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Empowering Embedded Systems

μC/TCP-IP

V1.90

User's Manual

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Contact address

Micrium
949 Crestview Circle
Weston, FL 33327-1848
U.S.A.
Phone : +1 954 217 2036
FAX : +1 954 217 2037
WEB : **www.micrium.com**
Email : **support@micrium.com**

Manual versions

If you find any errors in this document, please inform us and we will make the appropriate corrections for future releases.

Manual Version	Date	By	Description
V1.54 Rev. A	2004/12/09	JJL	Combined chapters in single document.
V1.54 Rev. B	2004/12/14	JJL	Added Configuration constants in Chapter 17
V1.56	2005/01/23	JJL	Added information about buffers and timers
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V1.85	2006/05/08	ITJ	Updated Debug Status Functions
V1.86	2006/08/08	ITJ	Corrected Socket API Descriptions
V1.87	2006/09/20	JJL	Updated Manual
V1.88	2006/11/27	ITJ	Updated Manual
V1.89	2007/03/08	ITJ	Corrected Socket API & Configuration Descriptions
V1.90	2007/05/24	ITJ	Updated Manual

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Introduction

µC/TCP-IP is a compact, reliable, high performance TCP/IP protocol stack. Built from the ground up with Micrium's renowned quality, scalability and reliability, µC/TCP-IP enables the rapid configuration of required network options to minimize your time to market. µC/TCP-IP is the result of many man-years of development.

The source code for µC/TCP-IP contains over 100,000 lines of the cleanest, most consistent ANSI C source code you will ever find in a TCP/IP stack implementation. C was chosen because C is still the most predominant language in the embedded industry. Over 50% of the code actually consists of comments. Most global variables and all functions are described. References to RFC (Request For Comments) are referenced in the code when applicable. The code is designed to be used with just about any CPU, RTOS and NIC (Network Interface Controller).

I.1 Portable

µC/TCP-IP was designed for resource constrained embedded applications. Although µC/TCP-IP can work on some 8 and 16-bit processors, µC/TCP-IP will work best with 32 or 64-bit CPUs.

I.2 Scalable

The memory footprint of µC/TCP-IP can be adjusted at compile time based on the features you need and the desired level of run-time argument checking. Also, throughout µC/TCP-IP, we keep track of statistics and, some of those can be disabled in order to further reduce the footprint.

I.3 Coding Standards

Coding standards have been established early in the design of µC/TCP-IP and include the following:

- C coding style
- Naming convention for `#define` constants, macros, variables and functions
- Commenting
- Directory structure

These conventions makes µC/TCP-IP the cleanest TCP/IP stack implementation in the industry and makes it easier to attain third party certification as outlined in the next section.

I.4 Third Party Certification

µC/TCP-IP has been designed from the ground up to be certifiable for use in avionics as well as medical and other safety critical products. A company called Validated Software is preparing a Validation Suite(tm) for µC/TCP-IP to provide all of the documentation necessary to deliver µC/TCP-IP as a pre-certifiable software component for safety critical systems, including avionics RTCA DO-178B and EUROCAE ED-12B, medical FDA 510(k), and IEC 61058 standard for transportation and nuclear systems. The very affordable Validation Suite(tm), is available through Validated Software. It will be immediately certifiable for the highest criticality systems, including DO-178B Level A, Class III medical devices, and SIL3/SIL4 IEC-certified systems. For more information, check out the µC/TCP-IP page on the Validated Software web site (**www.ValidatedSoftware.com**).

If your product is NOT safety critical, you should view the certification as proof that µC/TCP-IP is a very robust and highly reliable TCP/IP stack.

I.5 MISRA C

The source code for µC/TCP-IP follows the Motor Industry Software Reliability Association (MISRA) C Coding Standards. These standards were created by MISRA to improve the reliability and predictability of C programs in critical automotive systems. Members of the MISRA consortium include Delco Electronics, Ford Motor Company, Jaguar Cars Ltd., Lotus Engineering, Lucas Electronics, Rolls-Royce, Rover Group Ltd., and other firms and universities dedicated to improving safety and reliability in automotive electronics. Full details of this standard can be obtained directly from the MISRA web site, **http://www.misra.org.uk**.

I.6 RTOS

µC/TCP-IP assumes the presence of an RTOS. However, we don't make any assumptions about which RTOS you will be using with µC/TCP-IP. The only requirements from the RTOS are:

1) The RTOS must be able to support multiple tasks
2) The RTOS must provide binary and counting semaphore management services

µC/TCP-IP contains an encapsulation layer that allows you to use just about any commercial or open source RTOS. In other words, details about the RTOS you use are hidden from µC/TCP-IP. µC/TCP-IP includes the encapsulation layer for µC/OS-II, The Real-Time Kernel.

I.7 Single Network Interface Controller (NIC)

The current version of µC/TCP-IP only allows the use of a single NIC for any one product/application. At this time, the single NIC must be an Ethernet controller. Any Ethernet-type NIC may be used provided a driver with the appropriate API and BSP software is provided. Interface to a specific NIC (i.e. chip) is encapsulated in a couple of files and it's quite easy to adapt different NICs to µC/TCP-IP.

We are currently working on adding PPP (Point-to-Point Protocol) support to µC/TCP-IP.

I.8 µC/TCP-IP Protocols

µC/TCP-IP consists of the following protocols:

- NIC driver
- Interface (Ethernet)
- ARP (Address Resolution Protocol)
- IP (Internet Protocol)
- ICMP (Internet Control Message Protocol)
- UDP (User Datagram Protocol)
- TCP (Transport Control Protocol)
- Sockets (BSD v4)

I.9 Application Protocols

µC/TCP-IP can work with well known application layer protocols such as DHCP, DNS, TFTP, HTTP servers (web server), FTP servers, SNTP clients, SNMP clients and more.

I.10 µC/TCP-IP Limitations

By design, we have limited some of the features of µC/TCP-IP. Table I-1 describes those limitations.

Supports a single network interface and one host IP address
Supports a single default gateway
No IP forwarding/routing
No IP multicasting
No IP transmit fragmentation
No IP Security options RFC #1108
No ICMP Address Mask Agent/Server RFC #1122, Section 3.2.2.9
No TCP Urgent Data
No TCP Security & Precedence

Table I-1, µC/TCP-IP limitations for current software version

Chapter 1

Getting Started with µC/TCP-IP

This chapter provides examples on how to use µC/TCP-IP. We decided to include this chapter early in the µC/TCP-IP manual so you could start using µC/TCP-IP as soon as possible. In fact, we assume you know little about µC/TCP-IP and networking. Concepts will be introduced as needed.

The sample code was compiled using the IAR Embedded Workbench V4.31a (or higher) for the ARM processor. Tests were done using a Cogent CSB337 (ARM9 CPU) board which has an AT91RM9200 EMAC Network Interface Controller (NIC). We selected an ARM processor because of its popularity in the networking world.

1.00 Installing µC/TCP-IP

The distribution of µC/TCP-IP is placed in a ZIP file called: `uC-TCPIP-Vxyy.zip`. The ZIP file contains all the source code and documentation for µC/TCP-IP. Support modules are needed by the protocol stack and provided in the µC/TCP-IP distribution. Support modules are placed in sub-directories as shown in Figure 1-1.

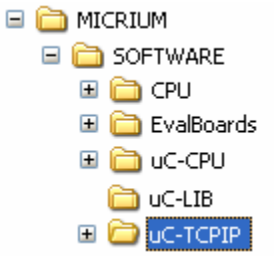


Figure 1-1, Test setup

\CPU

This sub-directory contains CPU specific header files and code. For example, header files would contain definition of CPU registers, I/O ports, timer registers and more. This sub-directory contains other sub-directories for each type of CPU manufacturer and actual CPUs. The sub-directories are organized as follows:

```
\CPU\<Manufacturer>\<CPU Model>
```

This directory is needed when testing code that uses the protocol stack on an actual target.

\EvalBoards

This sub-directory contains sample code for evaluation boards. The sub-directories are organized as follows:

```
\EvalBoards\<Manufacturer>\<Eval. Board Name>\<Compiler>\<Example Name>
```

The distribution contains sample code for the Cogent CSB337 Evaluation Board.

\uC-CPU

This sub-directory contains CPU specific code which depends on the compiler used. The uC-CPU sub-directory also contains additional sub-directories which are organized as follows:

```
\uC-CPU\<CPU Type>\<Compiler>
```

The uC-CPU sub-directory (and sub-directory) contains three files:

cpu_def.h

This file (which is found directly in the uC-CPU directory) declares #define constants for CPU alignment, endianness, and other generic declarations.

cpu.h

This file is placed in the \uC-CPU\<CPU Type>\<Compiler> directory and contains type definitions for 8, 16 and 32-bit signed and unsigned numbers. These are needed to be independent of processor and compiler word size definitions. In other words, µC/TCP-IP always uses its own datatypes instead of the C data types. cpu.h also declares other #define values, data types and function prototypes.

cpu_a.asm

This file is placed in the \uC-CPU\<CPU Type>\<Compiler> directory and contains code to enable/disable interrupts for the specific CPU.

\uC-LIB

This sub-directory contains libraries that are common to all modules. The files in this directory are needed if you compile µC/TCP-IP because we use the code found in these files. The directory contains the following files:

lib_def.h

This file defines such things as TRUE/FALSE but, all #defines in this file starts with DEF_ and thus TRUE/FALSE are actually DEF_TRUE and DEF_FALSE.

lib_mem.c and **lib_mem.h**

These files contain code to replace the standard library functions `memclr()`, `memset()`, `memcpy()` and `memcmp()`. These functions are replaced by `Mem_Clr()`, `Mem_Set()`, `Mem_Copy()` and `Mem_Cmp()`, respectively. The reason we declared our own functions is for third party certification purposes. Specifically, FAA (Federal Aviation Administration) certification requires that ALL the source code be available to certify a product that is intended to be air worthy.

lib_str.c and **lib_str.h**

These files contain code to replace the standard library functions `str???()` with their equivalent `Str_???()` functions. Again, this is to simplify third party certification for avionics and medical use.

\uC-TCPIP This is the main sub-directory for µC/TCP-IP. This sub-directory contains additional sub-directories for the different components of µC/TCP-IP. Code in `\uC-TCPIP` is independent of the CPU used and its interrupt structure, the actual hardware (whether memory or I/O mapped), etc. In other words, this code should be able to be used unchanged on a large number of different platforms.

µC/TCP-IP assumes the presence of a Real-Time Operating System (RTOS). However, µC/TCP-IP can work with just about any RTOS as long as the RTOS allows you to create tasks, assign priorities to tasks and supports semaphores. Most RTOSs provide these basic functions.

1.01 Example #1

Examples #1 is used to show you the basic architecture of µC/TCP-IP and build an empty application. The application also uses µC/OS-II as the RTOS. Figure 1-2 shows the test setup for Example #1. A Windows-based PC and the target system were connected to a 10 Mbps 10-Base-T hub. The PC's IP address was set to `10.10.10.111` and the target address was hard coded to `10.10.10.64`.

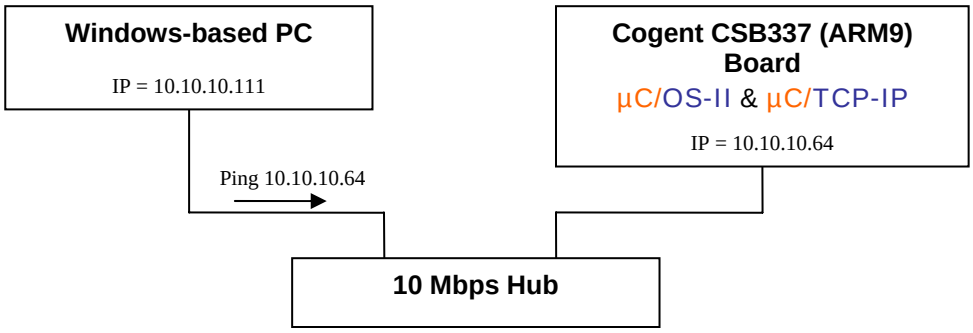


Figure 1-2, Test setup

This example contains enough code to be able to 'ping' the board.

'ping' is a utility found on most computer (Windows-based PCs, Linux, Unix, etc.) and allows you to see if a particular network enabled device is connected to your network. The IP address of the board is forced to `10.10.10.64` so, if you were to have a similar setup, you would be able to issue the following command from a command-prompt:

```
ping 10.10.10.64
```

Ping (on the PC) should reply back with the ping time to the target. We had ping times of less than 10 milliseconds.

Figure 1-3 shows the directory tree of the different components needed to build a µC/TCP-IP based application. For now, we will examine the contents of the following directories:

```
\Micrium\Software\EvalBoards\Cogent\CSB337\IAR\BSP
\Micrium\Software\EvalBoards\Cogent\CSB337\IAR\uC-Apps\Ex1
```

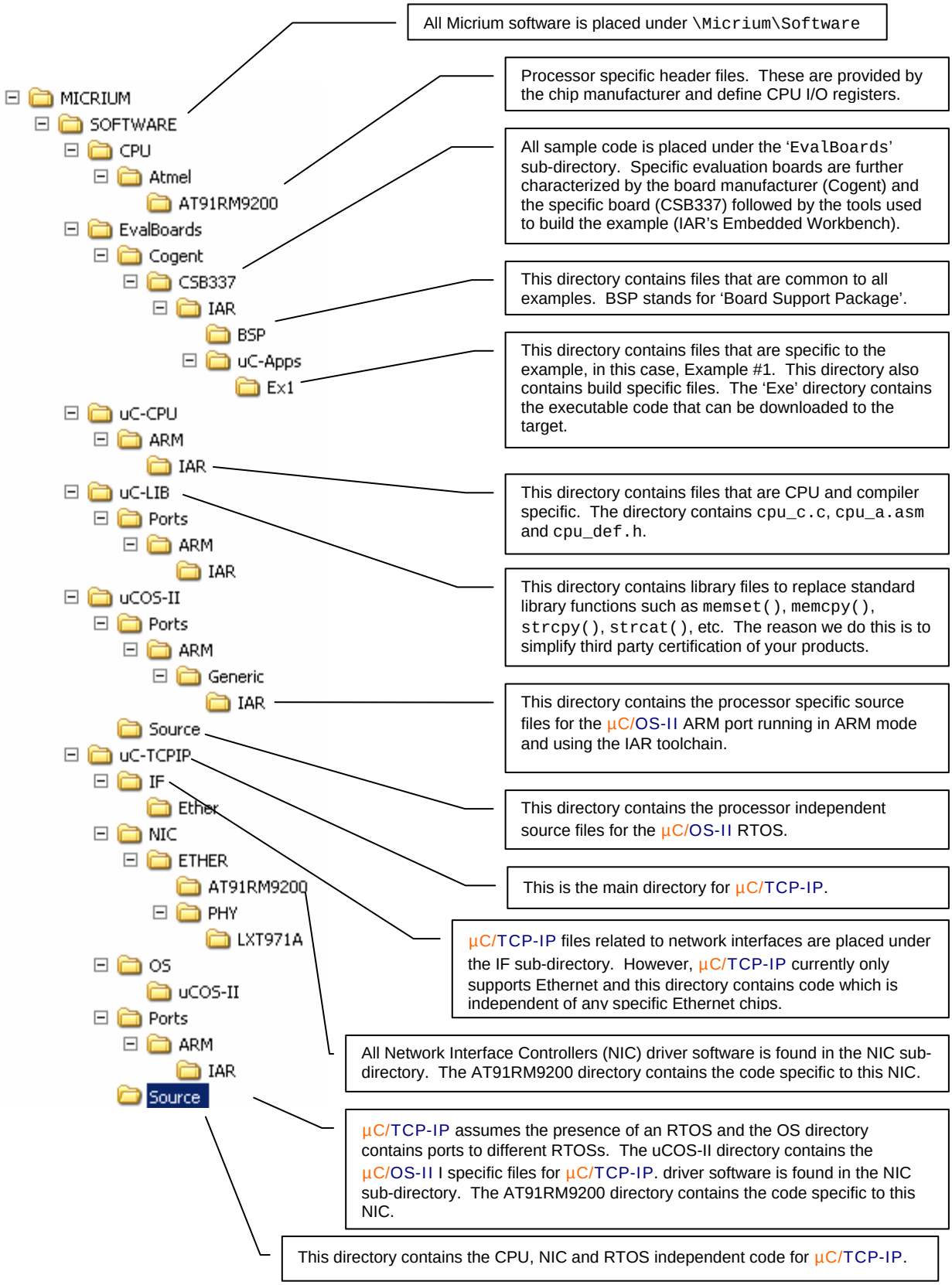


Figure 1-3, Directory tree for µC/TCP-IP based project

1.01.01 BSP (Board Support Package)

As described in Figure 1-3, the BSP (Board Support Package) directory contains common code that can be used in more than one example. Specifically, the BSP directory contains the following files:

```
bsp.c
bsp.h
net_bsp.c
net_bsp.h
net_isr.c
csb33x_lnk_ram.xcl
```

`bsp.c` and `bsp.h`

BSP stands for Board Support Package and we place 'services' that the board provides in such a file. In our case, `bsp.c` contains I/O, timer initialization code, LED control code, and more. The I/Os that we use on the board are initialized when `BSP_Init()` is called.

The concept of a BSP is to hide the hardware details from the application code. It is important that functions in a BSP reflect the function and does not make references to any CPU specifics. For example, the code to turn on an LED is called `LED_On()` and not `csb337_led()`. If you use `LED_On()` in your code, you can easily port your code to another processor (or board) simply by rewriting `LED_On()` to control the LEDs on a different board. The same is true for other services. You will also notice that BSP functions are prefixed with the function's group. LED services start with `LED_`, Timer services start with `Tmr_`, etc. In other words, BSP functions don't need to be prefixed by `BSP_`.

`net_bsp.c`, `net_bsp.h` and `net_isr.c`

This file contains code specific to the NIC (Network Interface Controller) used and other functions that are dependent of the hardware. Specifically, this file contains code to read data from and write data to the NIC, provide delay functions, control power to the NIC, get a time stamp and more.

`csb33x_lnk_ram.xcl`

This file contains the linker command file for the IAR toolchain. This file specifies where code and data is placed in memory. In this case, all the code is placed in RAM to make it easier to debug. When you are ready to deploy your product, you will most likely need to create a `csb33x_lnk_flash.xcl` to locate your code in Flash instead of RAM.

1.01.02 Ex1

This directory contains the code for this example and consist of:

```
app.c
app_cfg.h
Ex1.*
fs_conf.h
includes.h
net_cfg.h
os_cfg.h
```

app.c

This file contains the application code for example #1. As with most C programs, code execution start at `main()` which is shown in listing 1-1. The example #1 starts µC/TCP-IP and a set of services that run on top of it. These services (like web server) are sold separately from µC/TCP-IP. See section 1.02 to know how to disable some services in the example if you have not purchased them.

Listing 1-1

```
int  main (void)
{
#if (OS_TASK_NAME_SIZE >= 16)
    CPU_INT08U  err;
#endif


    BSP_Init();                     /* (1) Initialize BSP.                                  */

    APP_TRACE_DEBUG("Initialize OS...\n");
    OSInit();                       /* (2) Initialize OS.                                   */

                                    /* (3) Create start task.                               */
    OSTaskCreateExt( AppTaskStart,
                    (void *)0,
                    (OS_STK *)&AppStartTaskStk[APP_START_OS_CFG_TASK_STK_SIZE - 1],
                     APP_START_OS_CFG_TASK_PRIO,
                     APP_START_OS_CFG_TASK_PRIO,
                    (OS_STK *)&AppStartTaskStk[0],
                     APP_START_OS_CFG_TASK_STK_SIZE,
                    (void *)0,
                     OS_TASK_OPT_STK_CHK | OS_TASK_OPT_STK_CLR);

                                    /* (4) Give a name to tasks.                            */
#if (OS_TASK_NAME_SIZE >= 16)
    OSTaskNameSet(OS_TASK_IDLE_PRIO,   "Idle task",  &err);
    OSTaskNameSet(OS_TASK_STAT_PRIO,   "Stat task",  &err);
    OSTaskNameSet(APP_START_OS_CFG_TASK_PRIO, "Start task", &err);
#endif

    APP_TRACE_DEBUG("Start OS...\n");
    OSStart();                      /* (5) Start OS.                                        */
}
```

L1-1(1) We start by initializing the I/Os we'll be using on this board as well as the µC/OS-II tick interrupt and the AT91RM9200's interrupt controller.

L1-1(2) The example code assumes the presence of an RTOS called µC/OS-II and `OSInit()` is used to initialize µC/OS-II.

L1-1(3) µC/OS-II requires that we create at least ONE application task. This is done by calling `OSTaskCreateExt()` and specifying the task start address, the top-of-stack to use for this task, the priority of the task and a few other arguments.

L1-1(4) µC/OS-II allows you to assign names to tasks that have been created. We thus assign a name to the application task. These names are used mostly during debug. In fact, task names are displayed during debug when using IAR's C-Spy debugger (or other µC/OS-II aware debuggers).

L1-1(5) In order to start multitasking, your application needs to call `OSStart()`. `OSStart()` determines which task, out of all the tasks created, will get to run on the CPU. In this case, µC/OS-II will run `AppTaskStart()`.

The first, and only 'application' task that µC/OS-II runs is shown in listing 1-2.

Listing 1-2

```
static  void  AppTaskStart (void  *p_arg)
{
    (void)p_arg;                    /*     Prevent compiler warning.                           */


    APP_TRACE_DEBUG("Initialize interrupt controller...\n");
    BSP_InitIntCtrl();              /* (1) Initialize interrupt controller.                    */

    APP_TRACE_DEBUG("Initialize OS timer...\n");
    Tmr_Init();                     /* (2) Initialize OS timer.                                */

#if (OS_TASK_STAT_EN > 0)
    APP_TRACE_DEBUG("Initialize OS statistic task...\n");
    OSStatInit();                   /* (3) Initialize OS statistic task.                       */
#endif

#if APP_FS_ENABLED
    AppInit_FS();                   /* (4) Initialize file system.                             */
#endif

    AppInit_TCPIP();                /* (5) Initialize TCP/IP stack.                            */

#if APP_DHCPc_ENABLED
    AppInit_DHCPc();                /* (6) Initialize DHCP client.                             */
#endif

#if APP_HTTPs_ENABLED
    APP_TRACE_DEBUG("Initialize HTTP server...\n");
    HTTPs_Init();                   /* (7) Initialize HTTP server.                             */
#endif

#if APP_FTPs_ENABLED
    APP_TRACE_DEBUG("Initialize FTP server...\n");
                                    /* (7) Initialize FTP server.                              */
    FTPs_Init(AppIP_Addr, FTPs_CFG_DTP_IPPORT);
#endif


#if APP_TFTPs_ENABLED
    APP_TRACE_DEBUG("Initialize TFTP server...\n");
    TFTPs_Init();                   /* (7) Initialize TFTP server.                             */
#endif
```

```
#if APP_DNSc_ENABLED
    DNSc_Init(AppIP_DNS_Srvr);     /* (8) Initialize DNS client.                              */

    AppTest_DNSc();                /*     Test DNS client.                                    */
#endif

#if APP_FTPc_ENABLED
    AppTest_FTPc();                /* (8) Test FTP client.                                    */
#endif

#if APP_POP3c_ENABLED
    AppTest_POP3c();               /* (8) Test POP3 client.                                   */
#endif

#if APP_SMTPc_ENABLED
    AppTest_SMTPc();               /* (8) Test SMTP client.                                   */
#endif

#if APP_SNTPc_ENABLED
    AppTest_SNTPc();               /* (8) Test SNTP client.                                   */
#endif

    APP_TRACE_DEBUG("Create application task...\n");
    AppTaskCreate();               /* (9) Create application task.                            */

    APP_TRACE_DEBUG("\n*********************************************************************");
    APP_TRACE_DEBUG("\n*                                                                   *");
    APP_TRACE_DEBUG("\n*    Micrium uC/TCP-IP TTCP Performance measurement                 *");
    APP_TRACE_DEBUG("\n*           AT91RM9200 on Cogent CSB337 SDK                         *");
    APP_TRACE_DEBUG("\n*                                                                   *");
    APP_TRACE_DEBUG("\n*********************************************************************");
    APP_TRACE_DEBUG("\n");
    TTCP_Init();                   /* (10)Initialize TTCP application                         */
#endif

    LED_Off(1);
    LED_Off(2);
    LED_Off(3);

    while (DEF_YES) {              /*     Task body, always written as an infinite loop.      */
        OSTimeDlyHMSM(0, 0, 0, 100);
    }
}
```

L1-2(1) `AppTaskStart()` starts off by initializing the AT91RM9200 interrupt controller and start handling interruptions.

L1-2(2) Enable the timer tick source from the microcontroller. µC/OS-II needs a time base to determine when it's time to preempt a task and let the next task scheduled to run. Details as to how this is done can be found in the µC/OS-II book.

L1-2(3) If you set `OS_TASK_STAT_EN` to `1` in `os_cfg.h` then the µC/OS-II statistic task is initialized by calling `OSStatInit()`. `OSStatInit()` basically figures out how fast the CPU is running in order to determine how much CPU usage your application will be consuming. Details as to how this is done can be found in the µC/OS-II book.

L1-2(4) Initialize File System. This is optional. File System is used by some µC/TCP-IP services. If you purchased the µC/FTPs, µC/HTTPs or µC/TFTPs, you also need µC/FS.

L1-2(5) We then initialize the TCP/IP stack by calling `NetInit()`. `NetInit()` initializes all of µC/TCP-IP's data structures and creates two tasks. One task waits for packets to be received and the other task manages timers.

IMPORTANT

`Net_Init()` returns an error code indicating whether the call was successful or not. If `Net_Init()` returns `NET_ERR_NONE` then `Net_Init()` properly initialized µC/TCP-IP. However, if `Net_Init()` returns something other than `NET_ERR_NONE` then you must examine the error code to determine the source of the error.

Just as important, `Net_Init()` 'aborts' the initialization as soon as it finds an error. In other words, if you don't examine the return value you might have a partially initialized µC/TCP-IP and the results are unpredictable.

L1-2(6) Each 'node' on a TCP/IP network requires a unique address. This is called the *IP address* and consists of a 32-bit value. An IP address is generally represented as four decimal numbers separated by a dot (Dotted Decimal Notation). Each value corresponds to an eight bit value and is assigned to its corresponding position in the 32-bit word. For example, `160.110.80.40` corresponds to an IP address of `0xA06E5028`.

You should note here that the address is determined at run-time (*Dynamic* IP address) by the use of a service called DHCP (dynamic host configuration protocol). The optional µC/DHCPc module implements this protocol that allows the IP address of your target system (and many other information) to be assigned by another computer on your network (typically DHCP server).

If you have not purchased the µC/DHCPc module, you should note that the address have to be determined at compile time by your test code (*Static* IP address).

L1-2(7) Initialize the server modules (µC/FTPs, µC/HTTPs or µC/TFTPs). If you have not purchased one or all of them, please look at section 1.02 how to disable them. Also, please look at their respective documentation about how to configure them.

L1-2(8) Test the optional client modules:

- µC/DNSc client module: The DNS (*domain name service*) protocol enable to resolve *fully qualified domain name* (FQDN) to IP addresses. Ex.: **www.micrium.com** resolved to "198.66.208.142". This enable the use of DNS name in code instead of the IP addresses, less descriptive and subject to change over time.
- µC/FTPc client module: The FTP (*file transfer protocol*) protocol enable the transfer of files over internet. You can transfer any kind of file to your target or from your target to your PC using this protocol. The µC/FTPc client module can get and store files directly in the target's RAM or using a file system. In this case, you will need to purchase the µC/FS module.
- µC/POP3c client module: The POP3 (*post office protocol 3*) protocol enable the reception of email messages from a mailserver. The email messages are stored in a user's mailbox in the server and *pulled* by the user. If you have to **receive** messages on your target from other computers, you need µC/POP3c client module. You also need µC/DNSc client module since POP3 servers are usually addressed by their DNS names.

