

Overview

Application Programming Interfaces

- Who defines POSIX?
- POSIX-compliance what does it mean?
- The structure of POSIX
- POSIX systems
- Mandatory vs. optional parts
- Compile-time and run-time checking
- POSIX-compliance the application's part

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Application Program Interfaces

• Application program interface (API):

An abstraction layer between an application and the OS

- Application *A* complies with (= is conformant to) an API standard *S*:
 - A must be source code level portable across OSs that conform to S
- OS *O* complies with an API standard *S*:
 - > O provides all the interface functions required by S
 - O may provide additional functions if these do not conflict with the required functions

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POSIX

- *POSIX*, the *Portable Operating System Interface*, is an API based on the UNIX process model
 - **POSIX.1** specified basic UNIX calls (1990)
 - POSIX.4 is a set of <u>RT extensions</u> to POSIX.1 (1993)

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Who Defines POSIX?

- POSIX is a (still evolving) *IEEE standard*
- Responsible for defining POSIX:
 - > Portable Applications Standards Committee (PASC)
 - Is part of IEEE Computer Society
- There also exist POSIX standards from *ISO*, *ANSI*, and national standards organizations (such as *DIN*)
- POSIX is developed by independent, industry wide committees
 - Includes representatives from all sides
 - Including the historically different UNIX fractions (Berkeley, AT&T, OSF, etc.)

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POSIX is on the Shopping Lists! • SW procurement requirement documents (e.g. from governments) often also refer to POSIX > *Example*: *FIPS 151-2*, specified by the US National Institute of Standards Technology (NIST), specifies POSIX.1 A product may become certified against FIPS 151-2 An agency may become certified as a FIPS 151-2 certifier • However, governments tend to get out of the business of specifying standards Gradually shift to referring to "commonly accepted," nongovernment standards E.g., FIPS 151-2 was deactivated in 1998 R. v. Hanxleden SS 2002 - Real-Time Systems Programming - Lecture_06.sdd Foil 6

POSIX Compliance – What Does It Mean?

- Most OSs claim "POSIX-compliance" of some sort however, it is not obvious what exactly this buys you
 - What components does POSIX consist of?
 - How do I find out which POSIX components my OS supports?

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The Structure of POSIX

• POSIX consists of many individual standards

Not all of these directly related to the OS API

- The POSIX components are identified by *project numbers*
 - Example: Core POSIX real-time extensions are typically referred to as "POSIX 1b," which refers to project number 1003.1b
- In 1994, POSIX projects have been *renumbered*, such that projects that result in amendments to 1003.1 (POSIX.1) now all have the 1003.1 prefix
 - *Example*: 1003.1b had been 1003.4 (POSIX.4) prior to renumbering

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New	Old	Title	Approval Date
1003.0	1003.0	Guide to POSIX OSE	1995-03
1003.1	1003.1	System Interface	1988
1003.1a	1003.1a	System Interface Extensions	
1003.1b	1003.4	Realtime	1993-09
1003.1c	1003.4a	Threads	1995-06
1003.1d	1003.4b	Realtime Extensions	1999-09
1003.1e/.2c	1003.6	Security	
1003.1f	1003.8	Transparent File Access	(withdrawn)
1003.1g	1003.12	Protocol Independent Interfaces	
1003.1h		Fault Tolerance	
1003.1i		Fixes to 1003.1b	1995-06
1003.1j	1003.4d	Advanced Realtime Extensions	2000-01
1003.1k		Removable Media API	(withdrawn)
1003.1m		Checkpoint/Restart	(withdrawn)
1003.1n		Fixes to 1003.1/1b/1c/1i	
1003.1p		Resource Limits	
1003.1q		Tracing	2000-09
1003.1r		Alignment with Single Unix Spec	(withdrawn)
1003.1s		Sync Clock	

