR Application has to explicitly call `pthread_attr_setschedpolicy(SCHED_FIFO)`,
- A conformant OE has to implement `pthread_attr_setschedpolicy()`, even if only supporting SCHED_FIFO.

2.2.2.7  Stack handling

**POSIX functions:** `pthread_attr_setsstack()` and `pthread_attr_setsstacksize()`.

POSIX standard is fully applicable.

The related accessors `pthread_attr_getstacksize()` and `pthread_attr_getstackaddr()` are members of Group A of functions, see § 3.2.

### 2.3  Semaphores

2.3.1  **Overview of Base AEPs Semaphores**

The following table gives the set of POSIX functions of the Base Lw and ULw AEPs for `Semaphores` capability.
Table 2 POSIX functions of the Base AEPs for Semaphores

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
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<td>Semaphore creation</td>
<td>Semaphores lifecycle</td>
</tr>
<tr>
<td>sem_post()</td>
<td>Posting</td>
<td>Semaphores usage</td>
</tr>
<tr>
<td>sem_wait()</td>
<td>Waiting</td>
<td>Semaphores usage</td>
</tr>
</tbody>
</table>

2.3.2 Normative content for Base AEPs Semaphores

2.3.2.1 Semaphores lifecycle

**POSIX functions**: `sem_init()`.

The related destructor `sem_destroy()` is member of Group B of functions, § 4.2.

POSIX standard is fully applicable.

2.3.2.2 Semaphores usage

**POSIX functions**: `sem_post()` and `sem_wait()`.

POSIX standard is fully applicable.

The accessor to instant value of semaphore `sem_getvalue()` is the member function of the Group A of functions, see § 3.2.

2.4 Mutexes

The following table gives the set of POSIX functions of the Base Lw and ULw AEPs for *Mutexes* capability.

Table 3 POSIX functions of the Base AEPs for Mutexes

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
<tbody>
<tr>
<td>pthread_mutex_init()</td>
<td>Mutex creation</td>
<td>Mutexes lifecycle</td>
</tr>
<tr>
<td>pthread_mutexattr_init()</td>
<td>Mutex attr creation</td>
<td>Mutexes attr lifecycle</td>
</tr>
<tr>
<td>pthread_mutexattr_destroy()</td>
<td>Mutex attr destruction</td>
<td>Mutexes attr lifecycle</td>
</tr>
<tr>
<td>pthread_mutexattr_setpriocelling()</td>
<td>Setting priocelling</td>
<td>Attribute priocelling</td>
</tr>
<tr>
<td>pthread_mutexattr_setprotocol()</td>
<td>Setting protocol</td>
<td>Attribute protocol</td>
</tr>
<tr>
<td>pthread_mutexattr_settype()</td>
<td>Setting type</td>
<td>Attribute type</td>
</tr>
<tr>
<td>pthread_mutex_lock()</td>
<td>Mutex locking</td>
<td>Mutexes usage</td>
</tr>
<tr>
<td>pthread_mutex_unlock()</td>
<td>Mutex unlocking</td>
<td>Mutexes usage</td>
</tr>
</tbody>
</table>

2.4.1 Mutexes lifecycle

**POSIX functions**: `pthread_mutex_init()`.

POSIX standard is fully applicable.

The related destructor `pthread_mutex_destroy()` is member of Group B of functions, § 4.2.
2.4.2 Mutexes attributes lifecycle

POSIX functions: `pthread_mutexattr_init()` and `pthread_mutexattr_destroy()`.

POSIX standard is fully applicable.

2.4.3 Attribute protocol

POSIX functions: `pthread_mutexattr_setprotocol()`.

POSIX standard is fully applicable.

Only the following POSIX-defined values are supported for attribute `protocol`: `PTHREAD_PRIO_INHERIT` and `PTHREAD_PRIO_PROTECT`.

The related accessor `pthread_mutexattr_getprotocol()` is member of the Group A of functions, see § 3.2.

Implications on conformant products:
- A conformant OE has to implement `pthread_mutexattr_setprotocol()`, with at least one `protocol` value supported among `PTHREAD_PRIO_INHERIT` and `PTHREAD_PRIO_PROTECT`.
- A conformant SDR Application has to use one of the available values for attribute `protocol`.
- A modification in the SDR Application can be required to adapt the SDR Application if migrating from one platform supporting one protocol to another only supporting protocol.

2.4.4 Attribute prioceiling

POSIX functions: `pthread_mutexattr_setprioceiling()`.

Those functions are only necessary in case `PTHREAD_PRIO_PROTECT` is the applicable protocol.

POSIX standard is fully applicable.

The related accessor `pthread_mutexattr_getprioceiling()` is member of the Group A of functions, see § 3.2.

Implications on conformant products:
- A conformant OE has to implement `pthread_attr_setprioceiling()`, if supporting `PTHREAD_PRIO_PROTECT`.
- A conformant SDR Application has to call `pthread_attr_setprioceiling()`, if using `PTHREAD_PRIO_PROTECT`.

2.4.5 Attribute type

POSIX functions: `pthread_mutexattr_settype()`.
The type attribute of mutexes is always equal to PTHREAD_MUTEX_NORMAL, implying usage of non-robust mutexes is sufficient.

POSIX standard is otherwise fully applicable.

The POSIX function pthread_mutexattr_settype() is in the Base AEPs, to explicitly set attribute type to PTHREAD_MUTEX_NORMAL.

The related accessor pthread_mutexattr_gettype() is member of the Group A of functions, see § 3.2.

**Implications on conformant products:**
- A conformant SDR Application has to explicitly call pthread_mutexattr_settype(PTHREAD_MUTEX_NORMAL),
- A conformant OE has to implement pthread_mutexattr_settype(), even if only supporting PTHREAD_MUTEX_NORMAL.