- µC/SMTPc client module: The SMTP (*simple mail transfer protocol*) protocol enable transfer of email messages over internet. The SMTP protocol is a *push* protocol. The sender of the message *pushes* the message to the recipient's mailbox. If you have to **send** email message from your target to other computer, you need µC/SMTPc client module. You also need µC/DNSc client module since POP3 servers are usually addressed by their DNS names.

- µC/SNTPc client module: The SNTP (*simple network time protocol*) protocol enable the synchronization of computer's real time clocks over the internet. The time information transferred is and offset from NTP epoch (1900-01-01 00:00:00 GMT) and the resolution is the millisecond. The µC/SNTPc client module *transfers* the current time over the internet but have no provision to store & update the time. For this feature, you need the µC/CLK module. µC/CLK and µC/SNTPc modules work independently. µC/CLK moduke can be initialized by any time source, including network source using µC/SNTPc. µC/SNTPc module can be used to synchronize any real-time clock, including µC/CLK, or just get a snapshot of the current time.

L1-2(9) Start the application task. The application task enters an infinite loop and blinks one of the LEDs.

L1-2(10) Initialize µC/TTCP module. This module enable user to make performance tests on µC/TCP-IP stack.

With this simple application code, another computer on the same network can send a ping Echo Request to this target.

app_cfg.h

This is an application-specific configuration file used to configure Micrium products and/or non-Micrium-related application files. You MUST include this file in your application because some of the modules in µC/TCP-IP assumes the presence of this file. `app_cfg.h` contains `#defines` to specify the task priorities of each of the tasks in your application (including those of µC/TCP-IP) as well as the stack size for those tasks.

The reason all task priorities are placed in one file is to make it easier to 'see' the task priorities for your entire application in one place.

includes.h

`includes.h` is a 'master' header file that contains `#include` directives to include other header files. This is done to make the code cleaner to read and easier to maintain. Note that we assume the presence of `includes.h`.

Ex1.*

These files are IAR embedded workbench project files.

net_cfg.h

This file is used to configure µC/TCP-IP and defines the number of timers used in µC/TCP-IP, the number of buffers for packets reception and transmission, the number of ARP (Address Resolution Protocol) cache entries, the number of Sockets that your application can open and more. In all, there are about `50` or so `#define` to set in this file.

os_cfg.h

This file is used to configure µC/OS-II and defines the number maximum number of tasks that your application can have, which services will be enabled (semaphores, mailboxes, queues, etc.), the size of the idle and statistic task and more. In all, there are about `60` or so `#define` that you can set in this file. Each entry is commented and additional information about the purpose of each `#define` can be found in the µC/OS-II book.

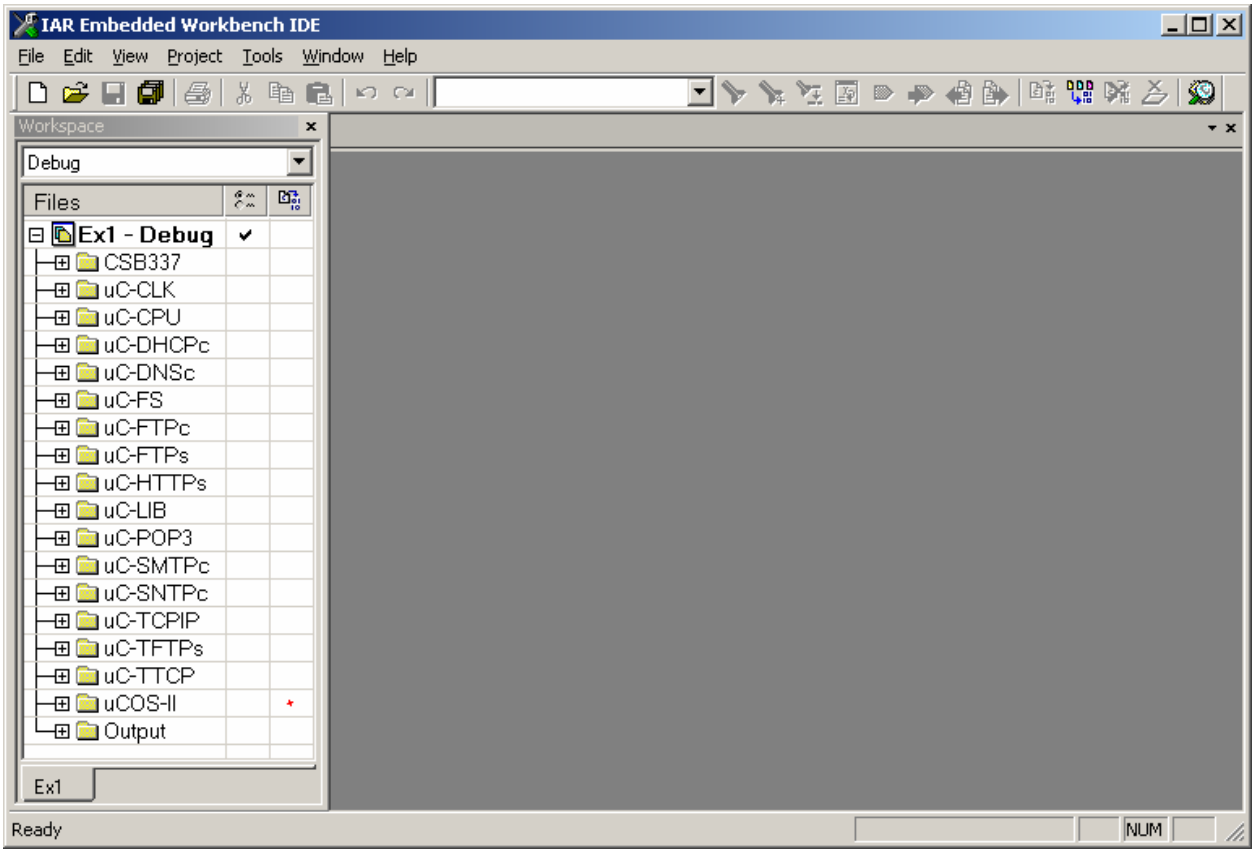
1.02 Configuration of the Example #1

Demonstration of the capabilities of the µC/TCP-IP stack is hard without code using it. There is a lot of services that have been designed for TCP-IP over the years. Many of them have been implemented has optional modules to run over µC/TCP-IP.

The example #1 integrates µC/TCP-IP and all the optional modules currently available. We are understanding that every client may get its own set of optional modules so we have to provide clients a way to disable the ones that they don't have.

Here is the way (using IAR tools) to disable optional modules and get a fully customized µC/TCP-IP demonstration example:

When the example project file is loaded into IAR tools, the screen look like this:



On the left pane, there is a list of different group of files included in the example, representing modules. Some are mandatory, some are optional.

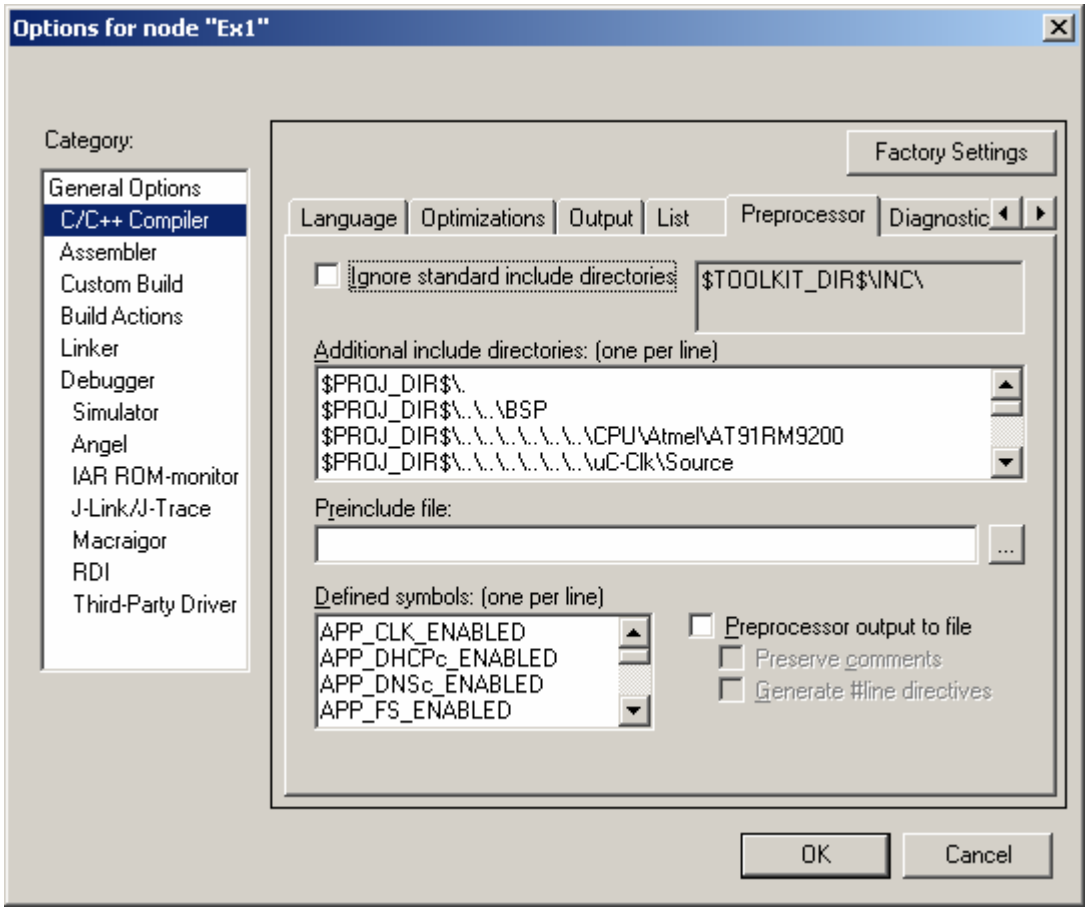
Mandatory modules: CSB337, µC/CPU, µC/LIB, µC/TCP-IP, µC/TTCP and µC/OS-II.
Optional modules: µC/CLK, µC/DHCPc, µC/DNSc, µC/FS, µC/FTPc, µC/FTPs, µC/HTTPs, µC/POP3, µC/SMTPc, µC/SNTPc and µC/TFTPs.

Optional modules have interdependencies on other optional modules.

µC/FTPs, µC/HTTPs and µC/TFTPs modules needs the FS module. µC/FTPc module may need it too, depending on configuration.

µC/DNSc is needed if you use DNS names instead of IP addresses in your application for addressing other machines.

To remove an optional module, there is two steps. First, select the corresponding group of files in the left, then press the "delete" key on your keyboard or select "remove" in the contextual menu. Then, select the "Ex1-Debug" entry in the left pane, select "options" in the contextual menu, then "C/C++ compiler", then preprocessor pane. You will see a window like this:



On the "Defined symbols" list, remove the entry corresponding to the module you want to remove. Ex: remove the APP_DHCPs_ENABLED entry if you want to remove the µC/DHCPc module.

After you are removed all the module you haven't purchased, you are ready to compile your own customized µC/TCP-IP example.

Chapter 2

µC/TCP-IP Architecture

µC/TCP-IP was written from the ground up to be modular and easy to adapt to different CPUs (Central Processing Units), RTOSs (Real-Time Operating Systems), NICs (Network Interface Controllers) and compilers. Figure 2-1 shows a simplified block diagram of the different elements and their relationship.

You will probably notice that all of the µC/TCP-IP files start with '`net_`'. This convention allows you to quickly identify files that belong to µC/TCP-IP. In fact, all functions and variables start with '`Net`' and, all macros and #defines start with '`NET_`'. These and other conventions are described in the '*µC/TCP-IP Coding Convention*' appendix.

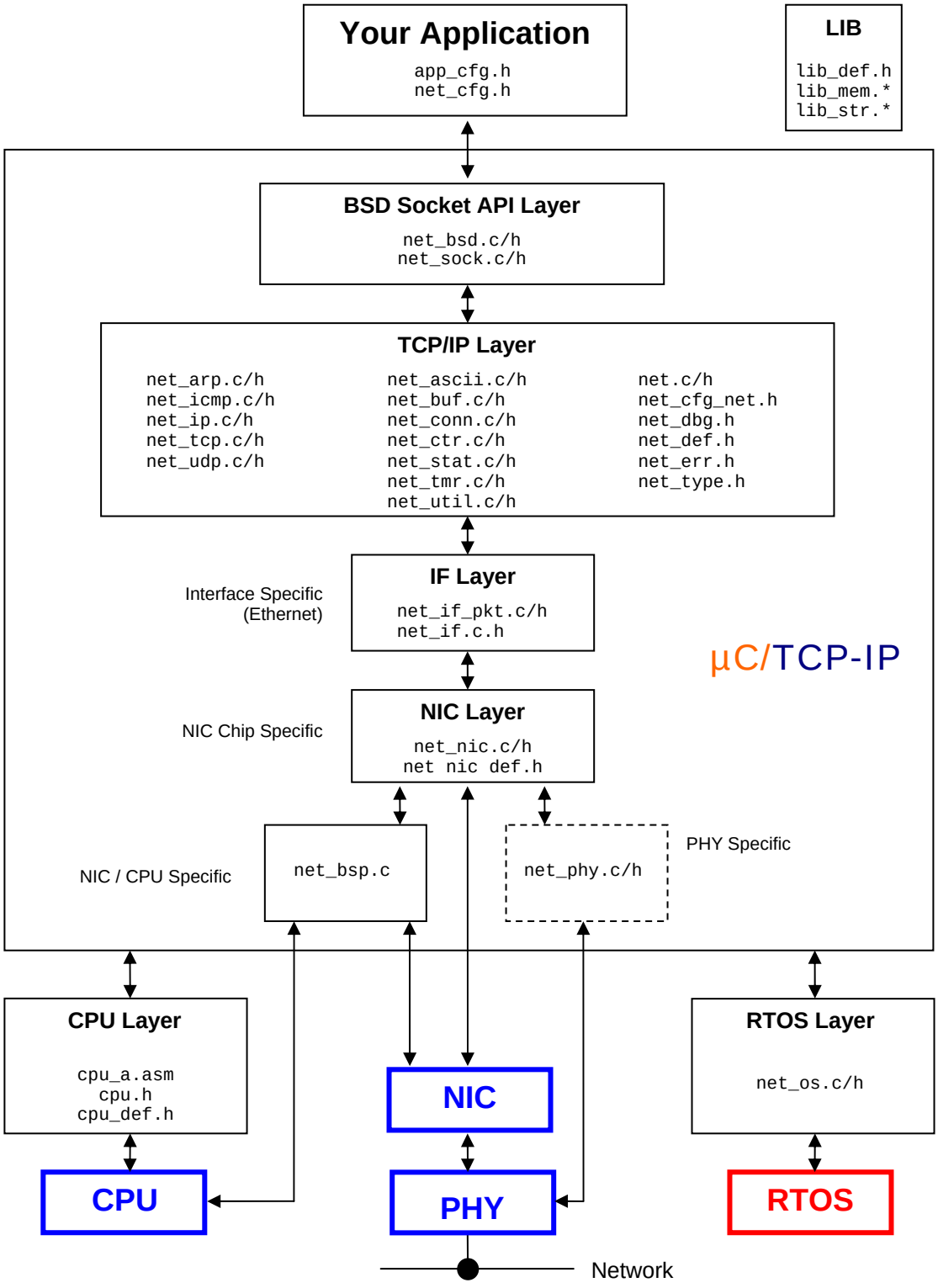


Figure 2-1, Relationship between Application, µC/TCP-IP, CPU, NIC and RTOS

2.01.01 Your Application

Your application needs to provide configuration information to µC/TCP-IP in the form of a C header files called `app_cfg.h` and `net_cfg.h`.

`app_cfg.h` is an application specific configuration file that MUST be present in your application. `app_cfg.h` contains `#define`s to specify the task priorities of each of the tasks in your application (including those of µC/TCP-IP) as well as the stack size for those tasks. The reason all task priorities are placed in one file is to make it easier to 'see' the task priorities for your entire application in one place.

Some of the configuration data in `net_cfg.h` consist of specifying how many buffers will be allocated to the TCP/IP stack, specify the number of timers to allocate to the stack, whether statistic counters will be maintained or not, whether the MAC (Media Access Control) address is obtained from the chip or is specified in the code, the number of ARP cache entries, whether UDP checksums are computed or not and more. In all, there are about 50 `#define` to set. However, most of the `#define` constants can be set to their recommended default value.

2.01.02 LIB (Libraries)

Because µC/TCP-IP is designed to be used in safety critical applications, all 'standard' library functions like `strcpy()`, `memset()`, etc. have been re-written to follow the same quality as the rest as the protocol stack.

2.01.03 BSD Socket API Layer

Your application interfaces to µC/TCP-IP using the well known BSD socket API (Application Programming Interface). You can either write your own TCP/IP applications using the BSD socket API or, you can purchase a number of off-the-shelf TCP/IP components (Telnet, Web server, FTP server, etc.) which all interface to the BSD socket interface. Note that the BSD socket layer is shown as a separate module but is actually part of µC/TCP-IP.

Alternatively, you can use µC/TCP-IP's own socket interface functions (`net_sock.*`). Basically, `net_bsd.*` is a layer of software to converts BSD socket calls to µC/TCP-IP socket calls. Of course, you would have a slight performance gain by interfacing directly to `net_sock.*` functions. Micrium network products uses the µC/TCP-IP socket interface functions.

2.01.04 TCP/IP Layer

This layer contains most of the CPU, NIC, RTOS and compiler independent code for µC/TCP-IP. There are three categories of files in this section:

1) TCP/IP protocol specific files
   a. ARP (`net_arp.*`),
   b. ICMP (`net_icmp.*`),
   c. IP (`net_ip.*`),
   d. TCP (`net_tcp.*`),
   e. UDP (`net_udp.*`)

2) Support files
   a. ASCII conversions (`net_ascii.*`),
   b. Buffer management (`net_buf.*`),
   c. TCP/UDP connection management (`net_conn.*`),
   d. Counter management (`net_ctr.*`),
   e. Statistics (`net_stat.*`),
   f. Timer Management (`net_tmr.*`),
   g. other utilities (`net_util.*`).

3) Miscellaneous header files
   a. Master µC/TCP-IP header file (`net.h`)
   b. File containing error codes (`net_err.h`)
   c. Miscellaneous µC/TCP-IP data types (`net_type.h`)
   d. Miscellaneous definitions (`net_def.h`)
   e. Debug (`net_dbg.h`)
   f. Configuration definitions (`net_cfg_net.h`)

2.01.05 IF Layer

The IF Layer understands about types of network interfaces (Ethernet, TokenRing, etc.). However, the current version of µC/TCP-IP only supports Ethernet interfaces. The IF layer is actually split into two sub-layers.

`net_if_pkt.*` is the interface between the TCP/IP Layer and *understands* packet type devices. `net_if_pkt.*` could actually be used as-is with other packet type interfaces (other than Ethernet).

`net_if_char.*` is the interface between the TCP/IP Layer and *understands* serial-character type devices.

`net_if.*` contains the interface specifics but, independent of the actual chip (i.e. hardware). In other words, for Ethernet, `net_if.*` understands about Ethernet frames, MAC addresses, frame demultiplexing, and so on but, assumes nothing about actual Ethernet hardware.

2.01.06 NIC Layer

µC/TCP-IP can work with just about any NIC (Network Interface Controller) and we have done everything we can to simplify the interface to different NICs. This layer knows about the specifics of the NIC: how to initialize the NIC, how to enable and disable interrupts from the NIC, how to find the size of a received packet, how to read a packet out of the NIC, how to write a packet to the NIC, how to set and get the NIC's MAC (Media Access Control) address and more.

In order to be independent of the ISR structure of your CPU and the mapping of the I/O registers of the NIC, we an additional file to encapsulate such details as the actual ISR(s) from the NIC and the method of reading and writing to the NIC registers.

`net_bsp.c` contains the code to read and write values from and to the NIC, time delays, ISR handler, obtaining a time stamp from the environment and so on. This file is assumed to reside in your application.

2.01.07 PHY Layer

Some NIC interfaces to physical layer devices which may need to be initialized and controlled. This layer is shown in Figure 2-1 as 'dotted' indicating that it's not present with all NICs. In fact, some NICs have PHY control built-in.

2.01.08 CPU Layer

µC/TCP-IP can work with either an 8, 16, 32 or even 64-bit CPU but, needs to have information about the CPU you are using. The CPU layer defines such things as the C data type corresponding to 16-bit and 32-bit variables, whether the CPU is little or big endian and, how interrupts are disabled and enabled on the CPU, etc.

CPU specific files are found in the …\uC-CPU directory and, in order to adapt µC/TCP-IP to a different CPU, you would need to either modify the cpu*.* files or, create new ones based on the ones supplied in the uC-CPU directory. In general, it's much easier to modify existing files because you have a better chance of not forgetting anything.

2.01.09 RTOS Layer

µC/TCP-IP assumes the presence of an RTOS but, the RTOS layer allows µC/TCP-IP to be independent of any specific RTOS. µC/TCP-IP consists of two tasks. One task is responsible for handling packet reception and sends a response, and the other task is responsible for managing timers.

As a minimum, the RTOS you use needs to provides the following services:

1) You need to be able to create at least two tasks (Rx packet task and the timer task)
2) Semaphore management (or the equivalent) and µC/TCP-IP needs to be able to create at least 2 semaphores for each socket and an additional 4 semaphores for internal use.
3) Provide timer management services

µC/TCP-IP is provided with a µC/OS-II interface. If you use a different RTOS, you can use the net_os.* for µC/OS-II as a template to interface to the RTOS of your choice. We discuss the RTOS interface in a later chapter.

2.02 Block Diagram

Figure 2-2 shows a block diagram of the modules found in µC/TCP-IP and their relationship. Also included are the names of the files that are related to µC/TCP-IP.

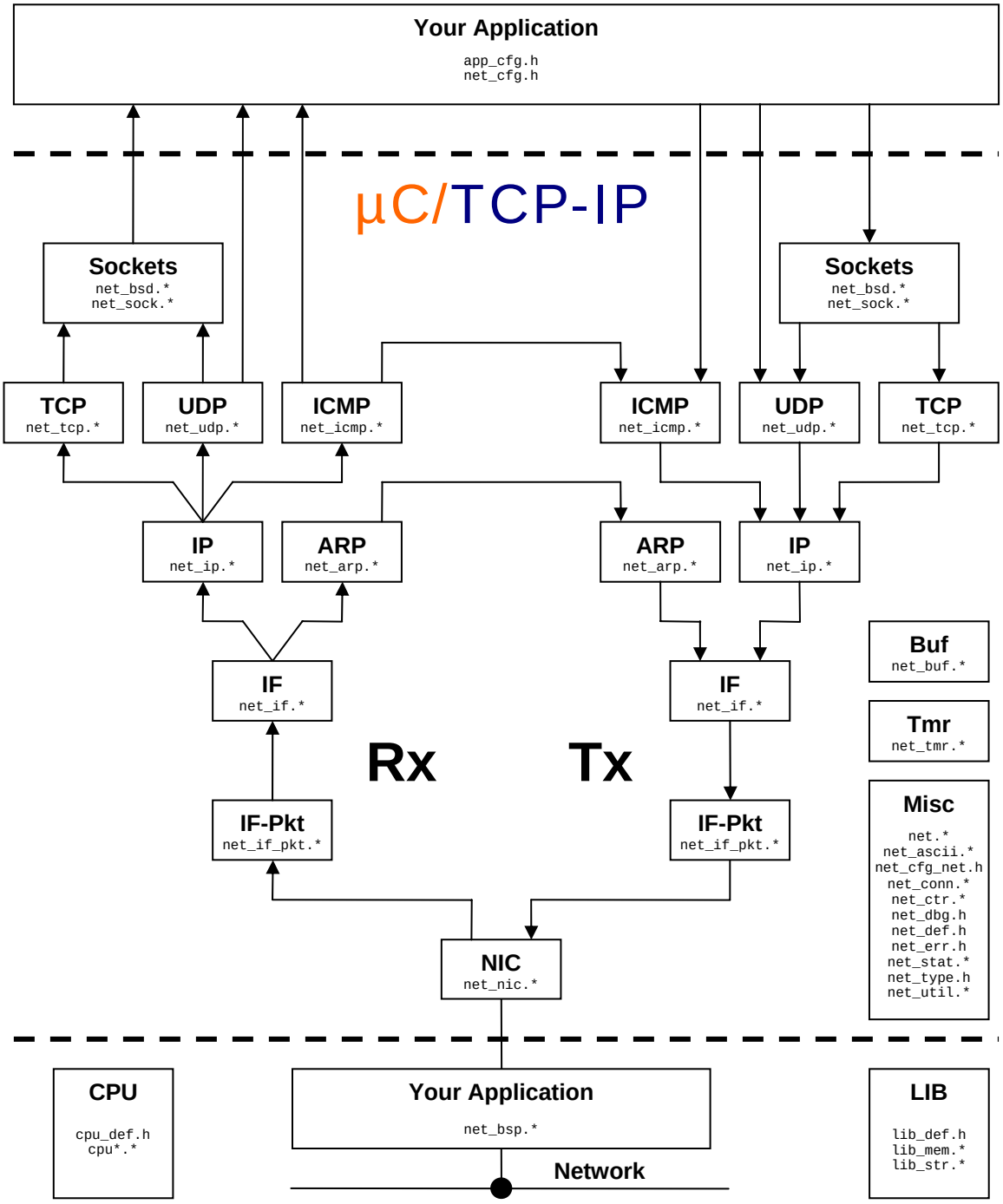


Figure 2-2, µC/TCP-IP Block Diagram

2.03 Directories

The files shown in figure 2-1 and 2-2 are placed in a directory structure such as to group common elements. The µC/TCP-IP distribution contains the following directories:

2.03.01 µC/TCP-IP Directories

`\Micrium\Software\uC-TCPIP`

This is the main directory for µC/TCP-IP.

`\Micrium\Software\uC-TCPIP\IF`

This directory contains interface specific files. Currently, µC/TCP-IP only supports one type of interface, Ethernet. The Ethernet interface specific files are found in the following directories:

`\Micrium\Software\uC-TCPIP\IF\net_if_pkt.*`
`net_if_pkt.*` contain an interface layer between the NIC (Network Interface Controller) and the Ethernet interface layer. This file should not have to change as long as we are dealing with 'packet' oriented interfaces such as Ethernet and Arcnet.

`\Micrium\Software\uC-TCPIP\IF\Ether\net_if.*`
`net_if.*` contains the Ethernet interface specifics. This file should not need to be modified.

`\Micrium\Software\uC-TCPIP\NIC`

This directory contains device drivers for different interfaces. Currently, µC/TCP-IP only supports one type of interface, Ethernet. We tested µC/TCP-IP with two types of NICs: a SMC LAN91C111 and an Atmel AT91RM9200 CPU containing an on-chip NIC. The NIC specific code is thus found in the following directories:

`\Micrium\Software\uC-TCPIP\NIC\Ether\LAN91C111\net_nic*.*`
`\Micrium\Software\uC-TCPIP\NIC\Ether\AT91RM9200\net_nic*.*`

Other Ethernet controller drivers will be placed under the `Ether` sub-directory. Note that other NIC drivers must also be called `net_nic*.*`. The directory determines which specific NIC your application will actually use.

`\Micrium\Software\uC-TCPIP\OS`

This directory contains the RTOS abstraction layer which allows you to use µC/TCP-IP with just about any commercial or in-house RTOS. You would place the abstraction layer for your own RTOS in a sub-directory under `OS` as follows:

`\Micrium\Software\uC-TCPIP\OS\rtos_name\net_os.*`

Note that you must always name the files for your RTOS abstraction layer `net_os.*`.

µC/TCP-IP has been tested with µC/OS-II and the RTOS layer files for this RTOS are found in the following directory:

`\Micrium\Software\uC-TCPIP\OS\uCOS-II\net_os.*`

\Micrium\Software\uC-TCPIP**Source**

This directory contains all the CPU, NIC and RTOS independent files as shown in figure 2-1 and 2-2. You should not have to change anything in this directory in order to use µC/TCP-IP.

2.03.01 Support Directories

µC/TCP-IP are assumes the presence of a number of support files as described in this section.

\Micrium\Software**CPU**

This directory contains files that are generally supplied by a CPU manufacturer and typically contains header files that define the access to CPU registers, I/O registers, timers and more. The name of the files are determined by the CPU manufacturer.