New	Old	Title	Approval Date
1003.2	1003.2	Shell and Utilities	1992-09
1003.2a	1003.2a	Shell and Utilities -	1992-09
		Tools & User Port. Ext.	
1003.2b	1003.2b	Additional Utilities	
1003.2d	1003.15	Batch Processing	1994-12
1003.4c	1003.4c	Realtime LIS	(withdrawn)
1003.5	1003.5	Ada binding to 1003.1	1992-06
1003.5a		Ada update	(withdrawn)
1003.5b	1003.20	Ada Realtime	1996-06
1003.5c		Ada binding to 1003.1g	1998-08
1003.5d	1003.5d	ADA PII - Sockets	(withdrawn)
1003.5f		Ada binding to 1003.21	
1003.5g		Ada binding to Real-Time Interfaces	
1003.5f		Ada binding to 1003.1s	
1003.9	1003.9	<i>Fortran</i> binding to 1003.1	1992-06
1003.10	1003.10	Supercomputing profile	1995-06
1003.11	1003.11	Transaction Processing profile	(withdrawn)

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New	Old	Title	Approval Date
1003.11	1003.11	Transaction Processing profile	(withdrawn)
1003.13	1003.13	Realtime profile	1998-03
1003.13a		Embedded Systems AEP	
1003.13b		Additional Real-time Profiles	
1003.14		Multi-Processing profile	(withdrawn)
1003.16	1003.16	1003.1 LIS-C Binding	(withdrawn)
1003.17	1003.17	Directory Services	1993-03
1003.18	1003.18	POSIX Profile	(withdrawn)
1003.19	1003.19	Fortran 90 binding for 1003.1	(withdrawn)
1003.21	1003.21	Realtime Distributed System	
		Communication LIS	
1003.22	1003.22	Security Framework guide	
1003.23	1003.23	Guide for Developing	1998-12
		User Organization OSE Profiles	
1003.24	1003.5e	Ada binding: X Window Modular Toolkit	
1224		ASN.1 Object Mgmt	1993-03
1224.1		DS (X.400) API - LIS	1993-03
1224.2		DS (X.500) API - LIS	1993-03
1295		Motif	1995

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New	Old	Title	Approval Date
1326.2		DS (X.500) API - Test Methods for LIS	
1327.2		DS (X.500) API - C Binding	
1328.2		DS (X.500) API - Test Methods for C Bindin	Ig
1351 & 1353	1238	ACSE & Pres. Layer: LI (1351). C (1353)	1994-09
1387	1003.7	System Administration	
1387.1	1003.7	System Administration Overview	(withdrawn)
1387.2	1003.7.2	Software Admin	1995-06
1387.3	1003.7.3	User/Group Acct Admin	1996-12
1387.4	1003.7.1	Print Admin	(withdrawn)
2000.1		Year 2000 Terminology	1998-06
2000.1a		Year 2000 Terms: Date Range Invariance	
2000.2		Year 2000: Test Methods	1999-06
2003	1003.3	Test Methods	
2003.1	1003.3.1	Test Methods for 1003.1	1992-12
2003.1b		Test Methods for 1003.1b	
2003.2	1003.3.2	Test Methods for 1003.2	1996-06
2003.5		Test Methods for Ada	

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	and it's even more comp	plicated:
• In addition	to the project number, also need the	he <i>year</i>
to refer to a	standard precisely	
• IEEE POS	IX 1003.1-1996 integrates	
≻ 1003.1-19	e	
≻ 1003.1b-1	993	
≻ 1003.1c-1	995	
• Furthermore	e, IEEE POSIX 1003.1-2001 inte	grates
≻ 1003.1d-1	999	
≻ 1003.1j-20	000	
≻ 1003.1q-2	2000	
≻ P1003.1a	draft standard	
≻ 1003.2d-1	994	
≻ P1003.2b	draft standard	
Selected p	oarts of 1003.1g-2000	
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See http://csa.compaq.com/CTJtext/Article29.html
See http://www.unixsystems.org/version3/online.html

Which Parts do We Care About?