### 2.4.6 Mutexes usage

**POSIX functions:** pthread_mutex_lock() and pthread_mutex_unlock().

POSIX standard is fully applicable.

### 2.5 Message queues

#### 2.5.1 Overview of Base AEPs Message queues

The following table gives the set of POSIX functions of the Base Lw and ULw AEPs for Message queues capability.

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
<tbody>
<tr>
<td>mq_open()</td>
<td>Message queue creation</td>
<td>Message queues lifecycle</td>
</tr>
<tr>
<td>mq_receive()</td>
<td>Message queue locking</td>
<td>Message queues usage</td>
</tr>
<tr>
<td>mq_send()</td>
<td>Message queue unlocking</td>
<td>Message queues usage</td>
</tr>
</tbody>
</table>

#### 2.5.2 Normative content for Base AEPs Message queues

#### 2.5.2.1 Message queues lifecycle

**POSIX functions:** mq_open().

POSIX standard is fully applicable.

The related destructor mq_close() is member of Group B of functions, § 4.2.
2.5.2.2 Message queues usage

**POSIX functions:** `mq_receive()` and `mq_send()`.

POSIX standard is fully applicable.

The flag O_NON_BLOCKING is never set, implying nominal blocking behavior is always used by message queues.

**IMPORTANT:** the following restrictions specifically apply to Base ULw AEP group of functions:
- No support of priorities,
- `mq_msgsize = sizeof(void *)`.

The Base Lw AEP group of functions is NOT affected by those restrictions.

### 2.6 Timers

The following table gives the set of POSIX functions of the Base Lw and ULw AEPs for Timers capability.

**Table 5 POSIX Functions of the Base AEPs for Timers**

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>timer_create()</code></td>
<td>Timer creation</td>
<td>Timers lifecycle</td>
</tr>
<tr>
<td><code>clock_gettime()</code></td>
<td>Timer activation</td>
<td>Timers usage</td>
</tr>
<tr>
<td><code>clock_getres()</code></td>
<td>Timer resolution</td>
<td>Clock resolution</td>
</tr>
<tr>
<td><code>clock_gettime()</code></td>
<td>Time retrieving</td>
<td>Clock usage</td>
</tr>
<tr>
<td><code>timer_settime()</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2.6.1 Timers lifecycle

**POSIX functions:** `timer_create()`.

For timers, particular dispositions apply to arguments `clockid` and `sigevent` of function `timer_create()`.

For `clockid`, no other POSIX-defined values than `CLOCK_REALTIME` can be used.

In case the resolution available with `CLOCK_REALTIME` is not satisfying the need of the SDR Application, usage of implementation-defined `clockid` values for higher resolution clocks is permitted.

For `sigevent` argument, the `sigev_notify` member of the `sigevent` structure has to be equal to `SIGEV_THREAD` or to one implementation-defined value.

In case `SIGEV_THREAD` is implemented, the thread of execution of the callback has to be a system thread created at timer creation, otherwise an implementation-defined mechanism is to be used.
The `sigevent` structure `sigev_notify` member values `SIGEV_NONE` and `SIGEV_SIGNAL` are not part of the required capabilities. Otherwise, POSIX standard is fully applicable.

The related destructor `timer_delete()` is member of Group B of functions, § 4.2.

**Implications on conformant products:**
- A conformant OE has to support value `CLOCK_REALTIME` for argument `clockid`, plus implementation-defined value for higher resolution if required,
- A conformant OE has to support, for member `sigev_notify` of argument `sigevent`, at least one value among `SIGEV_THREAD` or implementation-defined value(s),
- A conformant SDR Application has to use one of the values supported by the OE (if several),
- A modification in the SDR Application will be required when adapting it to support an implementation-defined value for `sigev_notify`.

### 2.6.2 Clock resolution

**POSIX functions:** `clock_getres()`.

POSIX standard is fully applicable.

Only `CLOCK_REALTIME` and implementation-defined value for higher resolution, if required, are supported for argument `clockid`.

### 2.6.3 Timers usage

**POSIX functions:** `timer_settime()`.

POSIX standard is fully applicable.

The dispositions described in § 2.6.1 are applicable to activation of callback at timer expiration.

The related accessor `timer_gettime()` is the member of Group A of functions, see § 3.2.

### 2.6.4 Clock usage

**POSIX functions:** `clock_gettime()`.

POSIX standard is fully applicable.

Only `CLOCK_REALTIME` and implementation-defined value for higher resolution, if required, are supported for argument `clockid`.

### 2.7 Condition variables

The following table gives the set of POSIX functions of the Base Lw AEP group of functions for `Condition variables` capability.
IMPORTANT: *Condition variables* are not supported in the Base ULw AEP group of functions.

Table 6 POSIX Functions of the Base Lw AEP for Condition Variables

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
<tbody>
<tr>
<td>pthread_cond_init()</td>
<td>Start of lifecycle</td>
<td>Condition variables lifecycle</td>
</tr>
<tr>
<td>pthread_cond_broadcast()</td>
<td>Wake-up all waiters</td>
<td>Condition variables usage</td>
</tr>
<tr>
<td>pthread_cond_signal()</td>
<td>Wake-up one waiter</td>
<td>Condition variables usage</td>
</tr>
<tr>
<td>pthread_cond_wait()</td>
<td>Wait for signal/broadcast</td>
<td>Condition variables usage</td>
</tr>
</tbody>
</table>

2.7.1 Condition variables lifecycle

**POSIX functions:** `pthread_cond_init()`.

POSIX standard is fully applicable.

The SDR Applications have to pass a NULL `pthread_cond_attr_t` pointer when calling `pthread_cond_init()`.

The related destructor `pthread_cond_destroy()` is member of Group B of functions, § 4.2.