\Micrium\Software**uC-CPU**

This directory contains files that are used to adapt to different CPUs/compilers.

`cpu_def.h`

This file contains definitions used by the other CPU specific files. In fact, `cpu_def.h` should be independent of the actual CPU used.

Within the `uC-CPU` directory, we define processor specific files.

\Micrium\Software\uC-CPU**cpu_type\compiler**

`cpu.h`

This file contains definitions of data word sizes. Specifically, you define here what C data types are associated with 8, 16 and 32 bit integers and, 32 and 64 bit floating point numbers. `cpu.h` also defines endianess, critical section macros `CPU_CRITICAL_ENTER()` and `CPU_CRITICAL_EXIT()`, and more.

`cpu_a.s`

This file contains functions to implement critical section protection for the specific CPU type used.

\Micrium\Software**uC-LIB**

This directory contains library support files that are independent of the CPU, µC/TCP-IP and compiler. Micrium doesn't uses standard C library functions in order to simplify third-party certification.

`lib_def.h`

This file contains definitions that can be used by other applications. All `#defines` in this file are prefixed by `DEF_` and contains definitions for `DEF_TRUE` and `DEF_FALSE`, `DEF_YES` and `DEF_NO`, `DEF_ON` and `DEF_OFF` and bit masks.

`lib_mem.c/h`

This file contains function to copy memory, clear memory, etc. All functions in this file start with `Mem_`.

`lib_str.c/h`

This file contains function to replace the standard `strcpy()`, `strcat()`, etc. All functions start with `Str_`.

2.03.02 Test Code Directories

`\Micrium\Software\`**`EvalBoards`**

Although not actually part of µC/TCP-IP, we created a standard directory structure where application examples are placed. Specifically, sample code is placed under an '`EvalBoards`' sub-directory. Each different evaluation board is categorized by its *manufacturer*, the actual *board name* and the *tools* that were used to test the sample code. Specifically, sample code is placed using the following structure:

`\Micrium\Software\`**`EvalBoard\manufacturer\board\tools`**

We tested µC/TCP-IP using the Cogent CSB337 (ARM9) processor using the IAR tool chain. Sample code is thus placed under the following directory:

`\Micrium\Software\`**`EvalBoard\Cogent\CSB337\IAR\uC-Apps\Ex??`**

Each different example (`Ex??`) has its own directory under the IAR directory. The example directories contain the following µC/TCP-IP related files:

```
app.c
app_cfg.h
includes.h
net_cfg.h
os_cfg.h
```

Of course, other source files, compiler build files, linker command files and so on are also found in the example directories in order to create the specific example.

Code that is common to all of the examples and related to control of I/Os for a given evaluation board are placed in a BSP sub-directory as shown below. BSP stands for 'Board Support Package'

`\Micrium\Software\`**`EvalBoard\Cogent\CSB337\IAR\BSP`**

The BSP directory can contain the following files:

```
bsp.c
bsp.h
net_bsp.c
net_bsp.h
net_isr.c
```

You will notice the presence of a `net_bsp.c` files. This file is placed in the BSP directory because it is dependent of the CPU and NIC used (interrupt structure, I/O ports, etc.) but, has a '`net_`' prefix indicating that it's a network specific file.

2.04 Task model

Figure 2-3 shows a simplified task model of µC/TCP-IP along with application tasks.

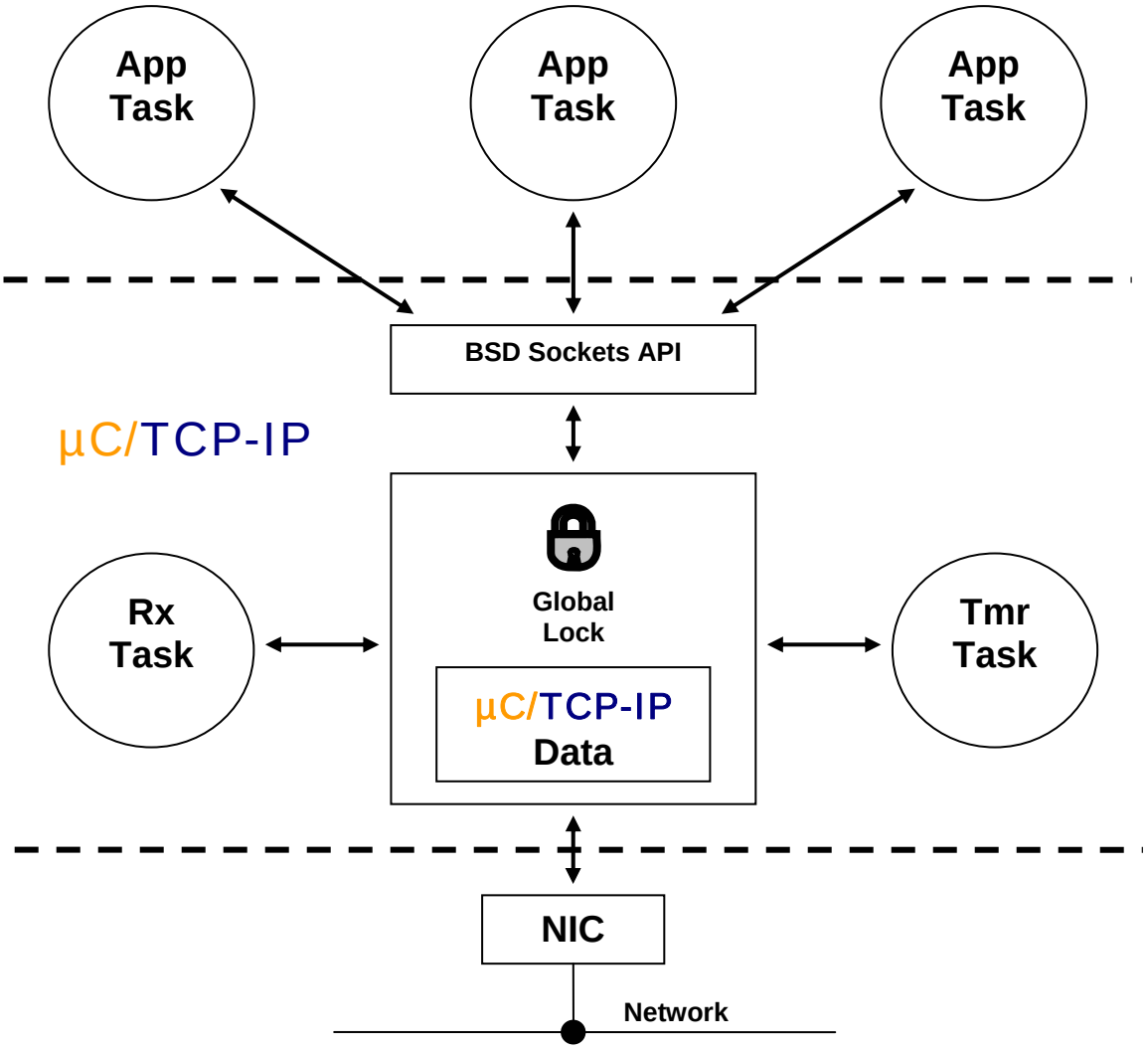


Figure 2-3, µC/TCP-IP, Task Model

Your application interfaces to µC/TCP-IP via a well known API (Application Programming Interface) called BSD sockets (or µC/TCP-IP's internal socket interface). Basically, you application can send and receive data to/from other hosts on the network via this interface.

The BSD sockets API interfaces to internal structures and variables (i.e. data) that are maintained by µC/TCP-IP. A binary semaphore (the global lock in Figure 2-3) is used to guard the access to this data to ensure exclusive access. In other words, to read or write to this data, a task needs to acquire the binary semaphore before it can access the data and release it when done. Of course, your application tasks don't have to know anything about this semaphore nor the data since its use is encapsulated by functions within µC/TCP-IP.

As we previously mentioned, µC/TCP-IP supports only one NIC (Network Interface Controller) at a time. Currently, µC/TCP-IP only works with Ethernet controller NICs but has been designed to support other types of NICs in the future. Writing a driver for different Ethernet controllers is fairly straightforward and generally consists of writing about two dozen fairly simple functions.

2.04.01 µC/TCP-IP Tasks and Priorities

µC/TCP-IP basically defines two internal tasks: a receive (Rx Task) and a timer task (Tmr Task). The *Rx Task* is responsible for processing received packets from the NIC. If the packet is destined for an application, the *Rx Task* will arrange to pass the information to the task using the appropriate TCP/IP protocol. The *Tmr Task* is responsible for handling all timeouts related to the TCP/IP protocols.

When setting up task priorities, it's recommended that you set the priority of tasks that will use µC/TCP-IP's services below that of the task priorities of µC/TCP-IP. In other words, µC/TCP-IP's tasks should have a higher priority than tasks that use µC/TCP-IP. This is to reduce starvation issues when an application task needs to send a lot of data. However, if your application task that uses µC/TCP-IP needs to have a higher priority then you should voluntarily relinquish the CPU on a regular basis. For example, you can suspend the task for a number of OS clock ticks.

2.04.02 Receiving a Packet

Figure 2-4 shows a simplified task model of µC/TCP-IP when packets are received from the NIC. Here we assume we have a TCP packet being received.

F2-4(1) A packet is sent on the network and the NIC recognizes its address as the destination for the packet. The NIC then generates an interrupt and the NIC ISR determines that the interrupt comes from a packet reception (as opposed to the completion of a transmission).

F2-4(2) Instead of processing the NIC directly from the ISR, we decided to pass the responsibility to a task. The *Rx ISR* thus simply 'signals' the *Rx Task* that there is a packet to process. A counting semaphore is used as the signaling mechanism. Note that further Rx interrupts are disabled to prevent re-entering the ISR because on most NICs, the interrupt status is cleared only when the packet is extracted from the NIC.

F2-4(3) The Rx Task does nothing until a signal is received from the *Rx ISR*.

F2-4(4) When a signal is received, the *Rx Task* wakes up and extracts the packet from the NIC and places it in a receive buffer.

µC/TCP-IP maintains two types of buffers: small and large. A small buffer can typically hold up to 256 bytes of data from the NIC. A large buffer can hold up to 1536 bytes. These sizes as well as the quantity of these buffers are actually configurable at compile time to better suit the actual intended application. The *Rx Task* queries the NIC for the size of the packet in order for it to know which type of buffer is needed (small or large).

F2-4(5) Buffers are shared resource and any access to those or any other µC/TCP-IP data structures is guarded by the binary semaphore guarding the data. This means that the *Rx Task* will need to acquire the semaphore before it can get a buffer from the pool.

F2-4(6) The *Rx Task* obtains a buffer from the buffer pool. The packet is removed from the NIC and placed in the buffer for further processing.

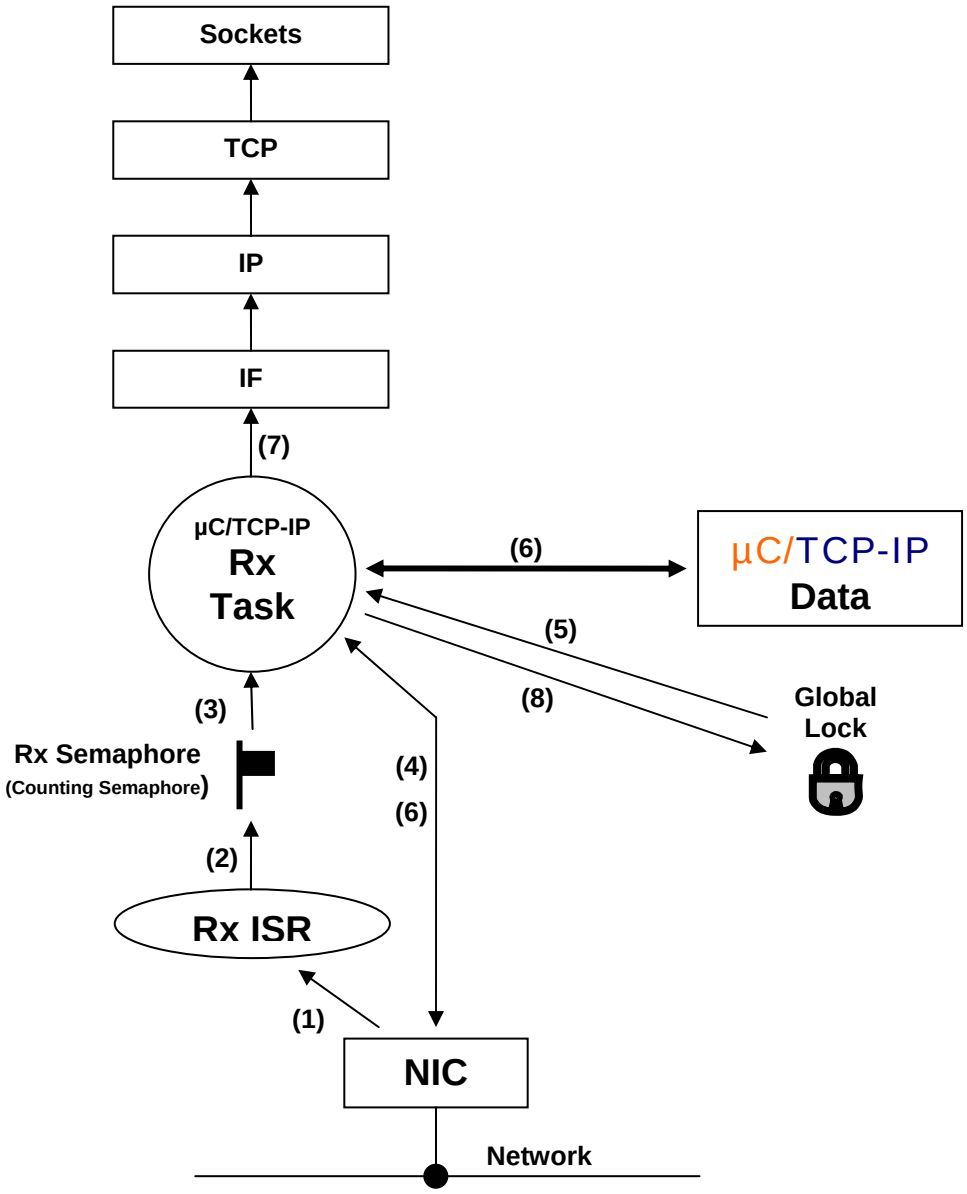


Figure 2-4, µC/TCP-IP, Receiving a Packet

F2-4(7) The *Rx Task* examines the Ethernet frame to determine whether the packet is destined for the ARP or IP layer and passes the buffer to the appropriate layer for further processing. Note that the *Rx Task* brings the data all the way up to the application layer and thus the appropriate µC/TCP-IP P functions operate within the context of the *Rx Task*.

F2-4(8) When the packet is processed, the lock is released.

2.04.03 Sending a Packet

Figure 2-5 shows a simplified task model of µC/TCP-IP when packets are sent through the NIC. In this example, we show a TCP packet being sent.

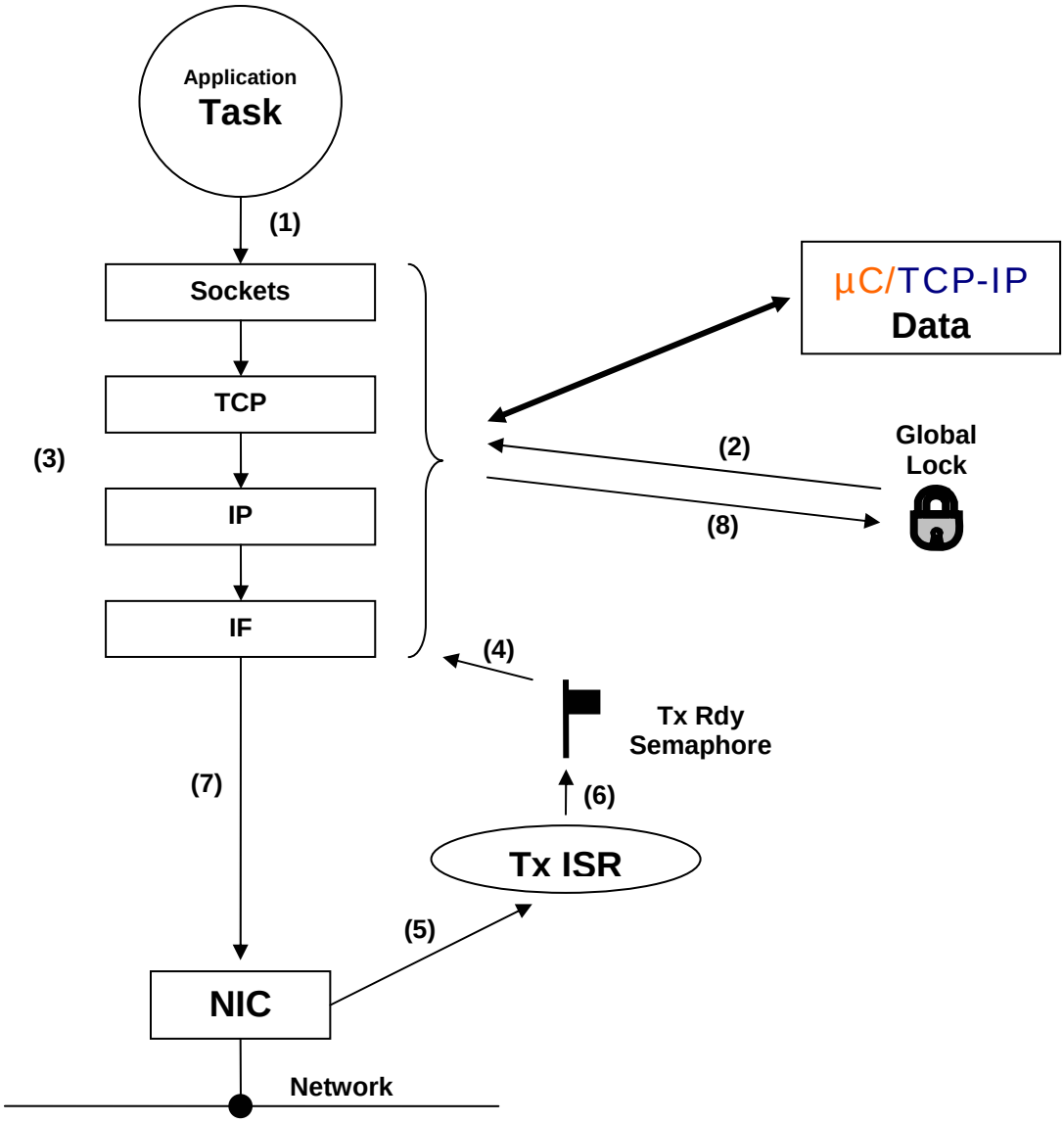


Figure 2-5, µC/TCP-IP, Sending a Packet

F2-5(1) A task (assuming an application task) that wants to send data interfaces to µC/TCP-IP through the BSD socket API.

F2-5(2) A function within µC/TCP-IP acquires the binary semaphore (i.e. the global lock) in order to place the data to send into µC/TCP-IP's data structures.

F2-5(3) The appropriate µC/TCP-IP layer processes the data to send to prepare it for transmission.

F2-5(4) The task (via the IF layer) then waits on a counting semaphore which is used to indicate that the transmitter in the NIC is available to send a packet. If the NIC is not able to send the packet, the task blocks until the semaphore is signaled by the NIC. Note that, at startup, the semaphore is initialized with a value corresponding to the number of packets that can be sent at one time through the NIC. In other words, if the NIC has sufficient buffer space to be able to queue up four packets then the counting semaphore is initialized with a count of 4.

F2-5(5) When the NIC completes sending a packet, the NIC generates an interrupt.

F2-5(6) The *Tx ISR* signals the *Tx Available* semaphore indicating that the NIC is able to send another packet.

F2-5(7) The task then wakes up and copies the packet to send into the NIC.

F2-5(8) After placing the packet into the NIC, the task releases the global data lock and continues execution.

Chapter 3

Buffer Management

µC/TCP-IP places received packets in network buffers to be processed by the upper layers and also, places data to send in network buffers. There are two types of buffers as shown in Figure 3-1: *small* and *large*. Each buffer contains a header portion that is used by µC/TCP-IP. This header provides information to µC/TCP-IP about the contents of the buffer. The data portion contains the data that has either been received by the NIC and thus will be processed by µC/TCP-IP or, data that is destined for the NIC. Buffer management functions are found in `net_buf.*`.

Small buffers are used by µC/TCP-IP when received data or, data to transmit fits in this size buffer.

The header structure is common to both types of buffers. A header currently requires about 200 bytes of storage.

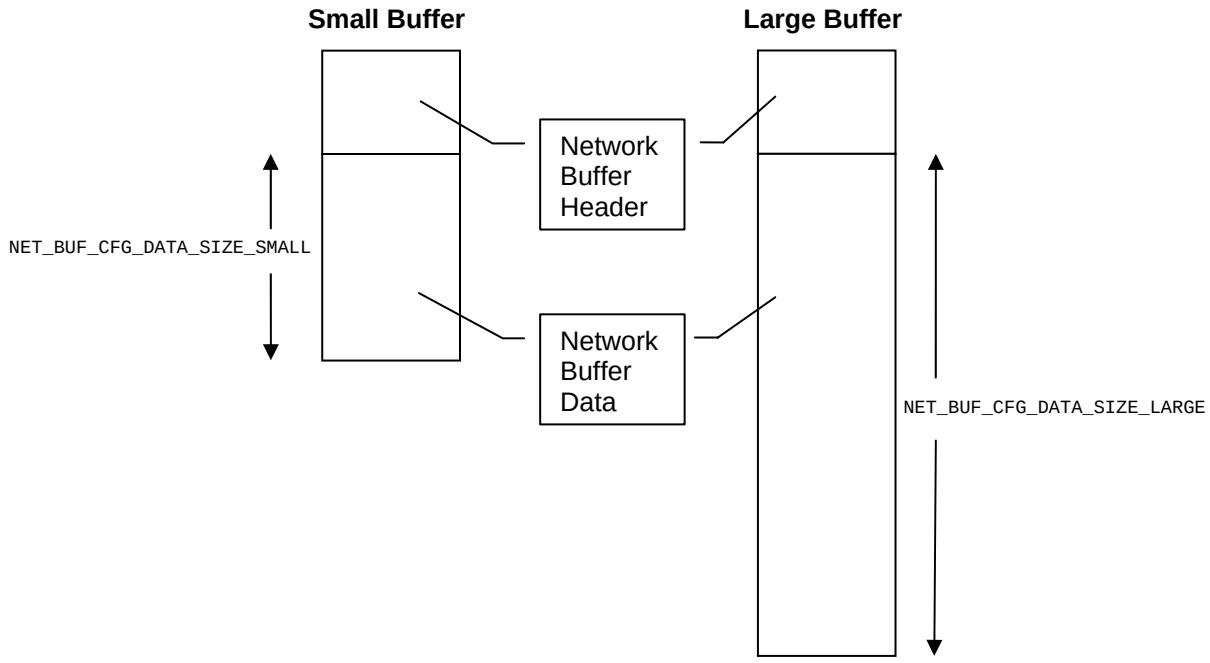


Figure 3-1, µC/TCP-IP's small and large buffers

There are currently four configurable options for network buffers. You change the configuration values in `net_cfg.h` which resides in your application:

`NET_BUF_CFG_NBR_SMALL`

This configuration constant determines the number of small network buffers used by µC/TCP-IP. The number of buffers needed depends on the run-time behavior of your network and the expected traffic on the network.

`NET_BUF_CFG_NBR_LARGE`

This configuration constant determines the number of large network buffers used by µC/TCP-IP. The number of buffers needed depends on the run-time behavior of your network and the expected traffic on the network.

`NET_BUF_CFG_DATA_SIZE_SMALL`

The configuration constant determines the size of the data portion for small buffers. The recommended size for small buffers is around **256** bytes.

`NET_BUF_CFG_DATA_SIZE_LARGE`

The configuration constant determines the size of the data portion for large buffers. Typically you would set large buffers to the largest packet that can be sent on the NIC. In the case of Ethernet, you should set this buffer to **1596**.

3.01 Buffer Statistics

µC/TCP-IP maintains run-time statistics on the usage of the buffers and your application can thus query µC/TCP-IP to find out how many buffers are available, how many buffers are used, what the maximum number of buffer usage is, and more. Your application can also reset the statistics of maximum number of buffers used.

Examining buffer statistics allows you to better manage your memory usage. Typically, you would allocate more buffers than you 'think' you need and then, by examining buffer usage statistics, you can make adjustments. For example, if you allocate 100 small buffers but your application never uses more than 25 buffers than, you might want to consider reducing the number of small buffers to something like 30 or so.

Statistics are kept in a data structure called `NET_STAT_POOL` (see `net_stat.h`). The data structure is shown below:

```
typedef  struct  net_stat_pool {
    NET_TYPE            Type;

    NET_STAT_POOL_QTY   EntriesInit;
    NET_STAT_POOL_QTY   EntriesTotal;
    NET_STAT_POOL_QTY   EntriesAvail;
    NET_STAT_POOL_QTY   EntriesUsed;
    NET_STAT_POOL_QTY   EntriesUsedMax;
    NET_STAT_POOL_QTY   EntriesLostCur;
    NET_STAT_POOL_QTY   EntriesLostTotal;

    CPU_INT32U          EntriesAllocatedCtr;
    CPU_INT32U          EntriesDeallocatedCtr;
} NET_STAT_POOL;
```

`NET_STAT_POOL_QTY` is a data type currently set to `CPU_INT16U` and thus can contains a maximum count of `65535`.

Access to buffer statistics is obtained via interface functions that your application can call (described in the next sections). Most likely, you will only need to examine the following variables in NET_STAT_POOL:

.EntriesAvail
This variable indicates how many buffers are available in the pool.

.EntriesUsed
This variable indicates how many buffers are currently used by the TCP/IP stack.

.EntriesUsedMax
This variable indicates the maximum number of buffers used since it was last reset.

.EntriesAllocatedCtr
This variable indicates the total number of times buffers were allocated (i.e. used by the TCP/IP stack).

.EntriesDeallocatedCtr
This variable indicates the total number of times buffers were returned back to the buffer pool.

3.01.01 Buffer Statistics, Getting SMALL buffer statistics

NetBuf_SmallPoolStatGet() allows you to obtain statistics on small buffer usage. The prototype of this function is shown below:

```
NET_STAT_POOL  NetBuf_SmallPoolStatGet (void);
```

You would use this function as follows:

```
NET_STAT_POOL  small_stats;


  :
  :
small_stats = NetBuf_SmallPoolStatGet();
printf("#Buffers Used     : %05d\n", small_stats.EntriesUsed);
printf("#Buffers Available: %05d\n", small_stats.EntriesAvail);
printf("Peak Buffer Usage : %05d\n", small_stats.EntriesUsedMax);
  :
  :
```

3.01.02 Buffer Statistics, Getting LARGE buffer statistics

`NetBuf_LargePoolStatGet()` allows you to obtain statistics on large buffer usage. The prototype of this function is shown below:

```
NET_STAT_POOL  NetBuf_LargePoolStatGet (void);
```

You would use this function as follows:

```
NET_STAT_POOL  large_stats;


  :
  :
large_stats = NetBuf_LargePoolStatGet();
printf("#Buffers Used     : %05d\n", large_stats.EntriesUsed);
printf("#Buffers Available: %05d\n", large_stats.EntriesAvail);
printf("Peak Buffer Usage : %05d\n", large_stats.EntriesUsedMax);
  :
  :
```

3.01.03 Buffer Statistics, Resetting the Maximum count of SMALL buffers used

You can RESET the maximum number of small buffers used by calling the following function:

```
void  NetBuf_SmallPoolStatResetUsedMax(void);
```

3.01.04 Buffer Statistics, Resetting the Maximum count of LARGE buffers used

You can RESET the maximum number of large buffers used by calling the following function:

```
void  NetBuf_LargePoolStatResetUsedMax(void);
```

Chapter 4

Timer Management

µC/TCP-IP manages software timers that are used to keep track of timeouts. Timer management functions are found in `net_tmr.*`. You can set the number of available timers via the configuration constant: `NET_TMR_CFG_NBR_TMR` (see `net_cfg.h`). The number of timers affect the amount of RAM required by µC/TCP-IP. Each timer requires 8 bytes plus 4 pointers. Timers are required for:

- Each ARP cache entry
- IP fragment reassembly
- The ICMP low-network-resources monitor task
- Each TCP connection for the TCP state machine

4.01 Timer Statistics

µC/TCP-IP maintains run-time statistics on the usage of the timers and your application can thus query µC/TCP-IP to find out how many timers are available, how many timers are used, what the maximum number of timer usage is, and more. Your application can also reset the statistics of maximum number of timers used.