- The most relevant parts for RT systems are
 - **POSIX.1** (1003.1): the basic OS interfaces (fork, exec, ...)
 - > **POSIX.1b** (1003.1b, was 1003.4): the RT extensions
 - > **POSIX.1c** (1003.1c, was 1003.4a): the threads extensions
- Each of these parts consists of
 - > Mandatory parts and
 - > Optional parts
- Furthermore, there are still standard UNIX functions that we may care about and that are *not part of POSIX* – such as select

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POSIX Systems

• POSIX is a standard to allow *source-code portability*

On a system conforming to a particular version of POSIX, one should be able to just compile and run those applications that use only those POSIX functions

• POSIX support consists of

- A compilation system
- ➤ Headers
- Libraries
- A run-time system

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The POSIX Compilation System

- The compilation system is supposed to support a standard language
- We'll assume that this is *ANSI C* (and thus, by extension, *Java*)

• In addition (or instead), we may also have

▹ Kernighan and Ritchie (K&R) C

≻ Ada

- > *Fortran* etc.
- May have to specify compile options to get POSIX support linked in

Example: in *LynxOS*, may use gcc -mposix1b

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POSIX Headers

- The system has to provide a set of headers that define the supported POSIX interface
- These are usually in /usr/include, but could also be elsewhere, esp. when cross-developing
- These headers are included in standard C fashion e.g. **#include** <unistd.h>

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POSIX Libraries

- Libraries are *pre-compiled*, vendor-supplied objects that implement the POSIX functionality
- The libraries are either
 - statically linked into the application at compile time, or
 - > dynamically shared at run time
- Normally, we do not want to look at libraries
- However, we may care about
 - which libraries are used, and
 - ➤ the *order* in which libraries are linked in
- Sometimes, archive tools such as **ar** or **nm** may be helpful (specified in POSIX.2)

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The POSIX Run-Time System

- After building the program, the run-time system (the OS) allows you to run your program
- For non-RT systems, not embedded systems the run time system is typically also the development system
- However, for RT applications, we are often *crossdeveloping*, and we have to deal with
 - The *compilation environment*, a workstation or PC, which provides a fairly user-friendly environment
 - The *run-time environment*, onto which an application is downloaded, which often has only bare-bones facilities

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Mandatory vs. Optional parts

- Each of the POSIX parts may consist of
 - Mandatory parts and
 - > Optional parts
- Much of the functionality that is relevant for us is *not mandatory* (semaphores, RT signals, shared memory, message queues etc.)
- Therefore "POSIX.1b compliance" is still not necessarily enough!
- We still need means to find out the details about the system that we are running on

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Mandatory vs. Optional POSIX.1

- POSIX.1 is fairly monolithic that is, *most of it is in the mandatory part*
- The only optional parts are those that were present in some UNIX systems, but not in others
- Examples for optional capabilities:
 - Suspension and resumption of process groups
 - Restricted chown
 - No silent truncation of overlong pathnames
 - Disabling of some terminal characters

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Mandatory vs. Optional POSIX.1b

• POSIX.1b is considered less basic, and therefore there is only a very small mandatory part

Example: the presence of real-time queued signals (SA_SIGINFO, SIGRTMIN, SIGRTMAX)

- Everything else is optional!
 - This includes for example additional signal functions (sigwaitinfo, sigtimedwait, sigqueue)
- *Thus, "POSIX.1b" compliance by itself means very little!*

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How to Find Out What is There

• A solid development path has to consist of two parts:

1. Compile-time checking

- Which version of POSIX am I using?
- > Are the *options* present that are needed by my application?
- > What are the numerical *limits*?

2. Run-time checking

- > What is the run-time *system configuration*?
- What is the *file-dependent configuration*?
- How is the *implementation-defined behavior* (e.g., what I/O operations are permitted for certain file types)?
- The latter is especially relevant for cross-development