2.7.2 Condition variables attributes lifecycle

**POSIX functions:** `pthread_condattr_init()` and `pthread_condattr_destroy()`.

POSIX standard is fully applicable.

2.7.3 Condition variables usage

**POSIX functions:** `pthread_cond_broadcast()`, `pthread_cond_signal()` and `pthread_cond_wait()`.

POSIX standard is fully applicable.
3 Group A of functions

3.1 Introduction

Group A essentially contains the POSIX functions enabling SDR Applications to get values of RTOS-related attributes ("get" functions). Their usage can typically ease the porting phase in enabling errors detection in the SDR Application code.

3.2 Group A Functions

The functions of Group A are listed in the following table.

Table 7 POSIX Group A Functions

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
<tbody>
<tr>
<td>pthread_attr_getguardsize()</td>
<td>Retrieving guardsize</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_attr_getdetachstate()</td>
<td>Retrieving detachstate</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_attr_getinheritsched()</td>
<td>Retrieving inheritsched</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_attr_getschedparam()</td>
<td>Retrieving schedparam</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_attr_getschedpolicy()</td>
<td>Retrieving schedpolicy</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_attr_getstackaddr()</td>
<td>Retrieving stackaddr</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_attr_getstacksize()</td>
<td>Retrieving stacksize</td>
<td>Threads creation attributes</td>
</tr>
<tr>
<td>pthread_mutexattr_getprioceiling()</td>
<td>Retrieving prioceiling</td>
<td>Mutexes creation attributes</td>
</tr>
<tr>
<td>pthread_mutexattr_getprotocol()</td>
<td>Retrieving protocol</td>
<td>Mutexes creation attributes</td>
</tr>
<tr>
<td>pthread_mutexattr_gettype()</td>
<td>Retrieving type</td>
<td>Mutexes creation attributes</td>
</tr>
<tr>
<td>pthread_attr_setguardsize()</td>
<td>Setting guardsize</td>
<td>Guard size handling</td>
</tr>
<tr>
<td>sem_getvalue()</td>
<td>Retrieving instant semaphore value</td>
<td>Semaphores monitoring</td>
</tr>
<tr>
<td>timer_gettime()</td>
<td>Retrieving instant timers time</td>
<td>Timers monitoring</td>
</tr>
</tbody>
</table>

To facilitate porting on an OE where Group A would not be available, a SDR Application conformant with Group A functions has to limit usage of Group A functions to run-time error detection.
3.2.1 Threads creation attributes

**POSIX functions:** `pthread_attr_getguardsize()`, `pthread_attr_getdetachstate()`, `pthread_attr_getinheritsched()`, `thread_attr_getschedparam()`, `pthread_attr_getschedpolicy()`, `pthread_attr_getschedstackaddr()` and `pthread_attr_getstksize()`.

POSIX standard is fully applicable.

3.2.2 Mutexes creation attributes

**POSIX functions:** `pthread_mutexattr_getprioceiling()`, `pthread_mutexattr_getprotocol()` and `pthread_mutexattr_gettype()`.

POSIX standard is fully applicable.

3.2.3 Guard size setting

**POSIX function:** `pthread_attr_setguardsize()` and `pthread_attr_getguardsize()`.

POSIX standard is fully applicable.

For OE where `guardsize` setting is not possible, the function `pthread_attr_setguardsize()` has to be implemented with a void behavior.

3.2.4 Semaphores monitoring

**POSIX function:** `sem_getvalue()`.

POSIX standard is fully applicable.

3.2.5 Timers monitoring

**POSIX function:** `timer_gettime()`.

POSIX standard is fully applicable.
4   Group B of functions

4.1   Introduction

Group B contains the POSIX functions enabling SDR Application to release RTOS resources. Their usage is required for termination of SDR Applications ensuring that no unused RTOS resource remains allocated once the application is inactive.

4.2   Group B Functions

The functions of Group B are listed in the following table.

<table>
<thead>
<tr>
<th>POSIX function</th>
<th>Summary role</th>
<th>Normative content in</th>
</tr>
</thead>
<tbody>
<tr>
<td>pthread_exit()</td>
<td>Terminate a thread</td>
<td>Threads resources releasing</td>
</tr>
<tr>
<td>sem_destroy()</td>
<td>Destroy a semaphore</td>
<td>Semaphore releasing</td>
</tr>
<tr>
<td>mq_close()</td>
<td>Close a message queue</td>
<td>Message queue releasing</td>
</tr>
<tr>
<td>pthread_mutex_destroy()</td>
<td>Destroy a mutex</td>
<td>Mutexes resources releasing</td>
</tr>
<tr>
<td>timer_delete()</td>
<td>Delete a timer</td>
<td>Timer releasing</td>
</tr>
<tr>
<td>pthread_cond_destroy()</td>
<td>Destroy a condition variable (Base Lw only)</td>
<td>Condition variable releasing</td>
</tr>
</tbody>
</table>

To facilitate porting on OE where Group B would not be available, a SDR Application conformant with Group B functions has to limit usage of Group B functions to the termination phase.

4.2.1   Threads resources releasing

**POSIX function:** pthread_exit().

POSIX standard is fully applicable.

4.2.2   Semaphore releasing

**POSIX function:** sem_destroy().

POSIX standard is fully applicable.

4.2.3   Message queue releasing

**POSIX function:** mq_close().

POSIX standard is fully applicable.

4.2.4   Mutexes resources releasing

**POSIX function:** pthread_mutex_destroy().
POSIX standard is fully applicable.

4.2.5  Timer releasing

**POSIX function:** `timer_delete()`.

POSIX standard is fully applicable.

4.2.6  Condition variable releasing

**POSIX function:** `pthread_cond_destroy()`.

POSIX standard is fully applicable.