Examining timer statistics allows you to better manage your memory usage. Typically, you would allocate more timers than you 'think' you need and then, by examining timer usage statistics, you can make adjustments.

Statistics are kept in a data structure called `NET_STAT_POOL` (see `net_stat.h`). The data structure is shown below:

```
typedef  struct  net_stat_pool {
    NET_TYPE            Type;

    NET_STAT_POOL_QTY   EntriesInit;
    NET_STAT_POOL_QTY   EntriesTotal;
    NET_STAT_POOL_QTY   EntriesAvail;
    NET_STAT_POOL_QTY   EntriesUsed;
    NET_STAT_POOL_QTY   EntriesUsedMax;
    NET_STAT_POOL_QTY   EntriesLostCur;
    NET_STAT_POOL_QTY   EntriesLostTotal;

    CPU_INT32U          EntriesAllocatedCtr;
    CPU_INT32U          EntriesDeallocatedCtr;
} NET_STAT_POOL;
```

NET_STAT_POOL_QTY is a data type currently set to CPU_INT16U and thus can contains a maximum count of 65535.

Access to timer statistics is obtained via interface functions that your application can call (described in the next sections). Most likely, you will only need to examine the following variables in NET_STAT_POOL:

.EntriesAvail
This variable indicates how many timers are available in the pool.

.EntriesUsed
This variable indicates how many timers are currently used by the TCP/IP stack.

.EntriesUsedMax
This variable indicates the maximum number of timers used since it was last reset.

.EntriesAllocatedCtr
This variable indicates the total number of times timers were allocated (i.e. used by the TCP/IP stack).

.EntriesDeallocatedCtr
This variable indicates the total number of times timers were returned back to the timer pool.

4.01.01 Timer Statistics, Getting statistics

NetTmr_PoolStatGet() allows you to obtain statistics on small buffer usage. The prototype of this function is shown below:

```
NET_STAT_POOL  NetTmr_PoolStatGet (void);
```

You would use this function as follows:

```
NET_STAT_POOL  tmr_stats;


  :
  :
tmr_stats = NetTmr_PoolStatGet();
printf("#Timers Used     : %05d\n", tmr_stats.EntriesUsed);
printf("#Timers Available: %05d\n", tmr_stats.EntriesAvail);
printf("Peak Timer Usage : %05d\n", tmr_stats.EntriesUsedMax);
  :
  :
```

Chapter 5

ASCII Utilities

µC/TCP-IP contains utility functions that are used to convert IP addresses to and from ASCII strings and also MAC addresses to and from ASCII strings. These functions are found in `net_ascii.*`.

5.01 String to MAC address, NetASCII_Str_to_MAC()

This function converts a series of hexadecimal numbers to a MAC address. The hexadecimal numbers must be separated by a colon character. The prototype for this function is:

```
void  NetASCII_Str_to_MAC (CPU_CHAR    *paddr_mac_ascii,
                           CPU_INT08U  *paddr_mac,
                           NET_ERR     *perr)
```

`pmac_ascii`

is a pointer to an ASCII string that contains hexadecimal numbers separated by colons that represents the MAC address. Note that the first ASCII character to the left is the most significant digit.

`"00:1A:07:AC:22:09"`

pmac

is a pointer to an array of `CPU_INT08U` large enough to hold `NET_IF_ADDR_SIZE` entries.

perr

is a pointer to an error code that is returned by this function and can be either:

`NET_ASCII_ERR_NONE`	MAC address successfully converted.
`NET_ASCII_ERR_NULL_PTR`	You passed a `NULL` pointer for argument `paddr_mac_ascii` or `paddr_mac`.
`NET_ASCII_ERR_INVALID_LEN`	Invalid ASCII string length.
`NET_ASCII_ERR_INVALID_CHAR`	Invalid ASCII character.
`NET_ASCII_ERR_INVALID_CHAR_LEN`	Invalid ASCII character length.
`NET_ASCII_ERR_INVALID_CHAR_SEQ`	Invalid ASCII character sequence.

5.02 MAC address to String, NetASCII_MAC_to_Str()

This function converts a MAC address to a series of hexadecimal numbers represented in ASCII. The hexadecimal numbers are separated by a colon character. The prototype for this function is:

```
void  NetASCII_MAC_to_Str (CPU_INT08U  *paddr_mac,
                           CPU_CHAR    *paddr_mac_ascii,
                           CPU_BOOLEAN  hex_lower_case,
                           NET_ERR     *perr)
```

pmac

is a pointer to an array of `CPU_INT08U` large enough to hold `NET_IF_ADDR_SIZE` entries.

pmac_ascii

is a pointer to an ASCII string that contains hexadecimal numbers separated by colons that represents the MAC address. Note that the first ASCII character to the left is the most significant digit. The string must be large enough to hold `(NET_IF_ADDR_SIZE * 3)` bytes.

hex_lower_case

indicates that you want to format Hexadecimal numbers using lower case characters instead of upper case characters. This argument can take the following values:

`DEF_NO`	Format alphabetic hexadecimal characters in upper case.
`DEF_YES`	Format alphabetic hexadecimal characters in lower case.

perr

is a pointer to an error code that is returned by this function and can be either:

`NET_ASCII_ERR_NONE`	ASCII string successfully formatted.
`NET_ASCII_ERR_NULL_PTR`	You passed a `NULL` pointer for argument `paddr_mac_ascii` or `paddr_mac`.

5.03 String to IP address, NetASCII_Str_to_IP()

This function converts an IPv4 address in ASCII dotted-decimal notation to a network protocol IPv4 address in host-order. The prototype for this function is:

```
NET_IP_ADDR  NetASCII_Str_to_IP (CPU_CHAR  *paddr_ip_ascii,
                                 NET_ERR   *perr)
```

paddr_ip_ascii

Pointer to an ASCII string that contains a dotted-decimal IPv4 address.

perr

Pointer to variable that will hold the return error code from this function :

NET_ASCII_ERR_NONE	IPv4 address successfully converted.
NET_ASCII_ERR_NULL_PTR	Argument 'paddr_ip_ascii' passed a NULL pointer.
NET_ASCII_ERR_INVALID_LEN	Invalid ASCII string length.
NET_ASCII_ERR_INVALID_CHAR	Invalid ASCII character.
NET_ASCII_ERR_INVALID_CHAR_LEN	Invalid ASCII character length.
NET_ASCII_ERR_INVALID_CHAR_VAL	Invalid ASCII character value.
NET_ASCII_ERR_INVALID_CHAR_SEQ	Invalid ASCII character sequence.

This function returns an IPv4 address represented by ASCII string, if NO errors. NET_IP_ADDR_NONE, otherwise.

RFC #1983 states that "dotted decimal notation ... refers [to] IP addresses of the form A.B.C.D; where each letter represents, in decimal, one byte of a four byte IP address". In other words, the dotted-decimal notation separates four decimal octet values by the dot, or period, character ('.'). Each decimal value represents one octet of the IP address starting with the most significant octet in network order.

IP Address Examples:

DOTTED DECIMAL NOTATION	HEXADECIMAL EQUIVALENT
127.0.0.1	0x7F000001
192.168.1.64	0xC0A80140
255.255.255.0	0xFFFFFF00

The dotted-decimal ASCII string MUST:

Include ONLY decimal values & the dot, or period, character ('.') ; ALL other characters are trapped as invalid, including any leading or trailing characters.

Include EXACTLY four decimal values separated by EXACTLY three dot characters.

Ensure that each decimal value does NOT exceed the maximum octet value (i.e. 255).

Ensure that each decimal value's number of decimal digits, including leading zeros, does NOT exceed the maximum number of digits, NET_ASCII_CHAR_MAX_OCTET_ADDR_IP.

5.04 IP address to String

This function convert a network protocol IPv4 address in host-order into a dotted-decimal notation ASCII string. The function prototype is:

```
void  NetASCII_IP_to_Str (NET_IP_ADDR   addr_ip,
                          CPU_CHAR     *paddr_ip_ascii,
                          CPU_BOOLEAN   lead_zeros,
                          NET_ERR      *perr)
```

addr_ip

IPv4 address.

paddr_ip_ascii

Pointer to an ASCII character array that will hold the return ASCII string from this function.

lead_zeros

Prepend leading zeros option:

`DEF_NO` Do NOT prepend leading zeros to each decimal octet value.
`DEF_YES` Prepend leading zeros to each decimal octet value.

perr

Pointer to variable that will hold the return error code from this function:

`NET_ASCII_ERR_NONE` ASCII string successfully created.
`NET_ASCII_ERR_NULL_PTR` Argument `paddr_ip_ascii` passed a `NULL` pointer.
`NET_ASCII_ERR_INVALID_CHAR_LEN` Invalid ASCII character length.

RFC #1983 states that "dotted decimal notation refers [to] IP addresses of the form A.B.C.D; where each letter represents, in decimal, one byte of a four byte IP address". In other words, the dotted-decimal notation separates four decimal octet values by the dot, or period, character ('.'). Each decimal value represents one octet of the IP address starting with the most significant octet in network order.

IP Address Examples:

DOTTED DECIMAL NOTATION	HEXADECIMAL EQUIVALENT
127.0.0.1	0x7F000001
192.168.1.64	0xC0A80140
255.255.255.0	0xFFFFFF00

The size of the ASCII character array that will hold the return ASCII string MUST be greater than or equal to `NET_ASCII_LEN_MAX_ADDR_IP`.

Leading zeros option prepends leading '0's prior to the first non-zero digit in each decimal octet value. The number of leading zeros is such that the decimal octet's number of decimal digits is equal to the maximum number of digits, `NET_ASCII_CHAR_MAX_OCTET_ADDR_IP`.

If leading zeros option `DISABLED` and the decimal value of the octet is zero; then one digit of '0' value is formatted. This is NOT a leading zero; but a single decimal digit of '0' value.

Chapter 6

BSD v4 Socket Interface

Your application interfaces to µC/TCP-IP using the well known BSD socket API (Application Programming Interface). You can either write your own TCP/IP applications using this API or, you can purchase a number of off-the-shelf TCP/IP components (Telnet, Web server, FTP server, etc.) which all interface to the BSD socket interface.

You can also use µC/TCP-IP's own socket interface functions which are found in the `net_sock.*` files. Basically, `net_bsd.*` is a layer of software that converts BSD socket calls to µC/TCP-IP socket calls as shown in Figure 6-1. You would have a slight performance gain by interfacing directly to `net_sock.*` functions. µC/TCP-IP's socket API is discussed in Chapter 7. Also, the µC/TCP-IP calls are more versatile because they provide an error code to the calling function instead of just `0` or `-1`. Micrium layer 7 application typically use the µC/TCP-IP socket interface functions instead of the BSD functions.

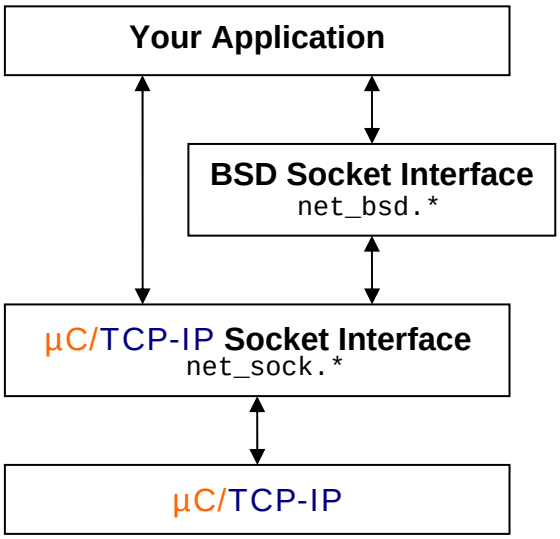


Figure 6-1, BSD Socket Interface relationship to µC/TCP-IP

6.01 UDP Socket Calls

Figure 6-2 shows a typical UDP client-server application and the BSD calls used. The client does not establish a connection with the server. Instead, the client simply sends datagrams to the server using `sendto()` which contains the address of the server as a parameter. The server calls `recvfrom()` which waits until data arrives from a client (assuming the socket has been open in 'blocking' mode). `recvfrom()` returns enough information about the client to allow the server to send it a response.

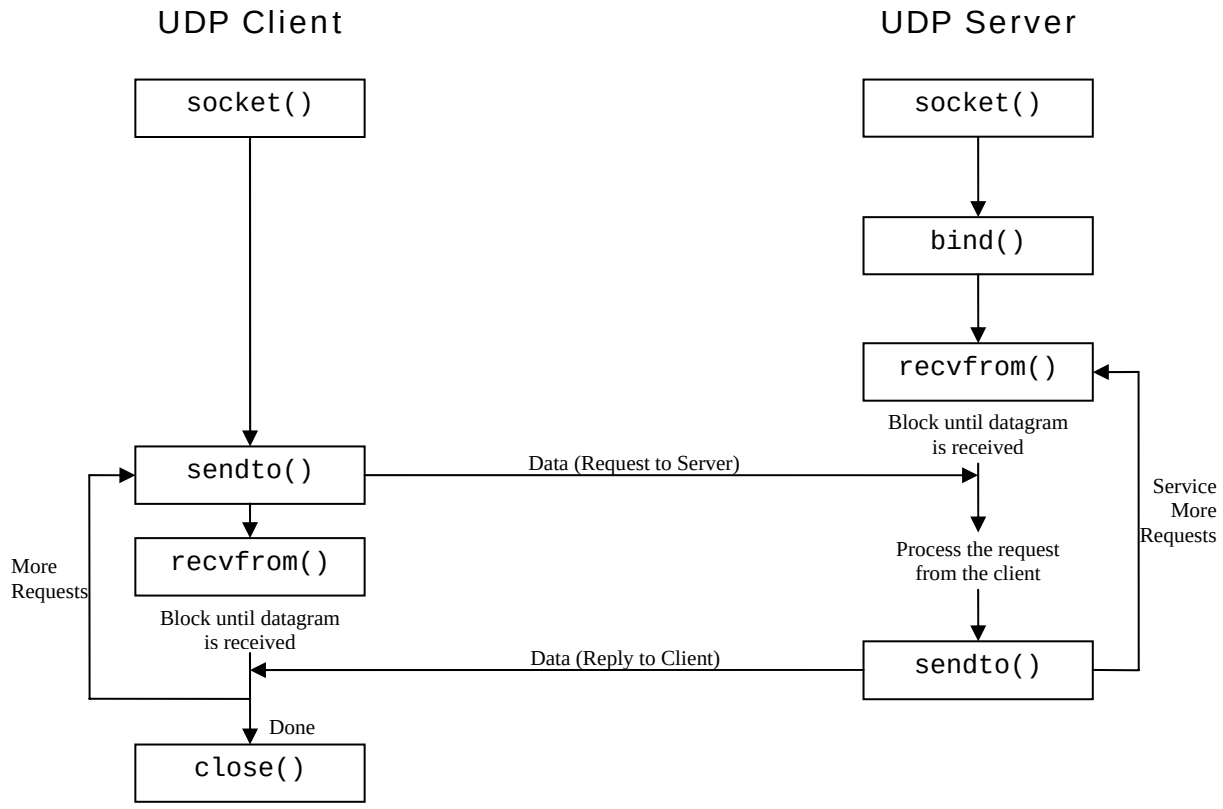


Figure 6-2, BSD Socket calls used in a typical UDP client-server application

6.02 TCP Socket Calls

Figure 6-3 shows a typical TCP client-server application and the BSD calls used. You would typically start the server first and then, sometime later, start the client which connects to the server. The client sends requests to the server, the server processes the request and then, sends back a reply to the client. This continues until the client closes its end of the connection. Closing the client causes the client to send a special notification to the server. The server then closes its end of the connection and, either terminates or, waits for a new client connection.

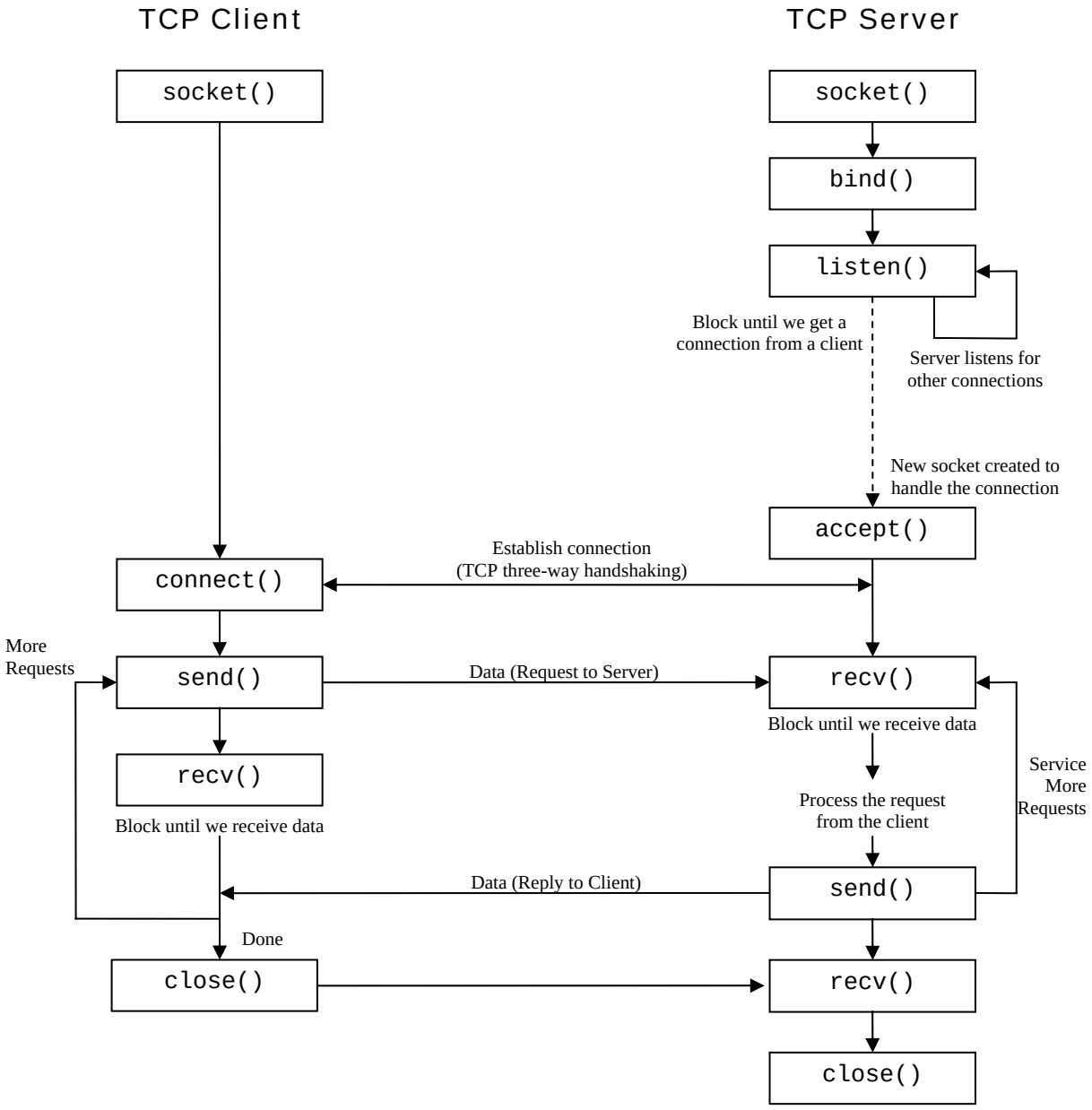


Figure 6-3, Using BSD Socket calls in a TCP connection

6.03 Data Structures

sockaddr

Generic (non-address-family-specific) address structure

```
struct  sockaddr {
    unsigned  short   sa_family;    /* Address family (e.g., AF_INET)        */
    char              sa_data[14];  /* Protocol-specific address information */
};
```

in_addr

Internet (IP) address structure

```
struct  in_addr {
    NET_IP_ADDR       s_addr;       /* IP address (32 bits)                  */
};
```

sockaddr_in

```
struct  sockaddr_in {
     CPU_INT16U       sin_family;   /* Internet protocol (PF_INET)           */
     CPU_INT16U       sin_port;     /* Address port (16 bits)                */
     struct  in_addr  sin_addr;     /* IP address   (32 bits)                */
     char             sin_zero[8];  /* Not used                              */
};
```

Family values must be in host CPU byte order. All address values must be in network byte order (big endian).

Figure 6-4 shows the `sockaddr` and the `sockaddr_in` data structures overlaid one on top of the other.

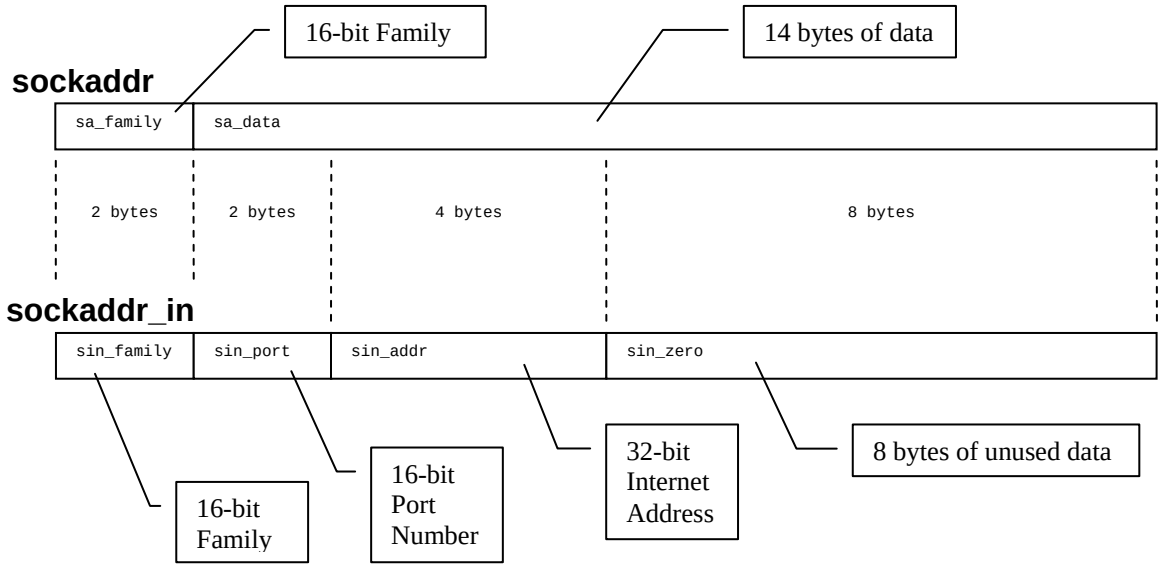


Figure 6-4, `sockaddr_in` is a different 'view' of the `sockaddr` data structure

6.04 accept() TCP

`accept()` normally blocks waiting for connections addressed to the IP address and port number to which the given socket is bound to (you must have previously called `listen()` on the given socket, see Figure 6-3). When a connection arrives and the TCP handshake is successfully completed, a new socket is returned. The local and remote address and port numbers of the new socket have been filled in with the local port number of the new socket, and the remote address information has been returned in the `sockaddr_in` structure.

Prototype

```
int  accept (int                 sock_id,
             struct  sockaddr   *paddr_remote,
             int                *paddr_len);
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created. `sock_id` assumes to be bound to an address by the `bind()` call and is listening for connections via the `listen()` call (see Figure 6-3).
`paddr_remote`	Pointer to the socket address structure (see section 6.03, Data Structures).
`paddr_len`	Pointer to the size of the socket address data structure and should always be: `sizeof(struct sockaddr_in)`

Returned Value

`accept()` returns a newly connected socket descriptor if no error occurs and `-1` otherwise. If the socket is configured for non-blocking, a return value of `-1` which could indicate that the no requests for connection were queued when `accept()` was called. In this case, the server could do something else and call `accept()` at a later time. In other words, the server can 'poll' for a connection.

Notes / Warnings

See '`net_bsd.h` BSD 4.x SOCKET ADDRESS DATA TYPES' for socket address format(s).

Socket addresses MUST be in network-order.

Uses µC/TCP-IP's Function

`NetSock_Accept()`

Example

```
int                 MySockID;
int                 NewSockID;
struct  sockaddr_in  MySockAddr;


void AppTask (void)
{
    int  bind_status;
    int  addr_len;

    :
    :
    /* Call bind()   */
    /* Call listen() */
    :
    NewSockID = accept(MySocketID,
                       (struct sockaddr *)&MySockAddr,
                       &addr_len);

    if (NewSockID < 0) {
        close(MySocketID);
    } else {
        /* Connection established with remote host, use NewSockID to communicate with client */
    }
    :
    :
}
```

6.05 bind() TCP/UDP

Addresses are assigned to sockets with the bind function. `bind()` is generally always called by servers and not clients. In all cases, a port number must be specified.

Prototype

```
int  bind (int                sock_id,
           struct  sockaddr  *paddr_local,
           int                addr_len);
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created.
`paddr_local`	Pointer to the socket address structure (see section 6.03, Data Structures).
`addr_len`	This argument specifies the size of the socket address data structure and should always be: `sizeof(struct sockaddr_in)`

Returned Value

`bind()` returns `0` if successful or `-1` upon error.

Notes / Warnings

See '`net_bsd.h` BSD 4.x SOCKET ADDRESS DATA TYPES' for socket address format(s).

Socket addresses MUST be in network-order.

Uses µC/TCP-IP's Function

`NetSock_Bind()`

Example

```
int                 MySockID;
struct  sockaddr_in  MySockAddr;


void AppTask (void)
{
    int  bind_status;

    :
    :
    MySockAddr.sin_family      = AF_INET;
    MySockAddr.sin_port        = htons(MY_SERVER_PORT_NBR);
    MySockAddr.sin_addr.s_addr = htonl(INADDR_ANY);

    bind_status                = bind(MySocketID,
                                      (struct sockaddr *)&MySockAddr,
                                      sizeof(struct sockaddr_in));
    if (bind_status < 0) {
        close(MySocketID);
    } else {
        /* Socket bound to desired port */
    }
    :
    :
}
```

Example Comment(s)

It's typical to specify `INADDR_ANY` as the IP address to bind to. This indicates that we would like to bind to any IP address in case the server has more than one IP address. However, the current version of µC/TCP-IP only supports one IP address per target system in which µC/TCP-IP runs on. It's preferable to bind to any IP address in case µC/TCP-IP supports multiple IP addresses in the future.

6.06 close() TCP/UDP

This function is called to terminate communications on a socket. The socket is marked to prevent further send and receives.

Prototype

```
int  close (int sock_id);
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created.

Returned Value

`close()` returns `0` if successful or `-1` upon error.

Notes / Warnings

None

Uses µC/TCP-IP's Function

`NetSock_Close()`

Example

```
int  MySocketID;


void AppTask (void)
{
    :
    :
    close(MySocketID);
    :
    :
}
```

6.07 connect() TCP/UDP

This function establishes a connection between the given socket and the remote socket associated with the foreign address, if any. If the function returns successfully, the given socket's local and remote IP address and port information have been filled in. If the socket was not previously bound to a local port, one is assigned randomly.

After a socket endpoint is created, a client task will normally try to connect to a server application. The meaning of `connect()` is very different for TCP and UDP sockets.

For TCP sockets, `connect()` returns successfully only after completing a handshake with the remote TCP implementation and the given socket's local and remote IP address and port information have been filled in, Success implies the existence of a reliable channel to that socket. `connect()` attempts to "dial a phone number" and connect with the server's socket similar to a telephone call. The connection is maintained for the life of the socket.

For UDP sockets, you can 'connect' to a different remote socket. All datagrams will be addressed to the same socket and, only datagrams from that socket will be accepted at this end while the 'connect' is still applicable.

Prototype

```
int  connect (int              sock_id
              struct sockaddr *paddr_remote_server,
              int              addr_len);
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created.
`paddr_remote_server`	This is a pointer to the protocol address of the remote server.
`addr_len`	This argument specifies the size of the socket address data structure and should always be: `sizeof(struct sockaddr_in)`

Returned Value

`connect()` returns `0` if successful or `-1` upon error.