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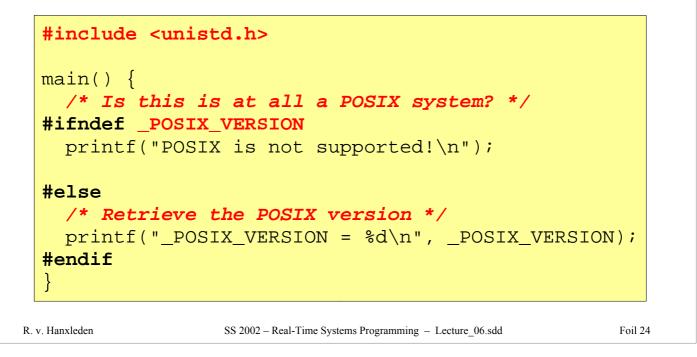
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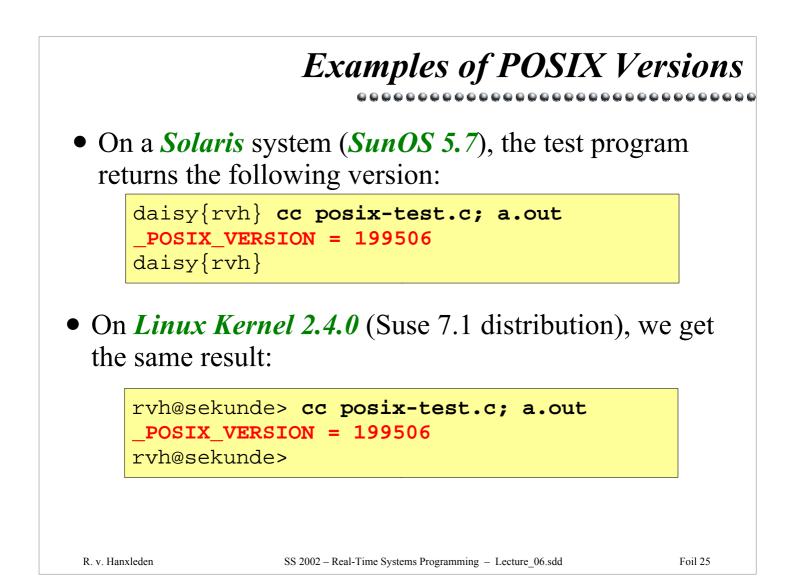
Which Version of POSIX?

• The macro **_POSIX_VERSION** tells us

whether POSIX is present at all

➢ if yes, which version of POSIX we are talking about





Typical POSIX Versions

- The common values of **_POSIX_VERSION** are
 - 198808: August 1988 is the approval date of POSIX.1 as IEEE standard
 - + This usually implies that the system passes the US FIPS 151-1 test suite
 - Igentiate 199009: The system conforms to the 1990, ISO version of POSIX
 - + This is not significantly different from 198808
 - + However, the system then also passes FIPS 151-2, which is better and harder to pass
 - > 199309: mandatory POSIX 1003.1b (real-time) is supported
 - 199506: mandatory POSIX 1003.1c (threads) is supported
 - > 200112L: supports POSIX 1003.1-2001

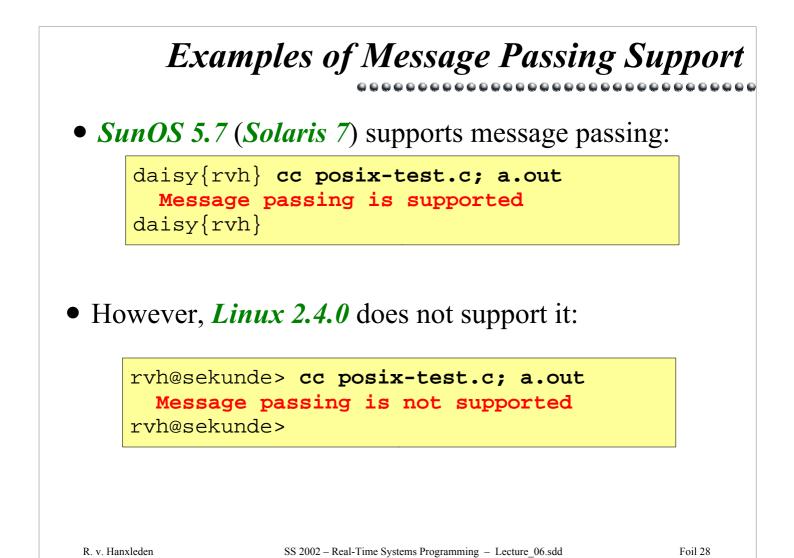
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Which Options are Present?