This function is member of Group B only when Base Lw AEP group is used, since only Lw features condition variables.
5 Perspectives on specification content

5.1 Possible applicable AEPs

The rules for elaboration of applicable AEPs result in the following 8 different possibilities for applicable AEPs:

- 4 variants of Lw AEPs:
  - Base Lw AEP functions group only,
  - Base Lw AEP functions group with Group A,
  - Base Lw AEP functions group with Group B,
  - Base Lw AEP functions group with Group A and Group B.

- 4 variants of ULw AEPs:
  - Base ULw AEP functions group only,
  - Base ULw AEP functions group with Group A,
  - Base ULw AEP functions group with Group B,
  - Base ULw AEP functions group with Group A and Group B.

The essential choice represents selection of the Base functions group, that will determine if the applicable AEP is Lw or ULw.

The variants allowed by presence of additional groups enable to broaden usage of the specification to a variety of porting situations.

Definition of more prescriptive requirements concerning usage of the specification is possible, for instance in limiting, for certain markets or users perspective, the number of applicable AEPs possibly used.

5.2 AEPs content

This section is based on tables that provide for each of the Base AEPs functions groups (Lw and ULw), a status regarding presence of each individual function of the functions group.

As such, the tables are close to those available in SCA Appendix B (see [Ref2]).

The status is provided according to the following convention:

- IN (MAN): the function is IN the profile, with no identified restriction compared to the POSIX standard
  - This is equivalent to the “mandatory = MAN” status used in SCA tables,
- OUT (NRQ): the function is OUT of the profile,
  - This is equivalent to the “not requested = NRQ” status used in SCA tables,
- PRT (PRT): the function is in the profile, with a partial set of capabilities with regards to full POSIX functionality,
  - This is somehow equivalent to the “partial = PRT” status used in SCA tables.

By contrast with SCA Appendix E, the only tables provided are corresponding to the function groups where at least one function is present IN the Base Lw and Base ULw functions groups:

- POSIX_MQUEUES: covers the message queues capability,
- POSIX_SEMAPHORES: covers the semaphores capability,
- POSIX_TIMERS: covers the timers capability,
- POSIX_THREADS_BASE: covers the threads, mutexes and condition variables capabilities.

5.2.1 POSIX_MQUEUE functions

Table 9 Specified functions groups wrt POSIX_MQUEUE

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPS</th>
<th>ULw AEPS</th>
<th>Diff Lw/ULw</th>
</tr>
</thead>
<tbody>
<tr>
<td>mq_close()</td>
<td>MAN</td>
<td>Group B</td>
<td>Group B</td>
<td></td>
</tr>
<tr>
<td>mq_getattr()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>mq_notify()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>mq_open()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>PRT (PRT)*</td>
<td>YES</td>
</tr>
<tr>
<td>mq_receive()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>mq_send()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>mq_setattr()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>mq_timedreceive()</td>
<td>NRQ</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>mq_timedsend()</td>
<td>NRQ</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>mq_unlink()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
</tbody>
</table>

*: the partial (PRT) indication for function `mq_open()` of the ULw AEP denotes absence of priorities support and the size limited to sizeof( void *).

This is one point of difference between the Lw and the ULw AEPs.

5.2.2 POSIX_SEMAPHORES functions

Table 10 Specification content wrt POSIX_SEMAPHORES

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPS</th>
<th>ULw AEPS</th>
<th>Diff Lw/Ulw</th>
</tr>
</thead>
<tbody>
<tr>
<td>sem_close()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>sem_destroy()</td>
<td>MAN</td>
<td>Group B</td>
<td>Group B</td>
<td></td>
</tr>
<tr>
<td>sem_getvalue()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>sem_init()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>sem_open()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>sem_post()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>sem_timedwait()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>sem.trywait()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>sem_unlink()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>sem_wait()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
</tbody>
</table>
5.2.3  POSIX_TIMERS functions

Table 11 Specification content wrt POSIX_TIMERS

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPs</th>
<th>ULw AEPs</th>
<th>Diff Lw/ULw</th>
</tr>
</thead>
<tbody>
<tr>
<td>clock_getres()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>clock_gettime()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>clock_settime()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>nanosleep()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>timer_create()</td>
<td>MAN</td>
<td>PRT (PRT)*</td>
<td>PRT (PRT)*</td>
<td></td>
</tr>
<tr>
<td>timer_delete()</td>
<td>MAN</td>
<td>Group B</td>
<td>Group B</td>
<td></td>
</tr>
<tr>
<td>timer_getovrun()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>timer_gettime()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>timer_settime()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
</tbody>
</table>

*: the partial (PRT) indication for function timer_create() denote the limitations set in timers expiration conditions, with either possibility to use SIGEV_THREAD or an implementation specific mechanism.
### 5.2.4 POSIX_THREADS functions

Table 12 Specification content wrt POSIX_THREADS_BASE (except mutexes and cond vars)

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPs</th>
<th>ULw AEPs</th>
<th>Diff Lw/Ulw</th>
</tr>
</thead>
<tbody>
<tr>
<td>pthread_atfork()</td>
<td>NRQ</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_init()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_destroy()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getdetachstate()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getguardsize()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getinheritsched()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getschedparam()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getschedpolicy()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getscope()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getstack()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getstackaddr()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_getstacksize()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setdetachstate()</td>
<td>MAN</td>
<td>PRT (PRT)*</td>
<td>PRT (PRT)*</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setguardsize()</td>
<td>MAN</td>
<td>Group A</td>
<td>Group A</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setinheritsched()</td>
<td>MAN</td>
<td>PRT (PRT)*</td>
<td>PRT (PRT)*</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setschedparam()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setschedpolicy()</td>
<td>MAN</td>
<td>PRT (PRT)*</td>
<td>PRT (PRT)*</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setscope()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setstack()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setstackaddr()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_attr_setstacksize()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_cancel()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_cleanup_xxx()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_create()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_detach()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_equal()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_exit()</td>
<td>MAN</td>
<td>Group B</td>
<td>Group B</td>
<td></td>
</tr>
<tr>
<td>pthread_getschedparam()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_getspecific()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_join()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_key_xxx()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_kill()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_once()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_self()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td>pthread_setcancelstate()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_setcanceltype()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
</tbody>
</table>
**AEPs Improvements for SCA4.1**