Notes / Warnings

None

Uses µC/TCP-IP's Function

`NetSock_Conn()`

Example

```
int                 MySockID;
struct  sockaddr_in  ServerAddr;


void AppTask (void)
{
    int  connect_status;

    :
    :
    ServerAddr.sin_family      = AF_INET;
    ServerAddr.sin_port        = htons(REMOTE_SERVER_PORT_NBR);
    MySockAddr.sin_addr.s_addr = htonl(INADDR_ANY);

    connect_status             = connect(MySocketID,
                                         (struct sockaddr *)&ServerAddr,
                                         sizeof(struct sockaddr_in));
    if (connect_status < 0) {
        close(MySocketID);
    } else {
        /* Socket connected to remote server */
    }
    :
    :
}
```

6.08 inet_addr()

This function converts an IPv4 address in ASCII dotted-decimal notation to a network protocol IPv4 address in network-order.

Prototype

```
in_addr_t  inet_addr (char *paddr)
```

Arguments

`paddr` Pointer to an ASCII string that contains a dotted-decimal IPv4 address (see Note #2).

Returned Value

Network-order IPv4 address represented by ASCII string, if NO errors.
`-1` otherwise (i.e. `0xFFFFFFFF`).

Notes / Warnings

1) RFC 1983 states that "dotted decimal notation ... refers [to] IP addresses of the form A.B.C.D; where each letter represents, in decimal, one byte of a four byte IP address".

   In other words, the dotted-decimal notation separates four decimal octet values by the dot, or period, character ('.'). Each decimal value represents one byte of the IP address starting with the most significant byte in network order.

   IP Address Examples :

DOTTED DECIMAL NOTATION	HEXADECIMAL EQUIVALENT
127.0.0.1	0x7F000001
192.168.1.64	0xC0A80140
255.255.255.0	0xFFFFFF00
MSO ……. LSO	MSO …. LSO

   MSO Most Significant Octet in Dotted Decimal IP Address
   LSO Least Significant Octet in Dotted Decimal IP Address

2) The dotted-decimal ASCII string MUST include ONLY decimal values and the dot, or period, character ('.'). ALL other characters trapped as invalid, including any leading or trailing characters. The ASCII string MUST also include EXACTLY four decimal values separated by EXACTLY three dot characters. Each decimal value MUST NOT exceed the maximum octet value (i.e. 255), ensure that each decimal value does NOT include leading zeros.

Uses µC/TCP-IP's Function / Macro

```
NetASCII_Str_to_IP()
NET_UTIL_HOST_TO_NET_32()
```

Example

```
void AppTask (void)
{
    inet_addr_t  ip;
    inet_addr_t  msk;

    :
    :
    ip  = inet_addr(“192.168.1.64”);
    msk = inet_addr(“255.255.255.0”);
    :
    :
}
```

6.09 inet_ntoa()

This function converts a network protocol IPv4 address in network-order to an IPv4 address in ASCII dotted-decimal notation.

Prototype

```
char  *inet_ntoa (struct  in_addr  addr)
```

Arguments

`in_addr` IPv4 address.

Returned Value

Pointer to ASCII string of converted IPv4 address (see Note #2), if NO errors.
`NULL` pointer otherwise.

Notes / Warnings

1) RFC #1983 states that "dotted decimal notation ... refers [to] IP addresses of the form A.B.C.D; where each letter represents, in decimal, one byte of a four byte IP address".

   In other words, the dotted-decimal notation separates four decimal octet values by the dot, or period, character ('.'). Each decimal value represents one octet of the IP address starting with the most significant octet in network order.

   IP Address Examples :

DOTTED DECIMAL NOTATION	HEXADECIMAL EQUIVALENT
127.0.0.1	0x7F000001
192.168.1.64	0xC0A80140
255.255.255.0	0xFFFFFF00
MSO ……. LSO	MSO …. LSO

   MSO Most Significant Octet in Dotted Decimal IP Address
   LSO Least Significant Octet in Dotted Decimal IP Address

2) Since the character string is returned in a single, global character string array, this conversion function is **NOT** reentrant.

3) The IP address is saved in a 'global' array called `NetBSD_IP_to_Str_Array[]` and needs to be copied 'out' of this array to be able to use `inet_ntoa()` for another IP address.

Uses µC/TCP-IP's Function

`NetASCII_IP_to_Str()`

Example

```
void AppTask (void)
{
    char *pstr;
    char  ascii_ip_addr[NET_BSD_ASCII_LEN_MAX_ADDR_IP];

    :
    :
    pstr = inet_ntoa(0xC0A80140);        /* Convert 192.168.1.64 to ASCII string */
    Str_Copy(ascii_ip_addr, pstr);       /* Copy this string to local buffer     */
    :
    :
}
```

6.10 listen() TCP

Indicates that the given socket is ready to accept incoming connections. The socket must already be associated with a local port (i.e., `bind()` must have been called previously). After this call, incoming TCP connection requests addressed to the given local port (and IP address, if specified previously) will be completed and queued until they are passed to the program via `accept()`.

`listen()` applies only to stream type sockets (i.e. TCP sockets).

Prototype

```
int  listen (int   sock_id,
             int   sock_q_size)
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created.
`Sock_q_size`	Maximum number of new connections (sockets) waiting. In other words, this argument specifies the maximum queue length of pending connections while the server is busy servicing the current request.

Returned Value

Returns `0` if no error and `-1` otherwise.

Notes / Warnings

None.

Uses µC/TCP-IP's Function

`NetSock_Listen()`

Example

```
int                 MySockID;
struct  sockaddr_in  MySockAddr;


void AppTask (void)
{
    int  listen_status;

    :
    :
    /* Call socket() */
    /* Call bind()   */

    listen_status = listen(MySocketID, 3);

    if (listen_status < 0) {
        close(MySocketID);
    } else {
        /* Socket placed in listening state, proceed to ‘accept’ connections */
        /* Call accept()                                                      */
    }
    :
    :
}
```

6.11 recv() TCP/UDP

This function copies up to a specified number of bytes, received on the socket, into a specified location. The specified socket must be in the connected state.

If the socket is configured for blocking mode, `recv()` blocks until either at least one byte is returned or the connection closes (indicated by returning `0`).

If the socket is configured for non-blocking mode, `recv()` returns a `-1` if no data is available.

The return value indicates the number of bytes actually copied into the buffer starting at the pointed-to location. For a stream socket (i.e. TCP), the bytes are delivered in the same order as they were transmitted, without omissions. For a datagram socket (i.e. UDP), each `recv()` returns the data from at most one `send()`, and order is not necessarily preserved. If the buffer provided to `recv()` is not big enough for the next available datagram, the datagram is silently truncated to the size of the buffer.

You would typically use `recv()` for TCP sockets and `recvfrom()` for UDP sockets.

Prototype

```
int  recv (int    sock_id,
           void  *pdata_buf,
           int    data_buf_len,
           int    flags)
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created.
`pdata_buf`	Is a pointer to where the received message will be stored.
`data_buf_len`	Contains the size of the destination buffer.
`flags`	Specifies receive options. You can logically OR the flags. Valid flags are: `0` No socket flags selected `MSG_PEEK` Receive socket data without consuming the data `MSG_DONTWAIT` Receive the data without blocking In most cases, you would set `flags` to `0`.

Returned Value

Returns either:

the number of bytes received
`0` if the connection is closed
`-1` if no data is available and you specified `MSG_DONTWAIT` as one of the `flags`.

Blocking vs Non-Blocking

The default setting for µC/TCP-IP is *blocking*. However, you can change that at compile time by setting the configuration #define (see net_cfg.h) NET_SOCK_CFG_BLOCK_SEL to one of the following values:

NET_SOCK_BLOCK_SEL_DFLT sets blocking mode to the default, or blocking, unless modified by run-time options.

NET_SOCK_BLOCK_SEL_BLOCK sets the blocking mode to blocking. This means that recv() will wait until data is available from the socket. After creating the socket, you can specify a timeout when in blocking mode by calling the µC/TCP-IP function NetSock_CfgTimeoutRxQ_Set(). In other words, recv() will wait forever until a message is received unless you specify a timeout value. NetSock_CfgTimeoutRxQ_Set() require three parameters:

```
NET_SOCK_ID    sock_id
CPU_INT32U     timeout_ms
NET_ERR       *perr
```

sock_id is the socket ID that you pass to recv().

timeout_ms is the amount of time (in milliseconds) to wait for data to be received from the socket. If you specify a time of NET_TMR_TIME_INFINITE then, the socket will wait forever for data to arrive.

perr is a pointer to an error code that is returned from NetSock_CfgTimeoutRxQ_Set(). NET_SOCK_ERR_NONE indicates that the socket timeout was set correctly.

NET_SOCK_BLOCK_SEL_NO_BLOCK sets the blocking mode to non-blocking. This means that recv() call will NOT wait if data is not available from the socket. The caller should examine the return code of the function. 0 indicates that the connection has been lost and -1 indicates that no data was available. Of course, you will have to 'poll' recv() on a regular basis if data is not available.

The current version of the software selects blocking or non-blocking at compile time for all sockets. A future version of µC/TCP-IP will allow the selection of blocking or non-bloacking at the individual socket level. However, each call to recv() can pass the MSG_DONTWAIT flag to disable blocking on that call.

Notes / Warnings

Only some recv() flag options are implemented. If other flag options are requested, recvfrom() returns an error so that flag options are NOT silently ignored.

Uses µC/TCP-IP's Function

NetSock_RxData()

Example

```
int            MySockID;
CPU_INT08U     RxBuf[100];


void AppTask (void)
{
    int  rx_data_len;

    :
    :
    rx_data_len = recv(MySocketID, (void *)&RxBuf[0], 100, 0);

    if (rx_data_len > 0) {                /* See if we received data         */
        /* Process data received */
    } else if (rx_data_len == 0) {        /* See if connection has been lost */
        close(MySocketID);
    } else {
        /* Data not received */
    }
    :
    :
}
```

6.12 recvfrom() TCP/UDP

`recvfrom()` is used to receive from a UDP socket. The function copies a specified number of bytes received on a socket to a specified location.

Prototype

```
int  recvfrom (        int         sock_id,
                       void       *pdata_buf,
                       int         data_buf_len,
                       int         flags,
               struct  sockaddr   *paddr_remote,
                       int        *paddr_len);
```

Arguments

`sock_id` This is the socket ID returned by the `socket()` call when the socket was created.

`pdata_buf` This is a pointer to where the data received from the socket will be placed.

`data_buf_len` This argument specifies the maximum number of bytes to place in the `pdata_buf` buffer.

`flags` Control flags and can be one of the following values. Note that options can be logically OR'd together:

`0`	No socket flags selected.
`MSG_PEEK`	Receive socket data without consuming the socket data.
`MSG_DONTWAIT`	Receive socket data without blocking.

In most cases, you would set `flags` to `0`.

`paddr_remote` Pointer to an address buffer that will hold the socket address structure with the received data's remote address.

`paddr_len` When `recvfrom()` is called, `paddrlen` contains the size of the address buffer pointed to by `paddr_remote`. When the function returns, `paddr_len` contains the actual size of socket address structure with the received data's remote address.

Returned Value

`recvfrom()` returns the number of data octets actually received or `-1` upon error.

Blocking vs Non-Blocking

The default setting for µC/TCP-IP is *blocking*. However, you can change that at compile time by setting the configuration `#define` (see `net_cfg.h`) `NET_SOCK_CFG_BLOCK_SEL` to one of the following values:

NET_SOCK_BLOCK_SEL_DFLT sets blocking mode to the default, or blocking, unless modified by run-time options.

NET_SOCK_BLOCK_SEL_BLOCK sets the blocking mode to blocking. This means that recvfrom() will wait until data is available from the socket. After creating the socket, you can specify a timeout when in blocking mode by calling the µC/TCP-IP function NetSock_CfgTimeoutRxQ_Set(). In other words, recvfrom() will wait forever until a message is received unless you specify a timeout value. NetSock_CfgTimeoutRxQ_Set() require three parameters:

```
NET_SOCK_ID    sock_id
CPU_INT32U     timeout_ms
NET_ERR       *perr
```

sock_id is the socket ID that you pass to recvfrom().

timeout_ms is the amount of time (in milliseconds) to wait for data to be received from the socket. If you specify a time of NET_TMR_TIME_INFINITE then, the socket will wait forever for data to arrive.

perr is a pointer to an error code that is returned from NetSock_CfgTimeoutRxQ_Set(). NET_SOCK_ERR_NONE indicates that the socket timeout was set correctly.

NET_SOCK_BLOCK_SEL_NO_BLOCK sets the blocking mode to non-blocking. This means that recvfrom() call will NOT wait if data is not available from the socket. The caller should examine the return code of the function. 0 indicates that data was received and -1 indicates that no data was available. Of course, you will have to 'poll' recvfrom() on a regular basis if data is not available.

The current version of the software selects blocking or non-blocking at compile time for all sockets. A future version of µC/TCP-IP will allow the selection of blocking or non-bloacking at the individual socket level. However, each call to recvfrom() can pass the MSG_DONTWAIT flag to disable blocking on that call.

Notes / Warnings

For UDP sockets, all data is transmitted and received atomically -- i.e. every single, complete datagram transmitted MUST be received as a single, complete datagram. Thus, if the socket's type is datagram and the receive data buffer size is NOT large enough for the received data, the remaining data octets are silently discarded and NO error is returned. See also 'net_sock.c NetSock_RxDataFrom() Note #3' & 'net_sock.c NetSock_RxDataHandler() Note #2'.

Only some recvfrom() flag options are implemented. If other flag options are requested, recvfrom() returns an error so that flag options are NOT silently ignored.

Uses µC/TCP-IP's Function

NetSock_RxDataFrom()

Example

```
char                 rx_buf[100];
struct  sockaddr_in  sock_addr;
int                  sock_addr_len;
int                  rx_msg_len;


sock_addr_len = sizeof(sock_addr);
rx_msg_len    = recvfrom(sock_id,
                         (void *)&rx_buf[0],
                         sizeof(rx_buf),
                         0,
                         (struct sockaddr *)&sock_addr,
                         &sock_addr_len);
if (rx_msg_len < 0) {
    /* Data not received */
} else {
    /* Data received     */
}
```

6.13 send() TCP/UDP

`send()` sends bytes contained in a buffer to a TCP socket. `send()` can only be used when a socket is in the connected state. If the socket does not have enough buffer space available to hold the message being sent, `send()` will block, unless the socket has been placed in non-blocking mode, or the `MSG_DONTWAIT` flag has been set in the `flags` parameter.

Prototype

```
int  send (int    sock_id,
           void  *p_data,
           int    data_len,
           int    flags);
```

Arguments

`sock_id` This is the socket ID returned by the `socket()` call when the socket was created.

`p_data` This is a pointer to the application data to send.

`data_len` This argument specifies the number of octets to send.

`flags` Control flags and ca be one of the following values:

`0`	No socket flags selected.
`MSG_DONTWAIT`	Send data without blocking.

In most cases, you would set `flags` to `0`.

Returned Value

`send()` returns the number of data octets actually sent, `-1` upon error and `0` indicates that the connection was lost. A positive return value does not mean that the message was delivered, it just indicates that it was sent.

Blocking vs Non-Blocking

The default setting for µC/TCP-IP is *blocking*. However, you can change that at compile time by setting the configuration `#define` (see `net_cfg.h`) `NET_SOCK_CFG_BLOCK_SEL` to one of the following values:

`NET_SOCK_BLOCK_SEL_DFLT` sets blocking mode to the default, or blocking, unless modified by run-time options.

`NET_SOCK_BLOCK_SEL_BLOCK` sets the blocking mode to blocking. This means that `send()` will wait until data is able to be prepared and/or transmitted through the socket. After creating the socket, you can specify a timeout when in blocking mode by calling the µC/TCP-IP function `NetSock_CfgTimeoutTxQ_Set()` for TCP sockets (UDP sockets are best effort and exit with error rather than block). In other words, `send()` will wait forever until a message is prepared and/or transmitted unless you specify a timeout value. `NetSock_CfgTimeoutTxQ_Set()` require three

parameters:

```
NET_SOCK_ID    sock_id
CPU_INT32U     timeout_ms
NET_ERR       *perr
```

`sock_id` is the socket ID that you pass to `send()`.

`timeout_ms` is the amount of time (in milliseconds) to wait for data to be prepared and/or transmitted through the socket. If you specify a `time` of `NET_TMR_TIME_INFINITE` then, the socket will wait forever for data to transmit.

`perr` is a pointer to an error code that is returned from `NetSock_CfgTimeoutTxQ_Set()`. `NET_SOCK_ERR_NONE` indicates that the socket timeout was set correctly.

`NET_SOCK_BLOCK_SEL_NO_BLOCK` sets the blocking mode to non-blocking. This means that `send()` call will NOT wait if data is not sent to the socket. As much data from the message that can fit in the TCP buffer will be sent. The caller should examine the return code of the function. A positive value indicates the number of octets that was sent data and `-1` indicates that no data was sent and, `0` indicates that the connection was lost. Of course, you will have to 'poll' `send()` on a regular basis if data is not sent.

The current version of the software selects blocking or non-blocking at compile time for all sockets. A future version of µC/TCP-IP will allow the selection of blocking or non-bloacking at the individual socket level. However, each call to `send()` can pass the `MSG_DONTWAIT` flag to disable blocking on that call.

Notes / Warnings

Even though you can select blocking or non-blocking at compile time, the current version of the software *indirectly* always blocks. We say indirectly because, it's not the socket that blocks but instead, it's the driver who waits for availability of the transmitter.

Only some `send()` flag options are implemented. If other flag options are requested, `send()` returns an error so that flag options are NOT silently ignored.

Uses µC/TCP-IP's Function

`NetSock_TxData()`

Example

```
int                 sock_id;
char                tx_buf[100];
int                 tx_msg_len;


/* Place message into tx_buf[] */
tx_msg_len = send(sock_id,
                  &tx_buf[0],
                  sizeof(tx_buf),
                  0);

if (tx_msg_len > 0) {
    /* Data was sent       */
} else if (tx_msg_len == 0) {
    /* Connection was lost */
} else {
    /* Data not sent       */
}
```

6.14 sendto() TCP/UDP

`sendto()`sends bytes contained in a buffer to a UDP socket. If the socket does not have enough buffer space available to hold the message being sent, `sendto()` will block, unless the socket has been placed in non-blocking mode, or the `MSG_DONTWAIT` flag has been set in the `flags` parameter.

Prototype

```
int  sendto (        int         sock_id,
                     void       *p_data,
                     int         data_len,
                     int         flags,
             struct  sockaddr   *paddr_remote,
                     int         addr_len);
```

Arguments

`sock_id`	This is the socket ID returned by the `socket()` call when the socket was created.
`p_data`	This is a pointer to the application data to send.
`data_len`	This argument specifies the number of octets to send.
`flags`	Control flags and ca be one of the following values:

`0`	No socket flags selected.
`MSG_DONTWAIT`	Send data without blocking.

In most cases, you would set `flags` to `0`.

`paddr_remote`	Pointer to the destination address buffer.
`addr_len`	Length of destination address buffer. Generally, this corresponds to `sizeof(struct sockaddr).`

Returned Value

`sendto()` returns the number of data octets actually sent or `-1` upon error. A positive return value does not mean that the message was delivered, it just indicates that it was sent.

Blocking vs Non-Blocking

The default setting for µC/TCP-IP is *blocking*. However, you can change that at compile time by setting the configuration `#define` (see `net_cfg.h`) `NET_SOCK_CFG_BLOCK_SEL` to one of the following values:

NET_SOCK_BLOCK_SEL_DFLT sets blocking mode to the default, or blocking, unless modified by run-time options.

NET_SOCK_BLOCK_SEL_BLOCK sets the blocking mode to blocking. This means that sendto() will wait until data is able to be prepared and/or transmitted through the socket. After creating the socket, you can specify a timeout when in blocking mode by calling the µC/TCP-IP function NetSock_CfgTimeoutTxQ_Set() for TCP sockets (UDP sockets are best effort and exit with error rather than block). In other words, sendto() will wait forever until a message is prepared and/or transmitted unless you specify a timeout value. NetSock_CfgTimeoutTxQ_Set() require three parameters:

```
NET_SOCK_ID    sock_id
CPU_INT32U     timeout_ms
NET_ERR       *perr
```

sock_id is the socket ID that you pass to sendto().

timeout_ms is the amount of time (in milliseconds) to wait for data to be prepared and/or transmitted through the socket. If you specify a time of NET_TMR_TIME_INFINITE then, the socket will wait forever for data to transmit.

perr is a pointer to an error code that is returned from NetSock_CfgTimeoutTxQ_Set(). NET_SOCK_ERR_NONE indicates that the socket timeout was set correctly.

NET_SOCK_BLOCK_SEL_NO_BLOCK sets the blocking mode to non-blocking. This means that sendto() call will NOT wait if data is not sent to the socket. The caller should examine the return code of the function. A positive value indicates the number of octets that was sent data and -1 indicates that no data was sent. Of course, you will have to 'poll' sendto() on a regular basis if data is not sent.

The current version of the software selects blocking or non-blocking at compile time for all sockets. A future version of µC/TCP-IP will allow the selection of blocking or non-bloacking at the individual socket level. However, each call to sendto() can pass the MSG_DONTWAIT flag to disable blocking on that call.

Notes / Warnings

Even though you can select blocking or non-blocking at compile time, the current version of the software *indirectly* always assumes blocking. We say indirectly because, it's not the socket that blocks but instead, it's the driver who waits for availability of the transmitter.

For UDP sockets, all data is transmitted atomically -- i.e. each call to transmit data MUST be transmitted in a single, complete datagram. Since IP transmit fragmentation is NOT currently supported (see 'net_ip.h Note #1e'), if the socket's type is datagram and the requested application/socket transmit data length is greater than MTU, then the socket data transmit is aborted and NO socket data is transmitted. See also 'net_sock.c NetSock_TxDataTo() Note #3' and 'net_sock.c NetSock_TxDataHandler() Note #2'.

Only some sendto() flag options are implemented. If other flag options are requested, sendto() returns an error so that flag options are NOT silently ignored.

Uses µC/TCP-IP's Function

`NetSock_TxDataTo()`

Example

```
int                 sock_id;
char                tx_buf[100];
struct  sockaddr_in sock_addr;
int                 tx_msg_len;


tx_msg_len = (CPU_INT16S)sendto(sock_id,
                                &tx_buf[0],
                                sizeof(tx_buf),
                                0,
                                (struct sockaddr *)&sock_addr,
                                sizeof(struct sockaddr));

if (tx_msg_len < 0) {
    /* Data not sent */
} else {
    /* Data sent     */
}
```

6.15 socket() TCP/UDP

Creates a TCP or UDP socket, which may then be used as a communication endpoint for sending and receiving data using the specified protocol. You would specify TCP with the socket type/protocol pair `SOCK_STREAM` / `IPPROTO TCP` and UDP, with the socket type/protocol pair `SOCK_DGRAM` / `IPPROTO_UDP`.

Prototype

```
int  socket (int  protocol_family,
             int  sock_type,
             int  protocol);
```

Arguments

`protocol_family` Always use `AF_INET` or `PF_INET` (both values are the same) for TCP/IP sockets. This field establishes the *domain*.

`sock_type` Type of socket:

`SOCK_STREAM` for TCP
`SOCK_DGRAM` for UDP

`SOCK_STREAM` is a reliable byte-stream flow, where bytes are received the remote application in the same order as they were sent. File transfer and terminal emulation are examples of applications that require this type of protocol.

`SOCK_DGRAM` preserve message boundaries. Applications that exchange client request messages and server response messages are examples of datagram communication

Note that you can in fact specify `0` as the `protocol` since specifying `SOCK_STREAM` for the `sock_type` implies `IPPROTO_TCP` and, specifying `SOCK_DGRAM` for the `sock_type` implies `IPPROTO_UDP`.

`protocol` Socket protocol:

`IPPROTO_TCP` for TCP
`IPPROTO_UDP` for UDP

Note that you can in fact specify `0` as the `protocol` since specifying `SOCK_STREAM` for the `sock_type` implies `IPPROTO_TCP` and, specifying `SOCK_DGRAM` for the `sock_type` implies `IPPROTO_UDP`.

Arguments Summary

The table below shows you the different ways you can specify the three arguments.

TCP/IP Protocol	Arguments		
	protocol_family	**sock_type**	**protocol**
TCP	AF_INET or PF_INET	SOCK_STREAM	IPPROTO_UDP
TCP	AF_INET or PF_INET	SOCK_STREAM	0
UDP	AF_INET or PF_INET	SOCK_DGRAM	IPPROTO_TCP
UDP	AF_INET or PF_INET	SOCK_DGRAM	0

Returned Value

`socket()` returns the descriptor of the new socket id (positive value) if no error occurs or -1 upon error.

Notes / Warnings

The protocol characteristics of a socket are frozen when it is created. In other words, you cannot change a stream socket to a datagram socket (or vice versa) at run-time.

It's also very important that both sides (your target and the remote host) have sockets with the same socket family type and, protocol.

Uses µC/TCP-IP's Function

`NetSock_Open()`

Example

```
int  AppTCPSockID_1;
int  AppTCPSockID_2;

int  AppUDPSockID_1;
int  AppUDPSockID_2;


void AppTask (void)
{
    :
    :
    AppTCPSockID_1 = socket(PF_INET, SOCK_STREAM, IPPROTO_TCP);
    AppTCPSockID_2 = socket(PF_INET, SOCK_STREAM, 0);
    :
    :
    AppUDPSockID_1 = socket(PF_INET, SOCK_DGRAM, IPPROTO_UDP);
    AppUDPSockID_2 = socket(PF_INET, SOCK_DGRAM, 0);
    :
    :
}
```

Chapter 7

Micriμm Socket Layer

In addition to the BSD socket API discussed in Chapter 6, your application may interface to μC/TCP-IP using its own socket API found in the `net_sock.*` files. Basically, your application would skip the BSD socket layer & instead directly call the μC/TCP-IP socket layer as shown in Figure 14-1. You would have a slight performance gain by interfacing directly to `net_sock.*` functions. The μC/TCP-IP calls are more versatile because they provide an error code to the calling function instead of just `0` or `-1`. Micrium layer 7 application typically use the μC/TCP-IP socket interface functions instead of the BSD functions.

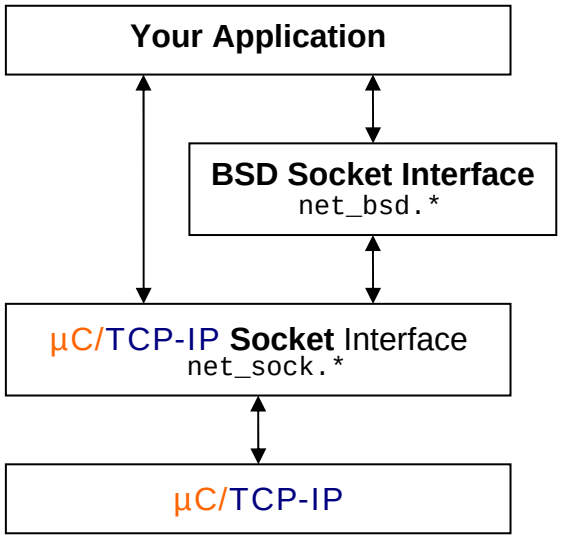


Figure 7-1, μC/TCP-IP Socket Interface

7.10 µC/TCP-IP Socket Error Codes

When socket functions return error codes, the error codes SHOULD be inspected to determine if the error is a temporary, non-fault condition (like no data to receive) or fatal (like the socket has been closed).