- There is a *feature test macro* defined for every optional part of POSIX
- For example, we can find out whether a system supports message passing as follows:





What are the Numerical Limits?

- If a feature is present, there may still be *numerical limits* associated with this feature
- Again there are feature test macros for this, defined in limits.h>
- The standard specifies *minimal limits*
 - These are also defined in limits.h>
 - If our application requires more, we have to test the actual system limits

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Example of a Numerical Limit ------• The results on *SunOS 5.7*: #include <unistd.h> #include <limits.h> main() { #ifdef _POSIX_MESSAGE_PASSING printf("Message passing is supported\n"); printf("POSIX standard: at most %d \ message queues per process\n", POSIX MQ OPEN MAX); #ifdef MQ_OPEN_MAX printf("This system: at most %d \ message queues per process\n", MQ_OPEN_MAX); #endif #endif } Message passing is supported POSIX standard: at most 8 message queues per process Foil 30 R. v. Hanxleden SS 2002 - Real-Time Systems Programming - Lecture_06.sdd

Run-Time Checking

- So far, we have discussed compile-time capabilities for examining our system capabilities
- However, there are several reasons to perform runtime checks as well:
 - The development platform may not be the target platform, and there may be uncertainties about the target platform
 - The target platform may change over the lifetime of our application
 - There may be implementation-dependent behavior for which there are no feature test macros available

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POSIX Run-Time Checking

- POSIX provides the following functions, declared in <unistd.h>:
 - sysconf: tests for the presence, absence, and numerical limits of an option on a per-system basis
 - pathconf: as sysconf, but testing is done on a perfile basis
 - **fpathconf**: as **pathconf**, but takes instead of a path a file descriptor to a file that we have already opened

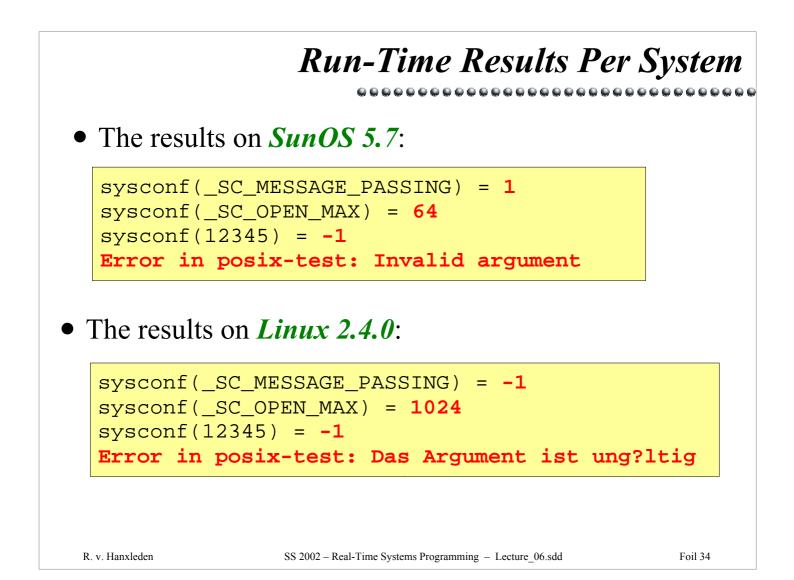
```
#include <unistd.h>
long sysconf(int name);
long pathconf(const char *pathname, int name);
long fpathconf(int fd, int name);
```

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Per-System Run-Time Checks

```
#include <errno.h>
#include <stdio.h>
#include <unistd.h>
#define CHECK_ERRNO if (errno != 0) \
  { perror("Error in posix-test"); errno = 0; }
main() {
  /* Have to reset errno */
  errno = 0;
  /* Run-time check for presence of message passing */
  printf("sysconf(_SC_MESSAGE_PASSING) = %d\n",
    sysconf(_SC_MESSAGE_PASSING));
  CHECK ERRNO;
  /* sysconf() may also return a numeric value */
  printf("sysconf(_SC_OPEN_MAX) = %d\n", sysconf(_SC_OPEN_MAX));
  CHECK_ERRNO;
  /* Better check errno for validity of argument! */
  printf("sysconf(12345) = %d\n", sysconf(12345));
  CHECK_ERRNO;
}
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```



Per-File Run-Time Checks