**Lw & ULw AEPs**

WINNF-14-S-0009-V1.0.1

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPs</th>
<th>ULw AEPs</th>
<th>Diff Lw/ULw</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pthread_setschedparam()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_setspecific()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_sigmask()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_testcancel()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
</tbody>
</table>

*: the partial (PRT) indications for functions `pthread_attr_setdetachstate()`, `pthread_attr_setinheritsched()` and `pthread_attr_setschedpolicy()` correspond to the limitations set on values of attributes `detachstate` (always equal to `PTHREAD_CREATE_DETACH`), `inheritsched` (always equal to `PTHREAD_EXPLICIT_SCHED`) and `schedpolicy` (always equal to `SCHED_FIFO`).

**Table 13 Specification content wrt POSIX_THREADS_BASE (mutexes)**

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPs</th>
<th>ULw AEPs</th>
<th>Diff Lw/ULw</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pthread_mutex_destroy()</code></td>
<td>MAN</td>
<td>Group B</td>
<td>Group B</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_getprioceiling()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_init()</code></td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_lock()</code></td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_setprioceiling()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_timedlock()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_trylock()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutex_unlock()</code></td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_destroy()</code></td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_getprioceiling()</code></td>
<td>MAN</td>
<td>Group A*</td>
<td>Group A*</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_getprotocol()</code></td>
<td>MAN</td>
<td>Group A**</td>
<td>Group A**</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_getpshared()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_gettype()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_init()</code></td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>IN (MAN)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_setprioceiling()</code></td>
<td>MAN</td>
<td>IN (MAN)*</td>
<td>IN (MAN)*</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_setprotocol()</code></td>
<td>MAN</td>
<td>IN (MAN)*</td>
<td>IN (MAN)*</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_setpshared()</code></td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td><code>pthread_mutexattr_settype()</code></td>
<td>MAN</td>
<td>PRT (PRT)**</td>
<td>PRT (PRT)**</td>
<td></td>
</tr>
</tbody>
</table>

*: only required if `THREAD_PRIO_PROTECT` is supported.

**: only support of one among `PTHREAD_PRIO_INHERIT` and `THREAD_PRIO_PROTECT` values for attribute `protocol` is required for the OE. On a given platform, the SDR Application needs to use one of the available protocols.

**: the partial (PRT) indication for function `pthread_mutexattr_settype()` corresponds to the limitation set on values of attribute `type` (always equal to `PTHREAD_MUTEX_NORMAL`).
**Table 14 Specification content wrt POSIX_THREADS_BASE (cond vars)**

<table>
<thead>
<tr>
<th>Function</th>
<th>SCA AEP</th>
<th>Lw AEPs</th>
<th>ULw AEPs</th>
<th>Diff Lw/ULw</th>
</tr>
</thead>
<tbody>
<tr>
<td>pthread_cond_broadcast()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>OUT (NRQ)</td>
<td>YES</td>
</tr>
<tr>
<td>pthread_cond_destroy()</td>
<td>MAN</td>
<td>Group B</td>
<td>OUT (NRQ)</td>
<td>YES</td>
</tr>
<tr>
<td>pthread_cond_init()</td>
<td>MAN</td>
<td>IN (MAN)*</td>
<td>OUT (NRQ)</td>
<td>YES</td>
</tr>
<tr>
<td>pthread_cond_signal()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>OUT (NRQ)</td>
<td>YES</td>
</tr>
<tr>
<td>pthread_cond_timedwait()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_cond_wait()</td>
<td>MAN</td>
<td>IN (MAN)</td>
<td>OUT (NRQ)</td>
<td>YES</td>
</tr>
<tr>
<td>pthread_condattr_destroy()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_condattr_init()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_condattr_getclock()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_condattr_setclock()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_condattr_getpshared()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
<tr>
<td>pthread_condattr_setpshared()</td>
<td>MAN</td>
<td>OUT (NRQ)</td>
<td>OUT (NRQ)</td>
<td></td>
</tr>
</tbody>
</table>

*: creation is to be done by SDR Applications passing a NULL `pthread_condattr_t` pointer.

Presence of POSIX Condition variables functions in the Base Lw AEP group and not in the Base ULw AEP group is the main difference between Base Lw and ULw groups.
6 Rationales

6.1 Design paradigm

6.1.1 Selection of main POSIX capabilities

This resulted in consensus regarding support of Threads, Semaphores, Mutexes, Timers and Message queues.

Support of Condition variables appeared to be a point of divergence that stemmed identification of distinct Lw and ULw Base AEP functions groups.

It was as well clarified that the scope of the specification would only address RTOS interfaces, considering as out of scope aspects related to support of standard C language libraries.

6.1.2 Function-by-function evaluation

The second step of convergence has been, for each of the selected functionalities, to determine which where the POSIX functions to be kept in.

Core functions, for creation and usage of the POSIX capability were included.

A number of limitations in the supported POSIX attributes were identified for some capabilities. This resulted in integration of some “set” functions with associated limitations in attributes value.

Consideration of Message queues brought additional differences between the Lw and ULw Base AEPs functions groups.

The case of “get” functions appeared to be hard to decide about, with grounded contradictory argumentations relative to their inclusion. The case of “destroy” functions appeared similarly hard to decide about.