Whenever any of the following fatal error codes are returned by any µC/TCP-IP socket function, that socket MUST be immediately `closed()`'d without further by other socket functions :

```
NET_SOCK_ERR_NOT_USED
NET_SOCK_ERR_INVALID_FAMILY
NET_SOCK_ERR_INVALID_PROTOCOL
NET_SOCK_ERR_INVALID_TYPE
NET_SOCK_ERR_INVALID_STATE
NET_SOCK_ERR_FAULT
```

Chapter 8

NIC Drivers

µC/TCP-IP is able to work with a number of Network Interface Controllers (NICs). If we don't have a driver for the specific NIC you are planning on using, you can write your own driver as described in this chapter. However, it's recommended that you modify an already existing NIC driver with your NIC's specific code. We recommend that you follow our coding convention for consistency reasons.

µC/TCP-IP currently only supports Ethernet type interface controllers. There are many Ethernet controllers available on the market and each one requires a driver to work with µC/TCP-IP. It's actually possible to adapt drivers written for other TCP/IP stacks because the drivers are basically only responsible for copying data to and from the NIC.

The amount of code needed to interface a specific NIC to µC/TCP-IP greatly depends on the complexity of the NIC.

8.01 Directories and Files

Drivers are placed under the NIC directory as shown below.

```
\Micrium\Software\uC-TCPIP\NIC
```

µC/TCP-IP is capable of supporting multiple types of NICs but, currently only supports Ethernet. Ethernet drivers are thus placed under the `\Ether` subdirectory as shown below.

```
\Micrium\Software\uC-TCPIP\NIC\Ether
```

Individual NICs are typically identified by the manufacturer's part number. µC/TCP-IP currently supports the SMC LAN91C111 and Atmel's AT91RM9200 integrated MAC (Media Access Controller). You will find the drivers for these NICs in the following directories (assuming you purchased them with µC/TCP-IP).

```
\Micrium\Software\uC-TCPIP\NIC\Ether\LAN91C111\net_nic*.*
\Micrium\Software\uC-TCPIP\NIC\Ether\AT91RM9200\net_nic*.*
```

Note that NIC drivers must be called `net_nic*.*`. The actual directory determines which specific NIC your application will actually use.

8.02 Interfacing to µC/TCP-IP

Figure 8-1 shows the relationship between µC/TCP-IP, the NIC driver, the RTOS (Real-Time Operating System) and your BSP (Board Support Package). Here is a brief description of the contents of each file. More details will be provided in subsequent sections.

`net_nic.*` contains the NIC specific code but, is independent of the CPU and RTOS used. Also, `net_nic.*` doesn't know about the interface to the actual chip (memory or I/O mapped).

`net_bsp_a.s` is an assembly language file that handles receive and transmit ISRs (Interrupt Service Routines) from your NIC. It is assumed to be part of your application code because it depends on the CPU you are using, its interrupt structure and the compiler used. The ISR is typically written in assembly language but could also written in C if your compiler and RTOS allows it.

`net_bsp.c` contains code specific to the actual chip in your system. As a minimum, this file contains functions to read data from and write commands/data to the NIC. This file can also contain other NIC specific functions as needed by the NIC. Specifically, it can contain code to enable/disable ISRs from the NIC, initialize the NIC's ISRs, and do other ISR related functions. `net_bsp.c` should contain code that is specific to the board or I/O structure of your target. This file is also assumed to be part of your application code because it depends on the CPU you are using, its interrupt structure and the compiler used.

`net_os.c` contains code that interfaces to your RTOS. Functions specific to the NIC will be discussed in this chapter.

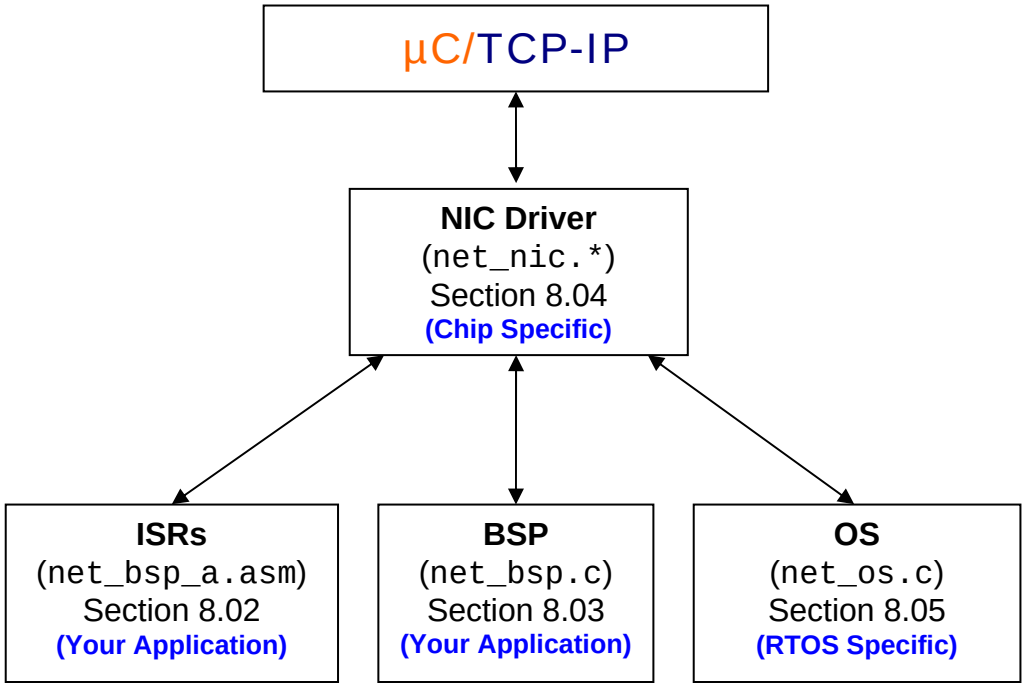


Figure 8-1, Interface relationship to NIC

8.02 ISRs, net_bsp_a.asm

µC/TCP-IP assumes that NIC handling is interrupt driven. Packets received will interrupt the CPU and the completion of a packet transmission will also interrupt the CPU. We assume that ISRs (Interrupt Service Routines) are part of your application code but will be calling services provided by the stack or the RTOS.

If you need to write your ISRs in assembly language, we recommend that you call the file `net_bsp_a.asm` for consistency. This file is assumed to be part of your application code and thus would be located in your application's directory. Listing 8-1 shows the pseudo-code of a typical NIC ISR. In most cases, `net_bsp_a.asm` only needs sufficient code to save/restore CPU registers and call the function `NetNIC_ISR_Handler()` which is found in `net_nic.c`.

Listing 8-1, Pseudo-code of NIC ISR written in assembly language

```
NetNIC_ISR:
   Save CPU registers;
   Call OS ISR entry function;
   Call NetNIC_ISR_Handler();
   Call OS ISR exit function;
   Restore CPU registers;
   Return from interrupt;
```

8.03 net_bsp.c

net_bsp.c is a file that is assumed to be part of your application code since it's specific to how the NIC is connected to your target as shown in Figure 8-2. It's assumed that the CPU interfaces with the NIC via a series registers defined by the NIC. Each register is identified by a unique ID or, address (0 .. N-1). The specific NIC defines what each register does. Figure 8-2 shows an interface to a NIC with 16-bit wide registers and thus, net_bsp.c defines two functions: NetNIC_Rd16() and NetNIC_Wr16(). The prototype for these functions is shown below:

```
CPU_INT16U  NetNIC_Rd_16 (CPU_INT16U reg_offset);
void        NetNIC_Wr_16 (CPU_INT16U reg_offset, CPU_INT16U val);
```

where:

reg_offset	is the register ID.
val	is the value to set the register to.

You will notice that the functions are prefixed with NetNIC_ even though they are in the file net_bsp.c. The reasoning is that NetNIC_Rd_16() (for example) is a NIC function that should have normally been part of net_nic.c but, because it's target specific, it needs to be placed in a file that will change based on the target.

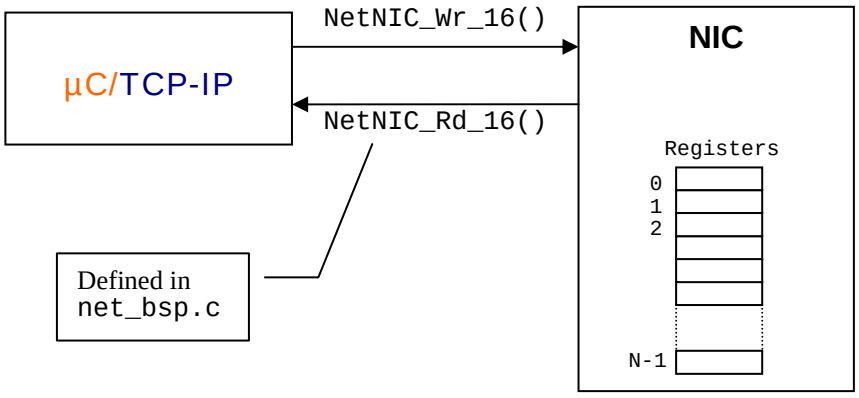


Figure 8-2, Interface between µC/TCP-IP and the NIC

net_bsp.c also contains ISR related functions such as initialization of the interrupt controller for the NIC ISR, setting up the interrupt vector, enabling and disabling interrupts from the NIC, etc. Below are additional functions that µC/TCP-IP expects to find in net_bsp.c:

NetNIC_IntInit() is a function that initializes the NIC interrupt on the target. Basically, this function sets up the interrupt controller (if present), sets up the interrupt vector associated with the NIC interrupt and, enables the NIC interrupt.

NetNIC_IntClr() is a function that clears the NIC interrupt. In other words, this is a function that indicates that the NIC interrupt has been serviced and that the NIC can receive another interrupt.

Code for these functions is assumed to be present if you set NET_NIC_CFG_INT_CTRL_EN to DEF_ENABLED in net_cfg.h.

8.04 net_nic.c

As previously mentioned, functions in this file contains the NIC specific code but, is independent of the CPU and RTOS used. Also, `net_nic.c` doesn't know about the interface to the actual chip (memory or I/O mapped).

This file contains code for the following functions:

```
void          NetNIC_Init              (NET_ERR *perr);

void          NetNIC_IntEn             (void);

CPU_BOOLEAN   NetNIC_ConnStatusGet     (void);
void          NetNIC_ConnStatusChk     (void);

void          NetNIC_ISR_Handler       (void);

CPU_INT16U    NetNIC_RxPktGetSize      (void);

void          NetNIC_RxPkt             (void         *ppkt,
                                        CPU_INT16U    size,
                                        NET_ERR      *perr);

void          NetNIC_RxPktDiscard      (CPU_INT16U    size,
                                        NET_ERR      *perr);

void          NetNIC_TxPkt             (void         *ppkt,
                                        CPU_INT16U    size,
                                        NET_ERR      *perr);
```

8.05.01 net_nic.c, NetNIC_Init()

This function is called by `Net_Init()` to initialize the NIC. The code in listing 8-2 shows the typical operations performed by `NetNIC_Init()`. You should simply copy this code for your own driver.

Listing 8-2, Initializing the NIC

```
void  NetNIC_Init (NET_ERR *perr)
{
    NetOS_NIC_Init(perr);                          /* Create NIC OS objects                */
    if (*perr != NET_OS_ERR_NONE) {
         return;
    }

    NetNIC_ConnStatus           =  DEF_OFF;        /* Initialize the NIC status            */

#if (NET_CTR_CFG_STAT_EN        == DEF_ENABLED)    /* Initialize NIC statistic counters    */
    NetNIC_StatRxPktCtr         =  0;
    NetNIC_StatTxPktCtr         =  0;
#endif

#if (NET_CTR_CFG_ERR_EN         == DEF_ENABLED)    /* Initialize NIC error counters        */
    NetNIC_ErrRxPktDiscardedCtr =  0;
    NetNIC_ErrTxPktDiscardedCtr =  0;
#endif

    NetNIC_InitHardware();                         /* Initialize the NIC hardware          */

   *perr = NET_NIC_ERR_NONE;
}
```

Listing 8-3 shows the pseudo-code for a function that would initialize the NIC hardware via the function `NetNIC_InitHardware()`.

Listing 8-3, Initializing the NIC hardware

```
void  NetNIC_InitHardware (void)
{
    /* Turn ON the NIC                              */
    /* Initialize the chip's registers              */
    /* Read the MAC address if it's store in EEPROM */
    /* Initiate auto negotiation                    */
    /* Enable the NIC's receiver                    */
    /* Enable the NIC's transmitter                 */

#if (NET_NIC_CFG_INT_CTRL_EN == DEF_ENABLED)
    NetNIC_IntInit();                /* Initialize the interrupt controller for the NIC .. */
                                     /* .. see net_bsp.c                                   */
#endif
}
```

8.05.02 net_nic.c, NetNIC_IntEn()

This function is called at the very end of `Net_Init()` to enable interrupts from the NIC. The pseudo-code for this function is shown in listing 8-4.

Listing 8-4, Enabling both Rx and Tx NIC interrupts

```
void  NetNIC_IntEn (void)
{
    /* Enable Rx interrupts from the NIC */
    /* Enable Tx interrupts from the NIC */
}
```

You will notice that we also transmit interrupts even though we don't have anything to transmit. The reason for this is explained in section 8.01.01, `NetOS_NIC_Init()`.

8.05.03 net_nic.c, NetNIC_ConnStatusGet()

This function is called to get the NIC's network connection status. Listing 8-5 shows the code for this function and in most cases, it doesn't need to change. However, the NIC's network connection status is encapsulated in this function for the possibility of obtaining the connection status using a non-trivial procedure.

Listing 8-5, Obtaining the connection status from the NIC

```
CPU_BOOLEAN  NetNIC_ConnStatusGet (void)
{
    return (NetNIC_ConnStatus);
}
```

8.05.04 net_nic.c, NetNIC_ISR_Handler()

This function is called by `NetNIC_ISR()` (possibly written in assembly language) to handler both Rx and Tx interrupts from the NIC. The pseudo-code for this function is shown in Listing 8-6. Note that at the end of the function we call `NetNIC_IntClr()` to clear the interrupt that appears on the interrupt controller (if one is used). You will recall that `NetNIC_IntClr()` is defined in `net_bsp.c` because the implementation depends on the interrupt structure of the CPU used in the target system.

Listing 8-6, Servicing both Rx and Tx interrupts

```
void  NetNIC_ISR_Handler (void)
{
    Determine the source of the interrupt;
    if (Rx interrupt) {
        NetNIC_RxISR_Handler();  /* Interrupt was from the reception of a packet               */
    }
    if (Tx interrupt) {
        NetNIC_TxISR_Handler();  /* Interrupt was from the completion of a packet transmission */
    }
#if (NET_NIC_CFG_INT_CTRL_EN == DEF_ENABLED)
    NetNIC_IntClr();             /* Clear the interrupt controller for the NIC interrupt       */
#endif
}
```

8.05.05 net_nic.c, NetNIC_RxPktGetSize()

This function is called by the IF layer to determine how many bytes were received by the NIC. This allows the IF layer to determine the size of the buffer needed to buffer the packet in order to pass it along to the other stack layers for processing. The pseudo-code in Listing 8-7 shows what this function needs to accomplish.

Listing 8-7, Obtaining the size of the packet received from the NIC

```
CPU_INT16U  NetNIC_RxPktGetSize (void)
{
    CPU_INT16U  size;


    size = Get the size (in bytes) of the packet received from the NIC;
    return (size);
}
```

8.05.06 net_nic.c, NetNIC_RxPkt()

This function is called by the IF layer (`NetIF_RxTaskHandler()`) to extract a packet received out of the NIC and place it into a network buffer. The pseudo-code for this function is shown in Listing 8-8. Note that if the packet is successfully read from the NIC we increment the `NetNIC_StatRxPktCtr` counter (to keep track of the number of packets received) using the `NET_CTR_STAT_INC()` macro. The local variable `cpu_sr` is necessary because the macro `NET_CTR_STAT_INC()` needs to increment `NetNIC_StatRxPktCtr` indivisibly.

`ppkt` is a pointer to the 'data' portion of the network buffer where the packet from the NIC will be placed.

`size` is the size (in number of bytes) of the packet to retrieve from the NIC. Note that the size was obtained by the `NetNIC_RxPktGetSize()` function discussed in section 8.05.05.

`perr` is a pointer to an variable that holds the error code reported by this function. Valid error code are:

`NET_NIC_ERR_NONE`	Packet successfully read.
`NET_ERR_INIT_INCOMPLETE`	Network initialization NOT complete.

The NIC packet receive function can read data from the NIC octet-by-octet **or** by words. By the way, an octet is 8 bits. This term is used in networking, rather than byte, because some systems might have bytes that are not 8 bits long.

For NICs with DMA capability, the NIC driver **MUST** DMA-receive NIC packets into its own memory buffer(s) in order to avoid CPU word-alignment exceptions. The NIC driver's `NetNIC_RxPkt()` function would then `Mem_Copy()` the received packet from the NIC's DMA memory buffer(s) into the 'data' portion of the network buffer pointed to by `ppkt`.

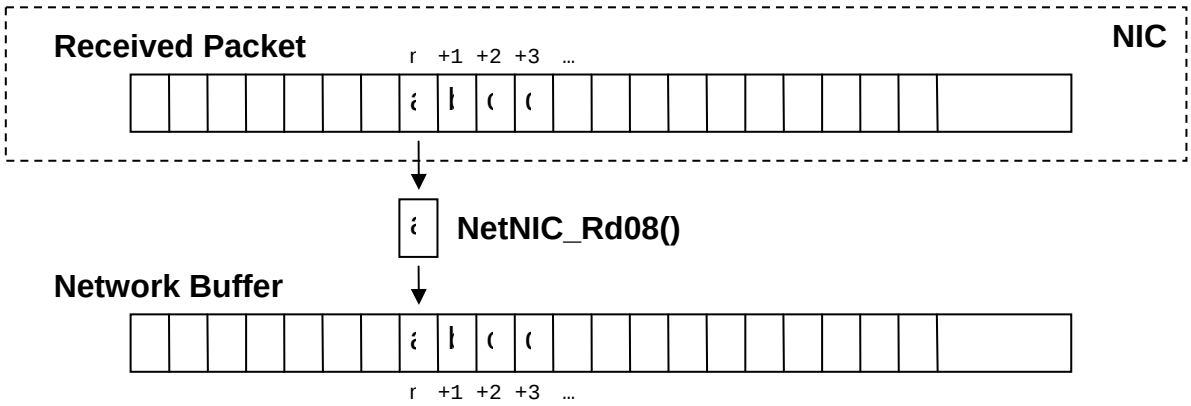


Figure 8-3, Reading the NIC one octet at a time

Listing 8-8, Reading a packet out of the NIC and into a network buffer

```
void  NetNIC_RxPkt (void        *ppkt,
                    CPU_INT16U   size,
                    NET_ERR     *perr)
{
#if ((NET_CTR_CFG_STAT_EN     == DEF_ENABLED)                    && \
     (CPU_CFG_CRITICAL_METHOD == CPU_CRITICAL_METHOD_STATUS_LOCAL))
    CPU_SR      cpu_sr;
#endif
    CPU_INT08U *p_buf;



    if (Net_InitDone != DEF_YES) {       /* Ignore packet if we haven't completed stack init. */
       *perr = NET_ERR_INIT_INCOMPLETE;
        return;
    }

    p_buf = (CPU_INT08U *)ppkt;          /* Point to destination buffer                       */
    while (size > 0) {
        *p_buf++ = NetNIC_Rd08();        /* Read one octet at a time from the NIC             */
        size--;
    }

    Re-enable Rx interrupts from the NIC;
    NET_CTR_STAT_INC(NetNIC_StatRxPktCtr);
   *perr = NET_NIC_ERR_NONE;
}
```

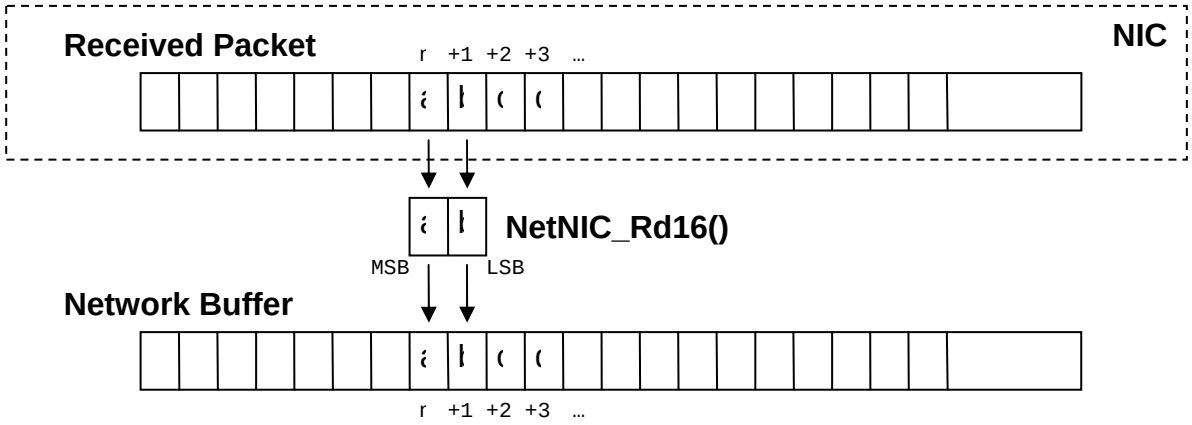


Figure 8-4, Reading the NIC two octets at a time (Network Order)

Listing 8-9, Reading a packet out of the NIC and into a network buffer

```
void  NetNIC_RxPkt (void        *ppkt,
                    CPU_INT16U   size,
                    NET_ERR     *perr)
{
#if ((NET_CTR_CFG_STAT_EN     == DEF_ENABLED)                    && \
     (CPU_CFG_CRITICAL_METHOD == CPU_CRITICAL_METHOD_STATUS_LOCAL))
    CPU_SR      cpu_sr;
#endif
    CPU_INT16U  rx_data;
    CPU_INT08U *p_buf;



    if (Net_InitDone != DEF_YES) {       /* Ignore packet if we haven't completed stack init. */
       *perr = NET_ERR_INIT_INCOMPLETE;
        return;
    }

    p_buf = (CPU_INT08U *)ppkt;          /* Point to destination buffer                       */
    while (size > 0) {
        rx_data  = NetNIC_Rd16();
        *p_buf++ = (CPU_INT08U)(rx_data >> 8);
        size--;
        if (size == 0) {
            break;
        } else {
            *p_buf++ = (CPU_INT08U)(rx_data & 0x00FF);
            size--;
        }
    }

    Re-enable Rx interrupts from the NIC;
    NET_CTR_STAT_INC(NetNIC_StatRxPktCtr);
   *perr = NET_NIC_ERR_NONE;
}
```

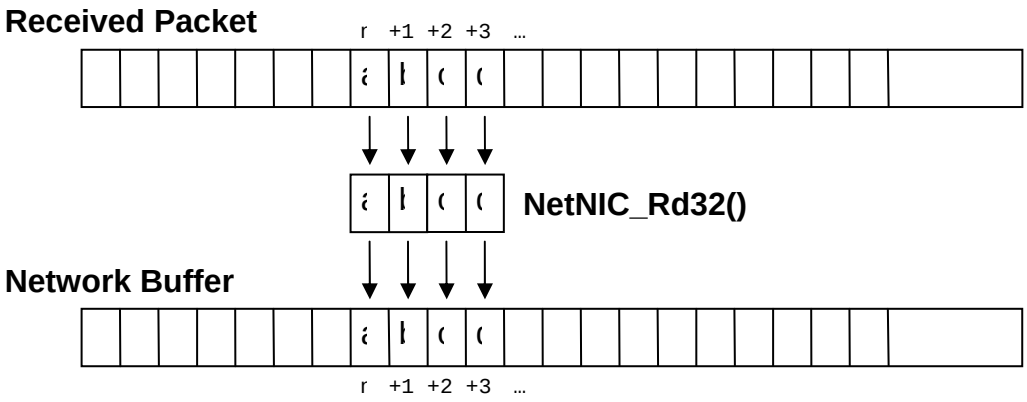


Figure 8-5, Reading the NIC four octets at a time (Network Order)

Listing 8-9, Reading a packet out of the NIC and into a network buffer

```
void  NetNIC_RxPkt (void        *ppkt,
                    CPU_INT16U   size,
                    NET_ERR     *perr)
{
#if ((NET_CTR_CFG_STAT_EN     == DEF_ENABLED)                    && \
     (CPU_CFG_CRITICAL_METHOD == CPU_CRITICAL_METHOD_STATUS_LOCAL))
    CPU_SR      cpu_sr;
#endif
    CPU_INT16U  rx_data;
    CPU_INT08U *p_buf;



    if (Net_InitDone != DEF_YES) {       /* Ignore packet if we haven't completed stack init. */
       *perr = NET_ERR_INIT_INCOMPLETE;
        return;
    }

    p_buf = (CPU_INT08U *)ppkt;          /* Point to destination buffer                       */
    while (size > 0) {
        rx_data  = NetNIC_Rd32();
        *p_buf++ = (CPU_INT08U)((rx_data >> 24) & 0xFF);
        size--;
        if (size == 0) {
            break;
        } else {
            *p_buf++ = (CPU_INT08U)((rx_data >> 16) & 0xFF);
            size--;
            if (size == 0) {
                break;
            } else {
                *p_buf++ = (CPU_INT08U)((rx_data >>  8) & 0xFF);
                size--;
                if (size == 0) {
                    break;
                } else {
                    *p_buf++ = (CPU_INT08U)(rx_data & 0xFF);
                    size--;
                }
            }
        }
    }

    Re-enable Rx interrupts from the NIC;
    NET_CTR_STAT_INC(NetNIC_StatRxPktCtr);
   *perr = NET_NIC_ERR_NONE;
}
```

8.05.07 net_nic.c, NetNIC_RxPktDiscard()

It is often necessary to discard packets because of error conditions that have been detected by the network stack. When this occurs, `NetNIC_RxPktDiscard()` is called. This function typically writes the appropriate command to the NIC to discard the received packet. However, depending on the NIC, it's possible that there is actually nothing to do and thus, this function would almost be empty. The pseudo-code and a portion of the actual code for this function is shown in listing 8-9. Note that if the packet is discarded, we increment the `NetNIC_ErrRxPktDiscardedCtr` counter using the `NET_CTR_ERR_INC()` macro. The local variable `cpu_sr` is necessary because the macro `NET_CTR_ERR_INC()` needs to increment `NetNIC_ErrRxPktDiscardedCtr` indivisibly.

`size` is the number of bytes to discard from the NIC.

`perr` is a pointer to an variable that holds the error code reported by this function. Valid error code are:

`NET_NIC_ERR_NONE`	Packet successfully discarded.
`NET_ERR_INIT_INCOMPLETE`	Network initialization NOT complete.

Listing 8-9, Getting the NIC to discard the received packet

```
void  NetNIC_RxPktDiscard (CPU_INT16U   size,
                           NET_ERR     *perr)
{
#if ((NET_CTR_CFG_STAT_EN     == DEF_ENABLED)                    && \
     (CPU_CFG_CRITICAL_METHOD == CPU_CRITICAL_METHOD_STATUS_LOCAL))
    CPU_SR  cpu_sr;
#endif


    if (Net_InitDone != DEF_YES) {           /* If not initialized, abort the discard    */
       *perr = NET_ERR_INIT_INCOMPLETE;
        return;
    }

    Write commands to the NIC to discard the last packet received;

    NET_CTR_ERR_INC(NetNIC_ErrRxPktDiscardedCtr);

   *perr = NET_NIC_ERR_NONE;
}
```

8.05.08.01 net_nic.c, NetNIC_TxPktPrepare()

This function is called by the `NetIF_Pkt_Tx()` function to prepare a NIC packet for transmission. Note that this function is necessary only if the NIC has multiple transmit packets & has the capability to transmit packet(s) while simultaneously preparing other NIC transmit packet(s).

From a CPU usage standpoint, preparing NIC transmit packet(s) separately from finally transmitting the packet(s) is no more or less efficient than if combined in a single transmit function. But from a network throughput standpoint, preparing additional NIC transmit packet(s) while the NIC is actively transmitting other previously-prepared packet(s) significantly improves network throughput performance.