```
. . .
main() {
  /* Have to reset errno */
  errno = 0;
  /* Request for file-specific information */
  printf("pathconf(\"my_file\", _PC_SYNC_IO) = %d\n",
    pathconf("my_file", _PC_SYNC_IO));
  CHECK ERRNO;
  /* Can also get information on directories */
  printf("pathconf(\".\", _PC_NAME_MAX) = %d\n",
    pathconf(".", _PC_NAME_MAX));
  CHECK_ERRNO;
  /* pathconf() complains if file does not exist! */
  printf("pathconf(\"non_existing_dir\", _PC_NAME_MAX) = %d\n",
    pathconf("non_existing_dir", _PC_NAME_MAX));
  CHECK_ERRNO;
}
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                                                                   Foil 35
```

Run-Time Results Per File

• The results on *SunOS 5.7*:

pathconf("my_file", _PC_SYNC_IO) = 1
pathconf(".", _PC_NAME_MAX) = 255
pathconf("non_existing_dir", _PC_NAME_MAX) = -1
Error in posix-test: No such file or directory

• The results on *Linux 2.4.0*:

pathconf("my_file", _PC_SYNC_IO) = -1
pathconf(".", _PC_NAME_MAX) = 255
pathconf("non_existing_dir", _PC_NAME_MAX) = -1
Error in posix-test: Datei oder Verzeichnis
nicht gefunden

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POSIX Compliance of the Application

- So far, we looked at how the *OS* expresses its POSIX compliance
- However, the *applications* may also have varying degrees of POSIX compliance
- An application can express that it uses the POSIX API functions (and *only* those functions) by defining
 <u>POSIX_C_SOURCE</u> with a value that expresses the
 POSIX version it is conforming to

	<pre>#define _POSIX_C_SOURCE 199506</pre>	
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Summary on the Mechanics of POSIX

- POSIX is a collection of *IEEE standards*
 - > The aim is *source-code compatibility*
 - POSIX is in many areas today's *de-facto industry* standard
- POSIX consists of many different parts, mostly stemming from *UNIX*, and originally designed for *C*
 - However, OSs such as Windows NT and applications written in languages such as Ada or Fortran can claim POSIX compliance as well
- The most relevant parts for us are
 - > **POSIX.1**
 - > **POSIX.1b** (was: POSIX.4): RT extensions
 - > *POSIX.1c* (was: POSIX.4a): threads

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Summary on POSIX Compliance Checking

• <i>Compile-time checking</i> , using feature test macros:
Test forPOSIX_VERSION
Test for presence of <i>options</i> required by app
If <i>numerical limits</i> guaranteed by the standard are not sufficient, evaluate the actual limits
• <i>Run-time checking</i> , esp. when cross-developing:
Check system configuration, using sysconf
Check file-dependent configuration, using pathconf or fpathconf
Perform ad-hoc checks on <i>implementation-dependent</i> behavior

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To Go Further

• **POSIX and RT programming in general:**

F [Gallmeister 1995]

• IEEE POSIX Std 1003.1-2001:

http://www.unix-systems.org/version3/online.html

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Problem Set 3 – Due: 2 May 2002

- 1) What are the pros and cons of using an API standard? Discuss from the standpoint of the *application developer*, the *OS developer*, and the *final user*. **(3 pts)**
- 2) Which version of POSIX does the OS you are typically using support? (2 pts)
- 3) In the IEEE POSIX Std 1003.1-2001 document
 - a) What are the differences between "may", "can", and "should"? (1 pt)
 - b) What are the differences between "unspecified" and "undefined"? (1 pt)
- 4) Find two features where Solaris and Linux currently differ in their level of POSIX support (apart from the ones mentioned in class) (2 pts)

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