6.1.3 Creation of the Additional groups

By contrast with the Lw vs ULw differences, usage or not of the “get” (=Group A) and “destroy” (=Group B) functions are of minor impact for SDR Application portability, and are mostly influenced by porting and integrations assumptions strongly depending on the usage context.

This justified to include those functions as additional groups possibly added to the Base AEPs functions groups, based on users decision related to porting objectives and constraints.

6.2 Design rationale for Base AEPs functions groups

6.2.1 Design rationale for Base AEPs Threads

Lifecycle management

POSIX functions for threads creation is IN the Base AEPs functions groups: pthread_create().
The related POSIX function for threads release, pthread_exit(), is in Group B.

POSIX functions for threads attributes creation and destruction are in the Base AEPs functions groups: pthread_attr_init() and pthread_attr_destroy().

pthread_attr_destroy() is in the Base AEPs functions group and not in Group B because the attributes destruction is typically done at the end of the SDR Application initialization, releasing the threads creation attributes from memory once threads have been created.

Threads cancelation is NOT allowed, so pthread_cancel() is NOT in the Base AEPs functions groups. Attributes cancelstate and canceltype are therefore undefined, with related POSIX functions pthread_[s|g]etcancelstate() and pthread_[s|g]etcanceltype() OUT of the Base AEPs functions groups.

Usage

No related POSIX functions for threads, since handled by the scheduler.

Attributes

The threads are created in a unique address space, with no processes. Attribute contentscope is therefore undefined, with related POSIX functions pthread_attr_[s|g]etscope() OUT of the Base AEPs functions groups.

The function pthread_attr_setschedparam() is IN the Base AEPs functions groups, with no specific limitation. The related accessor pthread_attr_getschedparam() is OUT of the Base AEPs functions groups, but is a member of Group A.

The threads have imposed values for the following attributes:
- Attribute detachstate: PTHREAD_CREATED_DETACHED,
- Attribute Inheritsched: PTHREAD_EXPLICIT_SCHED,
- Attribute schedpolicy: SCHED_FIFO.

To enable portability of SDR Application on OEs with RTOS supporting more creation attributes values that the limited set defined by the Base AEPs functions groups, the related attributes handling POSIX functions are IN the Base AEPs functions groups: pthread_attr_setdetachstate(), pthread_attr_setinheritsched(), pthread_attr_setschedpolicy().

The related accessors pthread_attr_getdetachstate(), pthread_attr_getinheritsched(), pthread_attr_getschedpolicy() are OUT of the Base AEPs functions groups, but are members of Group A.

Stack size handling functions are IN the Base AEPs functions groups: pthread_attr_setstacksize().

Stack base address handling functions are IN the profile, with pthread_attr_setstack(), enabling simultaneous setting of stack address and size. The function pthread_attr_setstackaddr() is OUT of the Base AEPs functions groups, since deprecated since POSIX 2008.1.
The accessors related to stack allocation `pthread_attr_getstacksize()` and `pthread_attr_getstackaddr()` are OUT of the Base AEPs functions groups, but are members of Group A.

Stack overflow detection functions `pthread_attr_[s|g]etguardsize()` are OUT of the Base AEPs functions groups, but are members of Group A.

The functions for dynamic handling of `schedparam` and `schedprio` attributes, `pthread_[s|g]etschedparam()` and `pthread_[s|g]etschedprio()` are OUT of the Base AEPs functions groups, since no dynamic handling of those parameters is not supported.

6.2.2 Design rationale for Base AEPs Semaphores

Lifecycle management

POSIX functions for `semaphores` creation is IN the Base AEPs functions groups: `sem_init()`.

The related POSIX function for `semaphores` release, `sem_destroy()`, is in Group B.

Since resource constrained processors have a single address space no support for named semaphores is required, therefore functions `sem_open()`, `sem_close()` and `sem_unlink()` are OUT of the Base AEPs functions groups.

Usage

The base POSIX functions for `semaphores` usage are IN the Base AEPs functions groups: `sem_post()` and `sem_wait()`.

Related accessor `sem_getvalue()` is OUT of the Base AEPs functions groups, but is member of Group A, see § 3.2.

Since the SDR applications considered for execution in resource constrained processors are designed according to hard real-time constraints, the functions `sem_timedwait()` and `sem_trywait()` are OUT of the Base AEPs functions groups.

Attributes

No attributes structure is defined for semaphores.

6.2.3 Rationale for design choices of Base AEPs Message queues

Lifecycle management

POSIX function for `message queues` creation is IN the Base AEPs functions groups: `mq_open()`.

The related POSIX function for `message queues` release, `mq_close()`, is in Group B.
Usage

The base POSIX functions for message queues usage are IN the Base AEPs functions groups: 
mq_send() and mq_receive().

The absence of support for messages priority of the Base ULw AEP functions group is motivated 
by lack of support of this feature in COTS micro-kernels, coupled to secondary added value in 
front of SDR Applications for resource constrained processors.

The Base Lw AEP functions groups supports messages priority since largely availability in COTS 
POSIX RTOS.

The limitation of messages size to sizeof(void *) in the Base ULw AEP functions group is justified 
by assignment of dynamic memory allocations so SDR Application, enabling optimization of 
memory allocation according to available memory types.

Since the SDR applications considered for execution in resource constrained processors are 
designed according to hard real-time constraints, the functions mq_timedreceive() and 
mq_timedsend() are OUT of the Base AEPs functions groups.

Since resource constrained processors have a single address space, functions mq_notify() and 
mq_unlink() are OUT of the Base AEPs functions groups.

Attributes

No dynamic modification of the message queue flag is supported. Therefore, the functions 
mq_getattr() and mq_setattr() are OUT of the Base AEPs functions groups.