To accomodate NICs with this simultaneous prepare & transmit packet(s) capability, the NIC driver may implement the transmit preparation in the `NetNIC_TxPktPrepare()` function and the `NET_NIC_CFG_TX_PKT_PREPARE_EN` configuration constant **MUST** be configured as `DEF_ENABLED`.

`ppkt` is a pointer to the first byte of data to write to the NIC.

`size` is the number of bytes to write to the NIC.

`perr` is a pointer to an variable that holds the error code reported by this function. Valid error code are:

`NET_NIC_ERR_NONE`	Packet successfully written/sent to the NIC.
`NET_ERR_INIT_INCOMPLETE`	Network initialization NOT complete.
`NET_ERR_TX`	NIC Transmit error.

For NIC's with DMA capability, the NIC driver **MUST** prepare DMA-transmit NIC packets from its own memory buffer(s) in order to avoid internal buffer corruption and deadlocks. The NIC driver's `NetNIC_TxPktPrepare()` function would `Mem_Copy()` the transmit packet from the 'data' portion of the network buffer pointed to by `ppkt` into the NIC's DMA memory buffer(s). The NIC driver could then configure the DMA transmit to start in `NetNIC_TxPkt()` or the NIC driver could wait until `NetNIC_TxPkt()` to start the DMA transmit.

If a NIC does **not** have the capability to simultaneously prepare and transmit packet(s), this function is not necessary and the preparation for transmitting packet(s) may be fully implemented in the `NetNIC_TxPkt()`. In this case, the NIC driver does need not to implement the `NetNIC_TxPktPrepare()` function but the `NET_NIC_CFG_TX_PKT_PREPARE_EN` configuration constant **MUST** be configured as `DEF_DISABLED`.

8.05.08.02 net_nic.c, NetNIC_TxPkt()

This function is called by the `NetIF_Pkt_Tx()` function to write a packet to the NIC for transmission. The pseudo-code and a portion of the actual code for this function is shown in listing 8-10. Note that if the packet is successfully written to the NIC, we assume that the packet has been sent and we thus increment the `NetNIC_StatTxPktCtr` counter using the `NET_CTR_STAT_INC()` macro. The local variable `cpu_sr` is necessary because the macro `NET_CTR_STAT_INC()` needs to increment `NetNIC_StatTxPktCtr` indivisibly.

`ppkt` is a pointer to the first byte of data to write to the NIC.

`size` is the number of bytes to write to the NIC.

`perr` is a pointer to an variable that holds the error code reported by this function. Valid error code are:

`NET_NIC_ERR_NONE`	Packet successfully written/sent to the NIC.
`NET_ERR_INIT_INCOMPLETE`	Network initialization NOT complete.
`NET_ERR_TX`	NIC Transmit error.

The NIC packet transmit function can write data into the NIC octet-by-octet **or** by words.

The NIC packet transmit function **MUST** read data from network buffers to ensure the following :

1) That the data reads from network buffers satisfies any CPU word-alignment requirements. Since various IF layers may require data to start on different word-aligned boundaries inside the network buffers, the packet data in the network buffer already ensures that internal accesses are CPU-word-size aligned.

   This means that the data must be read from network buffers either :
   a) Octet-by-octet starting from the data pointer address (`ppkt`)
   b) By words aligned to the starting data pointer address (`ppkt`) –
   which may NOT necessarily start on a CPU-word-size aligned boundary

   If the packet transmit data is written into the NIC in words, then the words must be appropriately constructed from network buffer data octets to satisfy the network CPU-word-size alignment requirements.

2) That the data writes into NIC transmit packets correctly order the data octets to maintain network-order.

For NIC's with DMA capability, the NIC driver **MUST** DMA-transmit NIC packets from its own memory buffer(s) in order to avoid internal buffer corruption and deadlocks. The NIC driver's `NetNIC_TxPkt()` function would `Mem_Copy()` the transmit packet from the 'data' portion of the network buffer pointed to by `ppkt` into the NIC's DMA memory buffer(s). The NIC driver would then configure the DMA transmit to start immediately or at some later point in time.

Listing 8-10, Writing a packet to the NIC

```
void  NetNIC_TxPkt (void        *ppkt,
                    CPU_INT16U   size,
                    NET_ERR     *perr)
{
#if ((NET_CTR_CFG_STAT_EN     == DEF_ENABLED)                    && \
     (CPU_CFG_CRITICAL_METHOD == CPU_CRITICAL_METHOD_STATUS_LOCAL))
    CPU_SR  cpu_sr;
#endif


    if (Net_InitDone != DEF_YES) {        /* Abort transmission if init NOT complete */
       *perr = NET_ERR_INIT_INCOMPLETE;
        return;
    }

    Write the packet into the NIC packet from the buffer pointed to by ‘ppkt’ and with size
‘size’ :
        while (size > 0) {
            Read  data octet from buffer;
            Write data octet into NIC;
            size--;
        }

           OR

        while (size > 0) {
            Read data word from buffer;
            if (data word aligned to   NIC packet) {
                Write data word   into NIC packet in network-order;
            } else {
                Split data word   into octets;
                Write data octets into NIC packet in network-order;
            }
            size -= word - size;
        }



    if (*perr != NET_NIC_ERR_NONE) {
        NetNIC_TxPktDiscard(perr);
        return;
    }

    NET_CTR_STAT_INC(NetNIC_StatTxPktCtr);
}
```

8.05.09 net_nic.c, NetNIC_RxISR_Handler()

This function is called by `NetNIC_ISR_Handler()` (see section 8.05.04) to handle packet reception. Note that this is a local function because it's called from within `net_nic.c`. We decided to make `NetNIC_RxISR_Handler()` a separate function to make the code cleaner. However, if your application needs every bit of performance, you can integrate the Rx portion of the handler directly in `NetNIC_ISR_Handler()`.

`NetNIC_RxISR_Handler()` doesn't actually do much except signal the **Rx Packet Semaphore** indicating that a packet was received from the NIC. This semaphore needs to be a counting semaphore because it needs to be able to 'remember' the number of times the NIC signaled the reception of packets which could happen if the NIC contains multiple receive buffers. Figure 8-3 shows the relationship between the NIC, the Rx ISR and the Rx task.

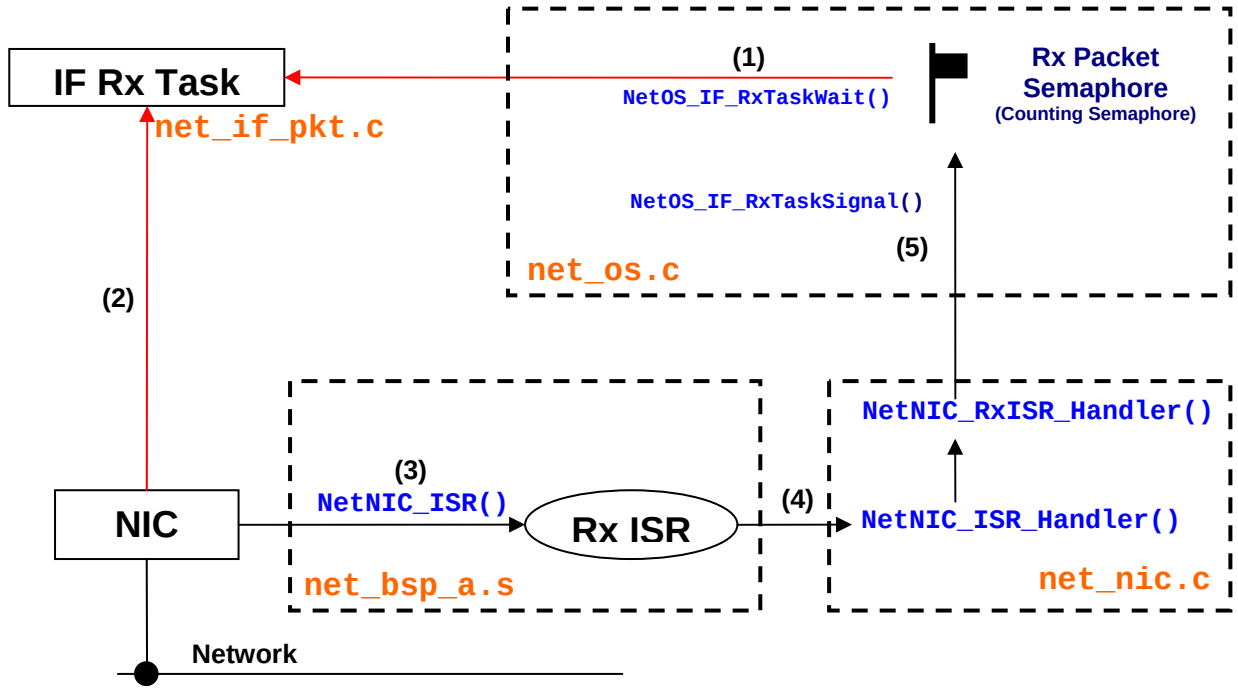


Figure 8-3, Packet reception interrupt and the Rx Packet Semaphore

F8-3(1) The IF layer always waits for packets to arrive and thus waits forever for the **Rx Packet Semaphore** to be signaled.

F8-3(2) When a packet arrives, the NIC signals the Rx Packet Semaphore (describe shortly) and the **IF Rx Task** reads the packet out of the NIC and places the read packet in a network buffer and passes this buffer to the upper layers of the protocol for processing.

F8-3(3) When a packet is received, the NIC generates an interrupt and `NetNIC_ISR()` is invoked.

F8-3(4) `NetNIC_ISR()` doesn't do much because typically this function is written in assembly language and we prefer writing most of the code in C and thus, `NetNIC_ISR()` simply calls `NetNIC_ISR_Handler()` which determines that the cause of the interrupt was from a packet reception and thus, calls `NetNIC_RxISR_Handler()`. The pseudo-code and a portion of the actual code for this function is shown in listing 8-11.

F8-3(5) `NetNIC_RxISR_Handler()` doesn't do much either except call `NetOS_IF_RxTaskSignal()` to notify the **IF Rx Task** that a packet was received. We decided to defer processing of the received packet to a task instead of handling it in the ISR to keep the ISR as short as possible and, make the driver easier to write. You will note that all RTOS related functions are encapsulated in a file called `net_os.c`. By simply changing the contents of `net_os.c`, you can adapt µC/TCP-IP to different RTOSs. Of course, for this to work, you need to maintain the same function names since the rest of the stack assumes these function names.

Listing 8-11, Handling packet reception interrupts

```
static  void  NetNIC_RxISR_Handler (void)
{
    NET_ERR  err;


    NetOS_IF_RxTaskSignal(&err);        /* Signal Net IF Rx Task that NIC received a packet */

    switch (err) {
        case NET_IF_ERR_NONE:
             Disable Rx interrupts from the NIC;
             break;

        case NET_IF_ERR_RX_Q_FULL:
        case NET_IF_ERR_RX_Q_POST_FAIL:
        default:
             NetNIC_RxPktDiscard(0, &err);
             break;
    }
}
```

With most NICs, the interrupt from the NIC is actually cleared when the NIC is read. Since we don't actually read the NIC from the ISR, we must disable further Rx interrupts from the NIC until we actually read the NIC which is done in the **IF Rx Task**.

8.05.10 net_nic.c, NetNIC_TxISR_Handler()

This function is called by `NetNIC_ISR_Handler()` when a packet is sent to the NIC. Note that this is a local function because it's called from within `net_nic.c`. We decided to make `NetNIC_TxISR_Handler()` a separate function to make the code cleaner. However, if your application needs every bit of performance, you can integrate the Tx portion of the handler directly in `NetNIC_ISR_Handler()`.

`NetNIC_TxISR_Handler()` doesn't actually do much except signal the **Tx Rdy Semaphore** indicating that the NIC completed sending a packet or, is ready to send a packet. Figure 8-4 shows the relationship between the NIC, the Tx ISR and the IF layer.

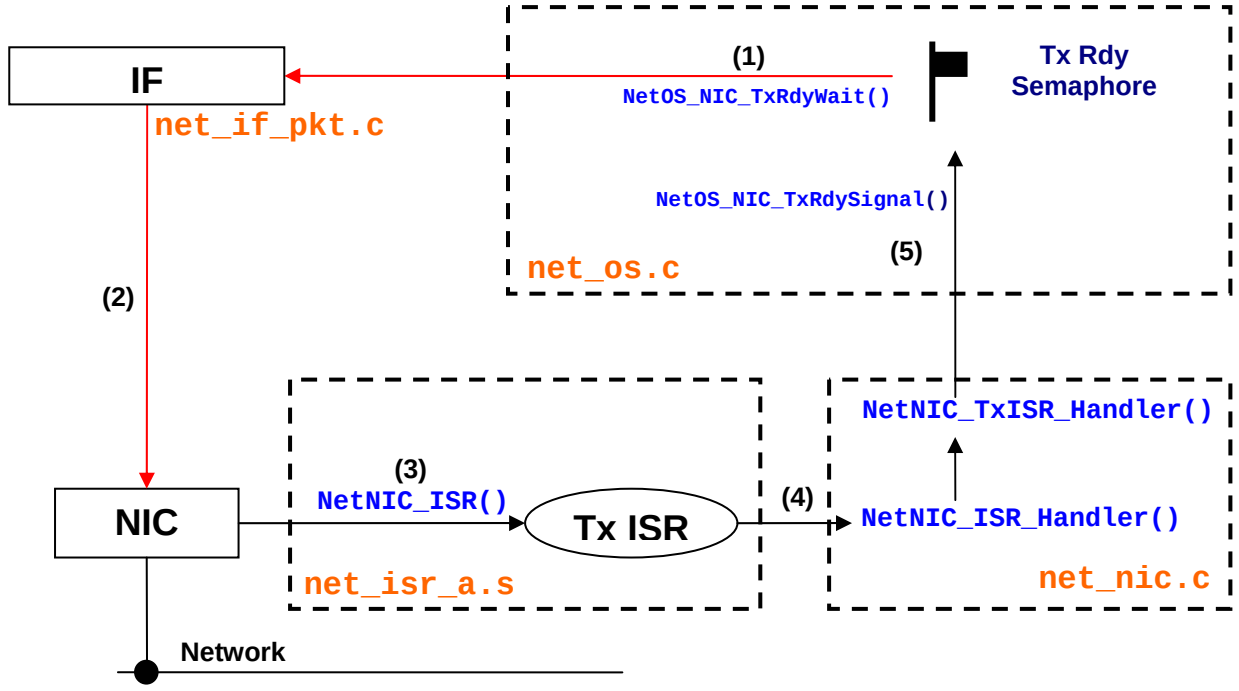


Figure 8-4, Sending a packet and the Tx Rdy Semaphore

F8-4(1) Before writing a packet to the NIC, the IF (Interface) layer needs to acquire the **Tx Rdy Semaphore**. A semaphore value greater than `0` indicates that the NIC is able to transmit a packet. A value of `0`, indicates that the NIC is unable to send a packet because it's already busy with processing a transmit request. The IF layer will thus WAIT (i.e. block) until the semaphore is signaled and thus available.

F8-4(2) If the semaphore is available (a value greater than `0`), the IF layer simply moves the packet to send onto the NIC for transmission. Of course, the semaphore value is decremented. This operation is performed atomically by your RTOS.

F8-4(3) When the NIC completes sending a packet, the NIC generates an interrupt. The function that handles the ISR is called `NetNIC_ISR()`. This function is found in `net_bsp_a.s` (or `net_bsp.c` if you can write all your ISRs in C).

F8-4(4)

F8-4(5) The NIC's **Tx ISR** calls the C handler `NetNIC_ISR_Handler()` to handle most of the ISR in C instead of assembly language. Note that on some NICs, there is a single ISR for both Rx and Tx interrupts. In this case, the ISR handler determines whether the interrupt was caused by a received packet or, completion of a transmitted packet (or a transmit empty condition). For the transmission interrupt, `NetNIC_ISR_Handler()` calls `NetNIC_TxISR_Handler()` which signals the **Tx Rdy Semaphore** (by calling `NetOS_NIC_TxRdySignal()`) indicating that the NIC is able to send another packet (because it just completed sending a packet). If the IF layer blocked waiting for the semaphore then, it's unblocked and the packet can be moved to the NIC as in F8-4(2). If the IF layer was not blocked (because it only had one packet to send) then, the semaphore is simply signaled and the **Tx ISR** terminates.

The pseudo-code for `NetNIC_TxISR_Handler()` is shown in Listing 8-12.

Listing 8-12, Handling packet transmission interrupts

```
static  void  NetNIC_TxISR_Handler (void)
{
    Acknowledge the Tx interrupt to clear the NIC interrupt;

    Re-enable Tx Interrupts;

    NetOS_NIC_TxRdySignal();
}
```

8.06 net_os.c

net_os.c contains RTOS interface functions to make µC/TCP-IP independent of the actual RTOS used. In this section, we only discuss the RTOS functions related to the NIC driver but, net_os.c contains many more RTOS related services needed by the network stack.

8.06.01 net_os.c, NetOS_NIC_Init()

This function is called to initialize RTOS objects used by the NIC driver. The NIC driver makes use of a semaphore that indicates when it's able to transmit data to the NIC. Figure 8-4 showed the relationship between the **Tx Rdy Semaphore**, the NIC and the NIC's **Tx ISR**.

The initial value of the semaphore greatly depends on how the Tx Interrupt is generated for the specific NIC. For the generic configuration of the NIC Tx Rdy Semaphore for single-transmit-packet-buffer NICs **ONLY**, configure NET_NIC_CFG_TX_RDY_INIT_VAL in net_cfg.h as follows:

`0` For NIC driver's that use the Transmit **Empty** interrupt

`1` For NIC driver's that use the Transmit **Complete** interrupt

NIC with Transmit **Empty** Interrupt:

For example, if a NIC driver is coded to use the Transmit **Empty** interrupt (i.e. an interrupt is generated *ONLY* when the transmitter goes from non-empty to empty), NET_NIC_CFG_TX_RDY_INIT_VAL would be set to `0`. The semaphore is initialized to `0` because as soon as we enable the transmit interrupt for the first time, the NIC will issue an interrupt. What we want to do is signal the semaphore to indicate that the transmitter is ready and then disable interrupts from the transmitter. The NIC Transmit **Empty** ISR must be written to:

- Clear the ISR
- Clear the interrupt enable
- Signal the OS object that the transmit is empty

It's also important to note that NetNIC_TxPkt() (or a subfunction) must re-enable the transmit interrupt after the transmit data has been written into the NIC.

NIC with Transmit **Complete** Interrupt:

If a NIC driver is coded to use the Transmit **Done/Complete** interrupt (i.e. an interrupt is generated *WHEN* the transmitter is done transmitting a packet), NET_NIC_CFG_TX_RDY_INIT_VAL would be set to `1`. The semaphore is initialized to `1` because at initialization, we would not transmit anything and thus, there would be no transmit complete interrupt issued. In other words, the transmit ready semaphore would indicate that the transmitter is ready to accept packets to send. The NIC Transmit **Complete** ISR must be written to:

- Clear the ISR
- Signal the OS object that the transmit is empty

You should note that the transmit interrupt is always enabled since it will only interrupt the CPU after a transmit packet has been sent.

The pseudo-code for `NetOS_NIC_Init()` is shown in listing 8-13.

Listing 8-13, Initializing RTOS objects used by the NIC

```
void  NetOS_NIC_Init (NET_ERR *perr)
{
    /* Initialize the Tx Rdy Semaphore (see above discussion for initial value) */
    *perr = NET_ERR_NONE;
}
```

8.06.02 net_os.c, NetOS_NIC_TxRdyWait()

`NetOS_NIC_TxRdyWait()` is the function that the IF calls to determine if the NIC is able to receive a packet for transmission. Typically, the caller should block (i.e. wait forever) for the semaphore to be available. Alternatively, you can implement the code to block with a timeout (if your RTOS allows this) and take corrective action if the block times out.

The pseudo-code for this function is shown in Listing 8-14.

Listing 8-14, Waiting for the NIC to be ready to transmit packets

```
void  NetOS_NIC_TxRdyWait (NET_ERR *perr)
{
    /* Wait for Tx Rdy Semaphore with optional timeout */

    switch (semaphore wait error code) {
        case 'no error':
            *perr = NET_NIC_ERR_NONE;
             break;

        case 'wait timed out':
        default:
            *perr = NET_NIC_ERR_TX_RDY_SIGNAL_TIMEOUT;
             break;
    }
}
```

Note that this function needs to set `*perr` to either `NET_NIC_ERR_NONE` if the wait was successful or, `NET_NIC_ERR_TX_RDY_SIGNAL_TIMEOUT` if the wait timed out.

8.06.03 net_os.c, NetOS_NIC_TxRdySignal()

This function is called by the NIC's Tx handler to indicate that the NIC has completed transmission of a packet. This function should generally map to a single OS call to perform the signaling. The pseudo-code is shown in listing 8-15.

Listing 8-15, Signaling completion of a transmitted packet

```
void  NetOS_NIC_TxRdySignal (void)
{
    /* Signal that NIC has transmitted a packet        */
}
```

Chapter 9

Configuration Manual

µC/TCP-IP is configurable at compile time via about 50 `#define`s. Of these, 5 values may likely never change (there is only currently only one configuration choice). This leaves 45 or so values to configure. `#define`s are used because they allow code and data sizes to be scaled at compile time based on your selection. In other words, this allows the footprint of µC/TCP-IP to be adjusted based on your requirements.

It's recommended that you start your configuration process with the recommended values. When multiple values for a `#define` are possible, the recommended or default value is shown in **RED**.

9.01 Network Configuration

There are two parameters to set for the network configuration:

```
NET_CFG_INIT_CFG_VALS
NET_CFG_OPTIMIZE
```

9.01.01 Network Configuration, NET_CFG_INIT_CFG_VALS

This configuration constant is used to determine whether internal TCP/IP parameters are set to default values or, are set by the user. `NET_CFG_INIT_CFG_VALS` can take on of two values:

`NET_INIT_CFG_VALS_DFLT`

Configure µC/TCP-IP's network parameters with default values. The application need only call `Net_Init()` to initialize both µC/TCP-IP and its configurable parameters. This configuration is highly recommended since configuring network parameters requires in-depth knowledge of the protocol stack. In fact, most books we have consulted recommend the default values that we selected.

Parameter	Units	Minimum	Maximum	Default
NetDbg_RsrcBufSmallThLo_nbr	#Small Buffers	1	(19 / 20) * #Small Buffers	Maximum Value
NetDbg_RsrcBufSmallThLoHyst_nbr	#Small Buffers	1	(1 / 6) * #Small Buffers	Maximum Value
NetDbg_RsrcBufLargeThLo_nbr	#Large Buffers	1	(19 / 20) * #Large Buffers	Maximum Value
NetDbg_RsrcBufLargeThLoHyst_nbr	#Large Buffers	1	(1 / 6) * #Large Buffers	Maximum Value
NetDbg_RsrcTmrThLo_nbr	#Timers	1	(19 / 20) * #Timers	Maximum Value
NetDbg_RsrcTmrThLoHyst_nbr	#Timers	1	(1 / 6) * #Timers	Maximum Value
NetDbg_RsrcConnThLo_nbr	#Connections	1	(19 / 20) * #Connections	Maximum Value
NetDbg_RsrcConnThLoHyst_nbr	#Connections	1	(1 / 6) * #Connections	Maximum Value
NetDbg_RsrcARP_CacheThLo_nbr	#ARP Caches	1	(19 / 20) * #ARP Caches	Maximum Value
NetDbg_RsrcARP_CacheThLoHyst_nbr	#ARP Caches	1	(1 / 6) * #ARP Caches	Maximum Value
NetDbg_RsrcTCP_ConnThLo_nbr	#TCP Connections	1	(19 / 20) * #TCP Connections	Maximum Value
NetDbg_RsrcTCP_ConnThLoHyst_nbr	#TCP Connections	1	(1 / 6) * #TCP Connections	Maximum Value
NetDbg_RsrcSockThLo_nbr	#Sockets	1	(19 / 20) * #Sockets	Maximum Value
NetDbg_RsrcSockThLoHyst_nbr	#Sockets	1	(1 / 6) * #Sockets	Maximum Value
NetDbg_MonTaskTime_sec	Seconds	1	600	60
NetConn_AccessedTh_nbr	#Connections	10	65000	100
NetARP_CacheTimeout_sec	Seconds	60	600	60
NetARP_CacheAccessedTh_nbr	#ARP Caches	100	65000	1000
NetARP_ReqMaxAttempts_nbr	#Attempts	1	6	4
NetARP_ReqTimeout_sec	Seconds	1	10	5
NetIP_AddrThisHost	IP address	0.0.0.0	255.255.255.255	0.0.0.0
NetIP_AddrThisHostSubnetMask	IP address	0.0.0.0	255.255.255.255	0.0.0.0
NetIP_AddrDfltGateway	IP address	0.0.0.0	255.255.255.255	0.0.0.0
NetIP_FragReasmTimeout_sec	Seconds	1	10	5
NetICMP_TxSrcQuenchTxTh_nbr	#Source Quenches Transmitted	1	100	5

Table 9-1, µC/TCP-IP Internal Parameters

NET_INIT_CFG_VALS_APP_INIT

It's possible to change the parameters listed in Table 9-1 by calling µC/TCP-IP functions that will do the work for you based on the parameter values you desire. Some of these values might in fact be stored in non-volatile memory that is recalled at power-up (e.g. using EEPROM or battery-backed RAM) by your application. If you select this option, you will need to initialize ALL of these configuration parameters.

Alternatively, you can first call `Net_InitDflt()` to initialize all the parameter to their default values and then simply change only the ones you need afterwards.

9.01.02 Network Configuration, NET_CFG_OPTIMIZE

Some of the code in µC/TCP-IP offers you the choice of optimizing the code for better performance or, for the smallest code size via the `NET_CFG_OPTIMIZE` value. The choices are:

`NET_OPTIMIZE_SPD`
Optimizes network protocol suite for best speed performance

`NET_OPTIMIZE_SIZE`
Optimizes network protocol suite for best binary image size

9.02 Debug Configuration

A fair amount of code in µC/TCP-IP has been included to simplify debugging. Two configuration constants are used for this purpose:

```
NET_DBG_CFG_DBG_INFO_EN
NET_DBG_CFG_TEST_EN
NET_DBG_CFG_MEM_CLR_EN
```

9.02.01 Debug Configuration, NET_DBG_CFG_DBG_INFO_EN

This configuration constant is used to enable/disable network protocol suite debug information:

- Internal constants assigned to global variables
- Internal variable data sizes calculated & assigned to global variables
- Run-time debug functions that provide information on :
    - Internal resource usage – low or lost resources
    - Internal faults or errors

The value can either be:

DEF_DISABLED

or

DEF_ENABLED

9.02.02 Debug Configuration, NET_DBG_CFG_MEM_CLR_EN

This configuration constant is used to clear internal network data structures when allocated & deallocated. By clearing we mean setting all bytes in the data structures to 0 or to default initialization values. You can set this configuration constant to either:

DEF_DISABLED

or

DEF_ENABLED

You would typically set it to **DEF_DISABLED** unless you are debugging a Layer 7 application and you want to examine the contents of the buffer. Having the buffer cleared generally helps you differentiate between 'proper' data and 'pollution'.