6.2.4 Rationale for design choices of Base AEPs Mutexes

Lifecycle management

POSIX function for mutexes creation is IN the Base AEPs functions groups: pthread_mutex_init(). 
The related POSIX function for mutexes release, pthread_mutex_destroy(), is in Group B.

POSIX functions for mutexes attributes creation and destruction are IN the Base AEPs functions 
groups: pthread_mutexattr_init() and pthread_mutexattr_destroy().

pthread_mutexattr_destroy() is in the Base AEPs functions group and not in Group B because the 
mutexes attributes destruction is typically done at the end of the SDR Application initialization, 
releasing the mutexes creation attributes from memory once mutexes have been created.

Usage

The base POSIX functions for mutexes usage are IN the Base AEPs functions groups: 
pthread_mutex_lock() and pthread_mutex_unlock().
Since the SDR applications considered for execution in resource constrained processors are designed according to hard real-time constraints, the function `pthread_mutex_trylock()` and `pthread_mutex_timedlock()` are OUT of the Base AEPs functions groups.

**Attributes**

Since resource constrained processors have a single address space, functions `pthread_mutexattr_[s]getpshared()` are OUT of the Base AEPs functions group.

For attribute `protocol`, some RTOS are only supporting value `PTHREAD_PRIO_PROTECT` while others only support `PTHREAD_PRIO_INHERIT`. Therefore the AEPs are including the two possibilities, with obligation for the OE to implement at least one. The function `pthread_mutexattr_setprotocol()` is therefore IN the Base AEPs functions groups.

Related accessor `pthread_mutexattr_getprotocol()` is OUT of the Base AEPs functions groups, but is member of Group A, see § 3.2.

In case `protocol` `PTHREAD_PRIO_PROTECT` is used, functions `pthread_mutexattr_setprioceiling()` is required. It is therefore IN the Base AEPs functions groups, in case `PTHREAD_PRIO_PROTECT` is used.

Related accessor `pthread_mutexattr_getprioceiling()` is OUT of the Base AEPs functions groups, but is member of Group A, see § 3.2.

The attribute `type` is always having value `NORMAL`. The functions `pthread_mutexattr_settype()` is therefore IN the Base AEPs functions groups to force this value. This implies that only non-robust mutexes are required.

Related accessor `pthread_mutexattr_gettype()` is OUT of the Base AEPs functions groups, but is member of Group A, see § 3.2.

6.2.5  **Rationale for design choices of AEPs Timers**

**Lifecycle management**

POSIX function for `timers` creation is IN the Base AEPs functions groups: `timer_create()`.

The related POSIX function for `timers` release, `timer_delete()`, is in Group B.

The possibility to use the SIGEV_THREAD value for `sigevent_notify` is allowed under the assumption that a system thread is used for callback execution. This precision is provided since POSIX implementations diverge in interpretation of the clause “as if executing in a newly created threads”. The recommendation followed in the Base AEPs functions groups is motivated by evident real-time efficiency considerations, since systematic creation of a dedicated thread for handling of each expiring timer is not real-time efficient.
SIGEV_SIGNAL is not permitted since signals are not supported in Base AEPs functions groups conformant RTOS. SIGEV_NONE is not permitted since a notification mechanism is evidently required in hard-real-time SDR Applications.

Therefore, the possibility to use other mechanism is offered for implementations where the SIGEV_THREAD interpretation would not allow for efficient timers expiration handling.

Usage

The base POSIX function for timers usage are IN the Base AEPs functions groups: timer_settime().

The POSIX function for SDR Application to retrieve time is IN the Base AEPs functions groups: clock_gettime(). This is allowed to enable usage of absolute time for timers expiration setting.

The associated accessor timer_gettime() is OUT of the Base AEPs functions groups, but is a member of Group A.

The base POSIX function for setting the clock value is OUT of the Base AEPs functions groups, since the SDR Application has no privilege to set clock time.

Attributes

The POSIX function for SDR Application to retrieve clock resolution is IN the Base AEPs functions group: clock_getres().

6.2.6 Rationale for design choices of AEPs Condition variables

Most RTOS have at least one native mechanism that allows one or more threads of control to wait for an “event” or “condition” and to be released (dispatched) from the waiting state when the event is “signaled” by some other thread of control.

The exact semantics of the native event wait dispatched mechanisms vary from vendor to vendor as is the case for other native mechanism (eg., native mutex versus the POSIX pthread_mutex_t.). The POSIX mapping of the event wait dispatched idiom is the POSIX Condition variable (pthread_cond_t). The POSIX Condition variable semantics were introduced in the original POSIX.1c (pthreads).

There is existing practice in SDR Applications (namely Waveforms) for the POSIX CondVar, justifying insertion of condition variables in Base Lw AEP functions group. The semantics of the POSIX CondVar are conducive to writing scalable, race-free multi-waiter/multi-dispatcher codes that are common in many multi-threaded real-time problems.

Conversely, there is existing practice of SDR Applications (namely Waveforms) the no condition variables or equivalent event dispatch mechanisms are used from the RTOS, justifying exclusion of condition variables in the Base ULw AEP functions group.
Lifecycle management

POSIX function for condition variables creation is IN the Base Lw AEP functions group: pthread_cond_init().

The related POSIX function for condition variables release, pthread_cond_destroy(), is in Group B.

POSIX functions for condition variables attributes lifecycle management are OUT the Base Lw AEP functions group: pthread_condattr_init() and pthread_condattr_destroy() since, as explained below in section Attributes, no specific attribute setting related to shared memory or time is supported by the Base Lw AEP functions group condition variables.

Usage

The base POSIX functions for condition variables usage are IN the Base Lw AEP functions group: pthread_cond_signal(), pthread_cond_broadcast() and pthread_cond_wait().

Since the SDR applications considered for execution in resource constrained processors are designed according to hard real-time constraints, the function pthread_cond_timedwait() is OUT of the Base Lw AEP functions group.

Attributes

The Base Lw AEP functions group provides no support for pthread_cond_timedwait(). Consistently, the pthread_condattr_[g|s]etclock() are not supported.

The Base Lw AEP function group provides no support for POSIX shared memory, therefore the associated functions pthread_condattr_[g|s]setpshared() are not supported.

As a consequence, condattr is not settable for condition variables.

6.3 Rationale for Group A

6.3.1 Rationale for Group A existence

The existence of Group A is justified by distinct cases for conforming or NOT conforming with Group A, as exposed hereinafter.

Case for conforming to Group A

Usage of Group A functions is nominal situation unless the processing resources constraints become predominant.

A SDR Application conformant with Group A will take advantage of the POSIX functions of Group A, typically for enabling errors detection based on the value of the “get” retrieved thanks to Group A functions. As stated in the normative content, the usage has to be limited to run-time errors detection.
An OE conformant with Group A will offer the set of POSIX functions of Group A. This is nominally provided by COTS POSIX-certified RTOS.

**Case for NOT conforming to Group A**

The case is grounded by situations where minimization of resources consumption for conformant products is considered more important than usage of values retrieved from the “get” functions.

A SDR Application NOT conformant with Group A only executes with the base AEPs functions. It is not benefitting of usage of the Group A functions, implying likely increase in porting efforts. This enables to avoid any overhead created by run-time errors detection.

An OE NOT conformant with Group A only implements the base AEPs functions. It is not enabling SDR Application to benefit from “get” values, but this saves memory footprint in the concerned OE.

This approach is particularly applicable in resource constrained OE where AEP-compliant RTOS capability is based on specific developments on top of scalable micro-kernels, eventually open source and recompiled by the OE provider.

6.3.2  **Rationale for design choices of Group A**

Only the POSIX “get” functions corresponding to “set” functions of the AEPs are IN Group A: `pthread_attr_getdetachstate()`, `pthread_attr_getinheritsched()`, `thread_attr_getschedparam()`, `pthread_attr_getschedpolicy()`, `pthread_attr_getschedstackaddr()` and `pthread_attr_getstaksize()`.

Only the POSIX “get” functions corresponding to “set” functions of the AEPs are IN Group A: `pthread_mutexattr_getprioceiling()`, `pthread_mutexattr_getprotocol()` and `pthread_mutexattr_gettype()`.

The case for having the previous “get” functions is primarily grounded on the possibility it offers for integrator to retrieve the default creation values of the RTOS when attributes are initialized.

The POSIX function `sem_getvalue()` is IN Group A, since getting the instant run-time value taken by a semaphore is enabling writing of error detection assertions related to semaphores status.

The POSIX function `timer_gettime()` is IN Group A, since getting the instant value of a timer count can be used is enabling writing of error detection assertions related to timers execution.

The POSIX function `pthread_attr_setguardsize()` is IN Group A, since enabling detection of stack memory leakage.

The POSIX “get” function `pthread_attr_getguardsize()` is IN Group A since its “set” function is IN Group A as well, in order to enable checking of correct support of the requested guard size by the RTOS.
6.4 Rationale for Group B

6.4.1 Rationale for Group B existence

The existence of Group B is justified by distinct cases for conforming or NOT conforming with Group B, as exposed hereinafter.

Case for conforming to Group B

The case is grounded by desire to have ability to terminate SDR Applications without resetting the processor. This implies to cleanly release the RTOS resources used by the SDR Application.

For SDR Application, the application will be capable to be dynamically removed without maintaining usage of RTOS resources.

For OE, the OE will support dynamic removal of SDR Applications.

Case for NOT conforming to Group B

The case is grounded by designs where the reconfiguration across SDR Application simply takes place using reset of the resource constrained processor.

For SDR Application, the application does not need to encode proper releasing of the RTOS resources it uses.

For OE, the OE does not have to implement the resource-releasing functions of Group B.

6.4.2 Rationale for design choices for Group B functions

All destructors associated to Base AEPs functions groups have been included in Group B, except destructors of threads and mutexes creation attributes, which are kept in Base AEPs since not related to termination of SDR Applications.
7 Acronyms List

<table>
<thead>
<tr>
<th>AEP</th>
<th>Application Environment Profile</th>
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<tbody>
<tr>
<td>COTS</td>
<td>Commercially Off-The-Shelf</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital Signal Processor</td>
</tr>
<tr>
<td>ESSOR</td>
<td>European Secure Software Radio</td>
</tr>
<tr>
<td>GPP</td>
<td>General Purpose Processor</td>
</tr>
<tr>
<td>JTNC</td>
<td>Joint Tactical Networking Center</td>
</tr>
<tr>
<td>Lw</td>
<td>Lightweight</td>
</tr>
<tr>
<td>OE</td>
<td>Operating Environment</td>
</tr>
<tr>
<td>POSIX</td>
<td>Portable Operating System Interface</td>
</tr>
<tr>
<td>RTOS</td>
<td>Real-Time Operating System</td>
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<tr>
<td>SCA</td>
<td>Software Communications Architecture</td>
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<tr>
<td>SDR</td>
<td>Software Defined Radio</td>
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<tr>
<td>ULw</td>
<td>Ultra-lightweight</td>
</tr>
<tr>
<td>WINNF</td>
<td>Wireless Innovation Forum</td>
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8 References

8.1 POSIX 2013
URL: http://pubs.opengroup.org/onlinepubs/9699919799/ (free online distribution, no file).

8.2 SCA 4.0.1 Appendix B

8.3 ESSOR Architecture DSP AEP
[Ref3] Reference content from ESSOR on DSP AEPs, input document to WINNF submitted by Indra Sistemas, WINNF-11-I-0007.
URL: http://groups.winnforum.org/d/do/4690 (.pdf file).

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