9.02.03 Debug Configuration, NET_DBG_CFG_TEST_EN

This configuration constant is used internally for testing/debugging purposes and can be set to either:

DEF_DISABLED

or

DEF_ENABLED

9.03 Argument Checking Configuration

Most functions in µC/TCP-IP include code to validate arguments that are passed to it. Specifically, µC/TCP-IP as code to check to see if a passed pointer is a NULL pointer, if an argument is within a valid range, etc. Two configuration constants are used for this purpose:

```
NET_ERR_CFG_ARG_CHK_EXT_EN
NET_ERR_CFG_ARG_CHK_DBG_EN
```

9.03.01 Argument Checking Configuration, NET_ERR_CFG_ARG_CHK_EXT_EN

This configuration constant allows code to be generated to check arguments for functions that can be called by the user and, for functions which are internal but receives arguments from an API that the user can call. Also, enabling this check verifies whether µC/TCP-IP is initialized before API tasks and functions perform the desired function. You can set this configuration constant to either:

```
DEF_DISABLED
```

or

```
DEF_ENABLED
```

9.03.02 Argument Checking Configuration, NET_ERR_CFG_ARG_CHK_DBG_EN

This configuration constant allows code to be generated which checks to make sure that pointers passed to functions are not NULL, that arguments are within range, etc. You can set this configuration constant to either:

```
DEF_DISABLED
```

or

```
DEF_ENABLED
```

9.04 Counters Configuration

µC/TCP-IP contains code that increments counters to keep of statistics such as the number of packets received, the number of packets transmitted, etc. Also, µC/TCP-IP contains counters that are incremented when error conditions are detected. There are two configuration constants for this:

```
NET_CTR_CFG_STAT_EN
NET_CTR_CFG_ERR_EN
```

9.04.01 Counters Configuration, NET_CTR_CFG_STAT_EN

This configuration constant determines whether the code and data space used to keep track of statistics will be included. You can set this configuration constant to either:

```
DEF_DISABLED
```

or

`DEF_ENABLED`

9.04.02 Counters Configuration, NET_CTR_CFG_ERR_EN

This configuration constant determines whether the code and data space used to keep track of errors will be included. You can set this configuration constant to either:

```
DEF_DISABLED
```

or

`DEF_ENABLED`

9.05 Timers Configuration

µC/TCP-IP manages software timers that are used to keep track of timeouts. There are currently only two configuration options for timers:

```
NET_TMR_CFG_NBR_TMR
NET_TMR_CFG_TASK_FREQ
```

9.05.01 Timers Configuration, NET_TMR_CFG_NBR_TMR

This configuration constant determines the number of timers that µC/TCP-IP will be managing. Of course, the number of timers affect the amount of RAM required by µC/TCP-IP. Each timer requires 8 bytes plus 4 pointers. Timers are required for:

- The Network Debug Monitor Task	1 total
- Each ARP cache entry	1 per ARP cache
- Each IP fragment reassembly	1 per IP fragment chain
- Each TCP connection	7 per TCP connection

A good starting point may be to allocate the maximum number of timers for all resources. For instance, if the Network Debug Monitor Task is enabled (see section 18.30), 20 ARP caches are configured (`NET_ARP_CFG_NBR_CACHE = 20`), & 10 TCP connections are configured (`NET_TCP_CFG_NBR_CONN = 10`); the maximum number of timers for these resources is `1` for the Network Debug Monitor Task, `(20 * 1)` for the ARP caches and, `(10 * 7)` for the TCP connections :

```
# Timers =  1  +  (20 * 1)  +  (10 * 7)  =  91
```

9.05.02 Timers Configuration, NET_TMR_CFG_TASK_FREQ

This configuration constant determines how often (in Hz) the network timers are to be updated. This value MUST NOT be configured as a floating-point number. You would be typically set this value to **10** Hz.

9.06 Network Buffers Configuration

µC/TCP-IP places received packets in network buffers to be processed by the upper layers and also, places data to send in network buffers. There are two types of buffers as shown in Figure 9-1: small and large. Each buffer contains a header portion that is used by µC/TCP-IP. This header provides information to µC/TCP-IP about the contents of the buffer. The data portion contains the data that has either been received by the NIC and thus will be processed by µC/TCP-IP or, data that is destined for the NIC.

Small buffers are used by µC/TCP-IP when received data or, data to transmit fits in this size buffer.

The header structure is common to both types of buffers. A header currently requires about 200 bytes of storage.

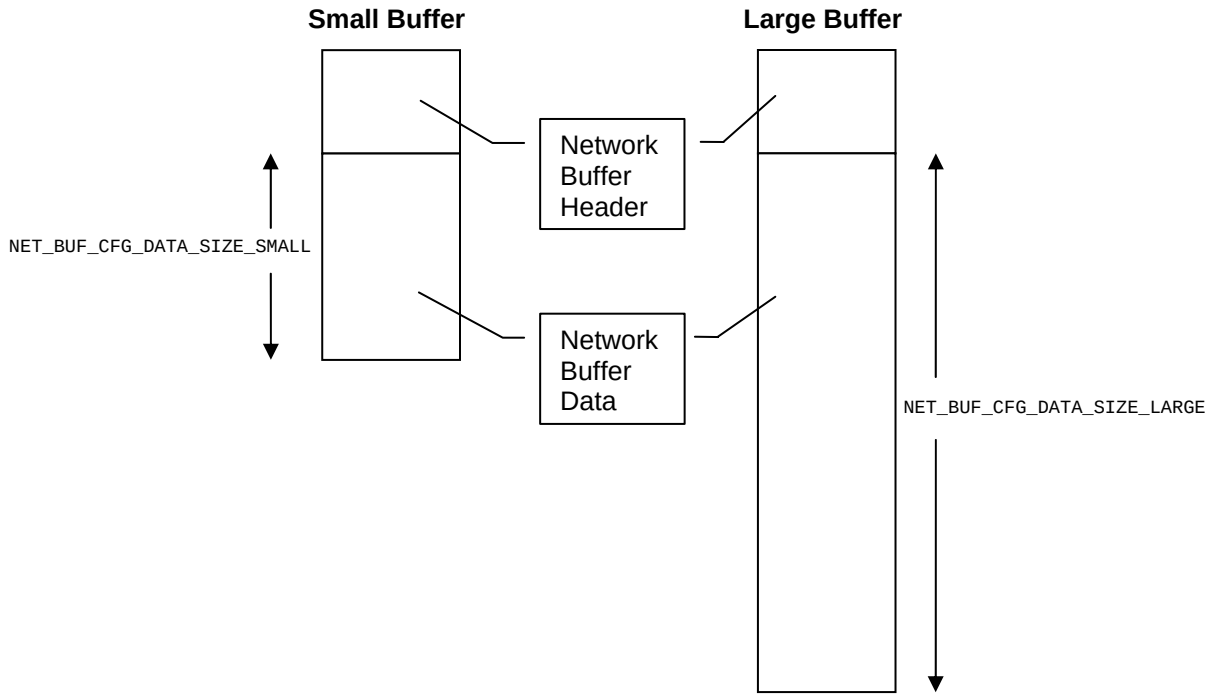


Figure 9-1, µC/TCP-IP's small and large buffers

There are currently four configurable options for network buffers:

```
NET_BUF_CFG_NBR_SMALL
NET_BUF_CFG_NBR_LARGE
NET_BUF_CFG_DATA_SIZE_SMALL
NET_BUF_CFG_DATA_SIZE_LARGE
```

9.06.01 Network Buffers Configuration, NET_BUF_CFG_NBR_SMALL

This configuration constant determines the number of small network buffers used by µC/TCP-IP. The number of buffers needed depends on the run-time behavior of your network and the expected traffic on the network. We tested µC/TCP-IP with **20** small buffers.

9.06.02 Network Buffers Configuration, NET_BUF_CFG_NBR_LARGE

This configuration constant determines the number of large network buffers used by µC/TCP-IP. The number of buffers needed depends on the run-time behavior of your network and the expected traffic on the network. We tested µC/TCP-IP with **20** large buffers.

9.06.03 Network Buffers Configuration, NET_BUF_CFG_DATA_SIZE_SMALL

The configuration constant determines the size of the data portion for small buffers. The recommended size for small buffers is around **256** bytes.

9.06.04 Network Buffers Configuration, NET_BUF_CFG_DATA_SIZE_LARGE

The configuration constant determines the size of the data portion for large buffers. Typically you would set large buffers to the largest packet that can be sent on the NIC. In the case of Ethernet, you should set this buffer to **1596**.

9.07 NIC (Network Interface Controller) Configuration

Currently, two parameters need to be configured for the NIC:

```
NET_NIC_CFG_TX_RDY_INIT_VAL
NET_NIC_CFG_INT_CTRL_EN
```

9.07.01 NIC Configuration, NET_NIC_CFG_TX_RDY_INIT_VAL

This configuration constant determines the initial value of the semaphore used to indicate whether the NIC is ready to transmit packet or not. Refer to the discussion on `NetOS_NIC_Init()` in the NIC Driver chapter. This value greatly depends on the type of NIC used.

9.07.02 NIC Configuration, NET_NIC_CFG_INT_CTRL_EN

This configuration constant tells the NIC driver whether there is an interrupt controller in your system. This is needed to allow the NIC to call a function to clear the interrupt source from the interrupt controller. This function is: `NetNIC_IntClr()`. This configuration value can either be set to:

`DEF_DISABLED` There is no interrupt controller in your system

or

`DEF_ENABLED` There is an interrupt controller in your system

9.07.03 NIC Configuration, NET_NIC_CFG_RD_WR_SEL

This optional configuration constant tells the NIC driver how the board-specific read/write functionality of the NIC should be implemented. This configuration value can either be set to:

`NET_NIC_RD_WR_SEL_MACRO` NIC read/write functionality SHOULD be implemented with macro's in the applications `net_bsp.h`

or

`NET_NIC_RD_WR_SEL_FNCT` NIC read/write functionality SHOULD be implemented with functions in the applications `net_bsp.c` and MUST be prototyped in the NIC's `net_nic.h`

9.08 Network Interface Layer Configuration

These configuration constants are used by the Interface Layer (IF layer). There are currently two configuration constants to set:

```
NET_IF_CFG_TYPE
NET_IF_CFG_ADDR_FLTR_EN
```

9.08.01 Network Interface Layer Configuration, NET_IF_CFG_TYPE

This configuration constant determines the type of network interface used by µC/TCP-IP. Currently, only Ethernet NICs can be used and thus, this parameter should **ALWAYS** be set to **NET_IF_TYPE_ETHER**.

9.08.02 Network Interface Layer Configuration, NET_IF_CFG_ADDR_FLTR_EN

This configuration constant determines whether address filtering is enabled or not. This configuration value can either be set to:

`DEF_DISABLED` Addresses are NOT filtered

or

`DEF_ENABLED` Addresses are filtered

9.09 ARP (Address Resolution Protocol) Configuration

ARP is only required for some network interfaces like Ethernet. There are currently four configuration constants to set:

```
NET_ARP_CFG_HW_TYPE
NET_ARP_CFG_PROTOCOL_TYPE
NET_ARP_CFG_NBR_CACHE
NET_ARP_CFG_ADDR_FLTR_EN
```

9.09.01 ARP Configuration, NET_ARP_CFG_HW_TYPE

The current version of µC/TCP-IP only supports Ethernet-type networks and thus, this configuration constant should **ALWAYS** be set to **NET_ARP_HW_TYPE_ETHER**.

9.09.02 ARP Configuration, NET_ARP_CFG_PROTOCOL_TYPE

The current version of µC/TCP-IP only supports IP v4 and thus, this configuration constant should **ALWAYS** be set to **NET_ARP_PROTOCOL_TYPE_IP_V4**.

9.09.03 ARP Configuration, NET_ARP_CFG_NBR_CACHE

ARP caches the mapping of IP addresses to physical (i.e. MAC) addresses. The number of cache entries depends on the size of your local network and the number of different hosts you expect your product to be communicating with. Each cache entry requires about 50 bytes of RAM (assuming IPv4, Ethernet NICs and 32-bit pointers). We tested µC/TCP-IP with a fairly small network and we set the size to **10**.

9.09.04 ARP Configuration, NET_ARP_CFG_ADDR_FLTR_EN

This configuration constant determines whether address filtering is enabled or not. This configuration value can either be set to:

DEF_DISABLED	Addresses are NOT filtered

or

DEF_ENABLED	Addresses are filtered

9.10 ICMP (Internet Control Message Protocol) Configuration

The ICMP configuration currently only requires you to set two configuration constants:

```
NET_ICMP_CFG_MON_TASK_EN
NET_ICMP_CFG_TX_SRC_QUENCH_SIZE
```

9.10.01 ICMP Configuration, NET_ICMP_CFG_TX_SRC_QUENCH_EN

ICMP transmits ICMP source quench messages to other hosts when the Network Resources are low (see section 18.30). This configuration value can either be set to:

DEF_DISABLED	ICMP Transmit Source Quenches disabled

or

DEF_ENABLED	ICMP Transmit Source Quenches enabled

9.10.02 ICMP Configuration, NET_ICMP_CFG_TX_SRC_QUENCH_SIZE

This configuration value sets the ICMP transmit source quench list size. The recommended initial value for this parameter is **10**.

9.11 Transport Layer Configuration, NET_CFG_TRANSPORT_LAYER_SEL

µC/TCP-IP allows you to either select to include code for UDP or for both UDP and TCP. Of course, enabling only UDP would reduce both the code size and data size required by µC/TCP-IP. However, some application software may need TCP. The allowable values for this configuration constant are:

NET_TRANSPORT_LAYER_SEL_UDP_TCP

or

NET_TRANSPORT_LAYER_SEL_UDP

9.12 UDP (User Datagram Protocol) Configuration

UDP configuration currently only requires you to set three configuration constants:

```
NET_UDP_CFG_APP_API_SEL
NET_UDP_CFG_RX_CHK_SUM_DISCARD_EN
NET_UDP_CFG_TX_CHK_SUM_EN
```

9.12.01 UDP Configuration, NET_UDP_CFG_APP_API_SEL

This configuration constant is used to determine where to send the demultiplexed UDP datagram. Specifically, the datagram may be sent to the socket layer, only to a function you would write in your application or both. The allowable values for this parameter are:

NET_UDP_APP_API_SEL_SOCK	Only send datagram to socket layer
NET_UDP_APP_API_SEL_APP	Only send datagram to your application
NET_UDP_APP_API_SEL_SOCK_APP	Send datagram first to the socket layer then, your application

If your application is to receive the datagram then, you will need to define the following function in your application to process the datagram received:

```
void  NetUDP_RxAppDataHandler(NET_BUF           *pbuf,
                              NET_IP_ADDR        src_addr,
                              NET_UDP_PORT_NBR   src_port,
                              NET_IP_ADDR        dest_addr,
                              NET_UDP_PORT_NBR   dest_port,
                              NET_ERR           *perr);
```

9.12.02 UDP Configuration, NET_UDP_CFG_RX_CHK_SUM_DISCARD_EN

This configuration constant is used to determine whether packets received without a valid checksum are discarded or kept. Before a UDP Datagram Check-Sum is validated, it is necessary to check whether the UDP datagram was transmitted with or without a computed Check-Sum (see RFC #768, Section 'Fields : Checksum'). See also `net_udp.c NetUDP_RxPktValidate()`, note #6d. This configuration value can either be set to:

DEF_DISABLED	ALL UDP datagrams received without a check-sum are flagged so that "an application may optionally discard datagrams without checksums" (see RFC #1122, Section 4.1.3.4).

or

DEF_ENABLED	ALL UDP datagrams received without a checksum are discarded.

9.12.03 UDP Configuration, NET_UDP_CFG_TX_CHK_SUM_EN

This configuration constant is used to determine whether UDP checksums are computed for transmission to other hosts. An application MAY optionally be able to control whether a UDP checksum will be generated (see RFC #1122, Section 4.1.3.4). See also `net_udp.c NetUDP_TxPktPrepareHdr()`, note #4b. This configuration value can either be set to:

`DEF_DISABLED`	ALL UDP datagrams are transmitted without a computed checksum

or

`DEF_ENABLED`	ALL UDP datagrams are transmitted with a computed checksum

9.13 TCP (Transport Control Protocol) Configuration, NET_TCP_CFG_NBR_CONN

TDP configuration currently only requires you to set four configuration constants:

```
NET_TCP_CFG_NBR_CONN
NET_TCP_CFG_RX_WIN_SIZE_OCTET
NET_TCP_CFG_TX_WIN_SIZE_OCTET
NET_TCP_CFG_TIMEOUT_CONN_MAX_SEG_SEC
NET_TCP_CFG_TIMEOUT_CONN_ACK_DLY_MS
NET_TCP_CFG_TIMEOUT_CONN_RX_Q_MS
NET_TCP_CFG_TIMEOUT_CONN_TX_Q_MS
```

9.13.01 TCP, NET_TCP_CFG_NBR_CONN

This configuration constant establishes the maximum number of concurrent TCP connections that µC/TCP-IP will be able to handle.

9.13.02 TCP, NET_TCP_CFG_RX_WIN_SIZE_OCTET

This configuration constant sets the connection receive window size. We recommend starting with a value of **4096**.

9.13.03 TCP, NET_TCP_CFG_TX_WIN_SIZE_OCTET

This configuration constant sets the connection transmit window size. We recommend starting with a value of **8192**.

9.13.04 TCP, NET_TCP_CFG_TIMEOUT_CONN_MAX_SEG_SEC

Configures TCP connections default maximum segment lifetime timeout (MSL) value. The value is specified in integer seconds. We recommend starting with a value of **3** seconds.

9.13.05 TCP, NET_TCP_CFG_TIMEOUT_CONN_ACK_DLY_MS

The constant sets up the TCP acknowledgement delay in integer milliseconds.

RFC #2581, Section 4.2 states that "an ACK MUST be generated within 500 ms of the arrival of the first unacknowledged packet". Thus, **500** ms is the default value.

9.13.06 TCP, NET_TCP_CFG_TIMEOUT_CONN_RX_Q_MS

Configures TCP connection receive queue timeout (in milliseconds). We recommend starting with a value of **3000** milliseconds.

9.13.07 TCP, NET_TCP_CFG_TIMEOUT_CONN_TX_Q_MS

Configures TCP connection transmit queue timeout (in milliseconds). We recommend starting with a value of **3000** milliseconds.

9.14 BSD v4 Sockets Configuration

The BSD v4 socket configuration currently only requires you to set nine values:

```
NET_SOCK_CFG_FAMILY
NET_SOCK_CFG_NBR_SOCK
NET_SOCK_CFG_BLOCK_SEL
NET_SOCK_CFG_CONN_ACCEPT_Q_SIZE_MAX
NET_SOCK_CFG_PORT_NBR_RANDOM_BASE
NET_SOCK_CFG_TIMEOUT_RX_Q_MS
NET_SOCK_CFG_TIMEOUT_CONN_REQ_MS
NET_SOCK_CFG_TIMEOUT_CONN_ACCEPT_MS
NET_SOCK_CFG_TIMEOUT_CONN_CLOSE_MS
```

9.14.01 BSD v4 Sockets Configuration, NET_SOCK_CFG_FAMILY

The current version of µC/TCP-IP only supports one option for this parameter: **NET_SOCK_FAMILY_IP_V4**.

9.14.02 BSD v4 Sockets Configuration, NET_SOCK_CFG_NBR_SOCK

This configuration constant determines the maximum number of sockets that can be opened at the same time. This value is application specific.

9.14.03 BSD v4 Sockets Configuration, NET_SOCK_CFG_BLOCK_SEL

This configuration constant determines the default blocking (or non-blocking) behavior for sockets. The default is non-blocking. This parameter can take the following values:

NET_SOCK_BLOCK_SEL_DFLT	Use the default (i.e. non-blocking)
NET_SOCK_BLOCK_SEL_BLOCK	Sockets will be blocking by default
NET_SOCK_BLOCK_SEL_NO_BLOCK	Sockets will be non-blocking by default

If you select blocking mode, you can block with a timeout. The amount of time for the timeout is determined by various timeout functions implemented in `net_sock.c`:

```
NetSock_CfgTimeoutRxQ_Set()
NetSock_CfgTimeoutConnReqSet()
NetSock_CfgTimeoutConnAcceptSet()
NetSock_CfgTimeoutConnCloseSet()
```

9.14.04 BSD v4 Sockets Configuration, NET_SOCK_CFG_CONN_ACCEPT_Q_SIZE_MAX

This configuration constant is used to configure stream-type sockets' accept queue maximum size. One recommended initial value for this parameter is **5**.

9.14.05 BSD v4 Sockets Configuration, NET_SOCK_CFG_PORT_NBR_RANDOM_BASE

This configuration constant is used to establish the starting number for the 'random port number'. Since two times the number of random ports are required for each socket, the base value for the random port number must be :

```
Random Port Number Base  <=  65535 – (2 * NET_SOCK_CFG_NBR_SOCK)
```

The arbitrary default value of **65000** is a good starting point for NET_SOCK_CFG_NBR_SOCK values less than 18.

9.14.06 BSD v4 Sockets Configuration, NET_SOCK_CFG_TIMEOUT_RX_Q_MS

This configuration constant is used to establish a socket receive queue timeout (in milliseconds). We recommend starting with a value of **3000** milliseconds.

9.14.07 BSD v4 Sockets Configuration, NET_SOCK_CFG_TIMEOUT_CONN_REQ_MS

This configuration constant is used to establish a socket connection request timeout (in milliseconds). We recommend starting with a value of at least **10000** milliseconds.

9.14.08 BSD v4 Sockets Configuration, NET_SOCK_CFG_TIMEOUT_CONN_ACCEPT_MS

This configuration constant is used to establish a socket connection accept timeout (in milliseconds). We recommend starting with a value of at least **3000** milliseconds.

9.14.09 BSD v4 Sockets Configuration, NET_SOCK_CFG_TIMEOUT_CONN_CLOSE_MS

This configuration constant is used to establish a socket connection close timeout (in milliseconds). We recommend starting with a value of at least **10000** milliseconds.

9.14.10 BSD v4 API Configuration, NET_BSD_CFG_API_EN

. This configuration value can either be set to:

DEF_DISABLED BSD 4.x layer API disabled

or

DEF_ENABLED BSD 4.x layer API enabled

9.15 Connection Manager Configuration

This section defines the connection manager's configuration. There are two configuration constants in this section:

```
NET_CONN_CFG_FAMILY
NET_CONN_CFG_NBR_CONN
```

9.15.01 Connection Manager Configuration, NET_CONN_CFG_FAMILY

This configuration constant determines the connection manager's family and should always be set to **`NET_CONN_FAMILY_IP_V4_SOCK`**.

9.15.02 Connection Manager Configuration, NET_CONN_CFG_NBR_CONN

This configuration constant determines the total number of connections for the stack. The configured number of connections MUST be greater than the configured/required/expected number of application connections & transport layer connections.

9.16 Application-Specific Configuration, app_cfg.h

This section defines the configuration constants that are related to µC/TCP-IP but are application-specific. Most of these configuration constants relate to the various ports for µC/TCP-IP such as the CPU, OS, NIC, or network interface ports. Some of the configuration constants relate to the compiler and standard library ports.

These configuration constants should be defined in an application's `app_cfg.h` file.

9.16.01 Application-Specific Configuration, Operating System Configuration

These configuration constants relate to the µC/TCP-IP OS port. For many OSs, the µC/TCP-IP task priorities, stack sizes, and other options may need to be explicitly configured.

The priority of µC/TCP-IP tasks is dependent on the network communication requirements of the application. For most applications, the priority for µC/TCP-IP tasks is typically lower than the priority for other application tasks.

Consult the specific OS's documentation to determine the OS's priority scheme.

For µC/OS-II, the following OS task priorities and OS stack sizes must be configured:

```
NET_OS_CFG_IF_RX_TASK_PRIO              50
NET_OS_CFG_TMR_TASK_PRIO                51
```

The arbitrary task priorities of **`50`** and **`51`** are a good starting point for most applications.

```
NET_OS_CFG_TMR_TASK_STK_SIZE          1000
NET_OS_CFG_IF_RX_TASK_STK_SIZE        1000
```

The arbitrary stack size of **`1000`** is a good starting point for most applications.

9.16.02 Application-Specific Configuration, uC_CFG_OPTIMIZE_ASM_EN

This configuration constant determines whether optimized assembly files/functions should be included in the µC/TCP-IP build. µC/TCP-IP optimization file(s), which are available only for certain processors and compilers, are located in the following directories:

```
\<µC-TCPIP>\Ports\<cpu>\<compiler>\

    where
          <µC-TCPIP>    directory path for µC/TCP-IP
          <Ports>       directory name for ALL processor specific code
          <cpu>         directory name for specific processor (CPU)
          <compiler>    directory name for specific compiler
```

Currently, only the following optimization files/functions are available for µC/TCP-IP:

```
\<µC-TCPIP>\Ports\<cpu>\<compiler>\net_util_a.asm

     NetUtil_16BitSumDataCalcAlign_32()
```

The `uC_CFG_OPTIMIZE_ASM_EN` configuration value can either be set to:

`DEF_DISABLED` No optimized assembly files/functions are included in the µC/TCP-IP build.

or

`DEF_ENABLED` Optimized assembly files/functions are included in the µC/TCP-IP build.

Chapter 10

Debug Management

µC/TCP-IP contains debug constants & functions that may be used by applications to determine network RAM usage, check run-time network resource usage, or check network error or fault conditions. These constants & functions are found in `net_dbg.*`. Most of these debug features must be enabled by appropriate configuration constants (see Chapter 9).

10.01 Network Debug Information Constants

Network debug information constants provide the developer with run-time statistics on µC/TCP-IP configuration, data type & structure sizes, & data RAM usage. The list of debug information constants can be found in `net_dbg.c` Sections `GLOBAL NETWORK MODULE DEBUG INFORMATION CONSTANTS` & `GLOBAL NETWORK MODULE DATA SIZE CONSTANTS`. These debug constants are enabled by configuring `NET_DBG_CFG_DBG_INFO_EN` to `DEF_ENABLED`.

You could use these constants as follows:

```
CPU_INT16U  net_version;
CPU_INT32U  net_data_size;
CPU_INT32U  net_data_size_buf_large;
CPU_INT32U  net_data_size_buf_large_tbl;


net_version                = Net_Version;
net_data_size              = Net_DataSize;
net_data_size_buf_large    = NetBuf_LargeSize;
net_data_size_buf_large_tbl = NetBuf_LargeTblSize;

printf("µC/TCP-IP Version              : %05d\n", net_version);
printf("Total Network RAM Used         : %05d\n", net_data_size);
printf("Large Network Buffer       Size : %05d\n", net_data_size_buf_large);
printf("Large Network Buffer Table Size : %05d\n", net_data_size_buf_large_tbl);
```

10.02.01 Check Network Status, NetDbg_ChkStatus()

This function returns the current run-time status of certain µC/TCP-IP conditions. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED. The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatus (void)
```

The function returns NET_DBG_STATUS_OK if all network conditions are OK; i.e. no warnings, faults, or errors currently exist. Otherwise, the function returns the following status condition codes logically OR'd :

NET_DBG_STATUS_FAULT	Some network status fault(s).
NET_DBG_STATUS_RSRC_LOST	Some network resources lost.
NET_DBG_STATUS_RSRC_LO	Some network resources low.
NET_DBG_STATUS_FAULT_BUF	Some network buffer management fault(s).
NET_DBG_STATUS_FAULT_TMR	Some network timer management fault(s).
NET_DBG_STATUS_FAULT_CONN	Some network connection management fault(s).
NET_DBG_STATUS_FAULT_TCP	Some TCP layer fault(s).

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_fault;
CPU_BOOLEAN     net_fault_conn;
CPU_BOOLEAN     net_rsrc_lost;
CPU_BOOLEAN     net_rsrc_low;


net_status     = NetDbg_ChkStatus();
net_fault      = DEF_BIT_IS_SET(net_status, NET_DBG_STATUS_FAULT);
net_fault_conn = DEF_BIT_IS_SET(net_status, NET_DBG_STATUS_FAULT_CONN);
net_rsrc_lost  = DEF_BIT_IS_SET(net_status, NET_DBG_STATUS_RSRC_LOST);
net_rsrc_lo    = DEF_BIT_IS_SET(net_status, NET_DBG_STATUS_RSRC_LO);
```

10.02.02 Check Network Resources Lost Status, NetDbg_ChkStatusRsrcLost()

This function returns whether any µC/TCP-IP resources have been lost. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED. The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatusRsrcLost (void)
```

The function returns NET_DBG_STATUS_OK if no network resources lost. Otherwise, the function returns the following resources lost condition codes logically OR'd :

NET_DBG_SF_RSRC_LOST	Some network	resources lost.
NET_DBG_SF_RSRC_LOST_BUF_SMALL	Some network SMALL buffer	resources lost.
NET_DBG_SF_RSRC_LOST_BUF_LARGE	Some network LARGE buffer	resources lost.
NET_DBG_SF_RSRC_LOST_TMR	Some network timer	resources lost.
NET_DBG_SF_RSRC_LOST_CONN	Some network connection	resources lost.
NET_DBG_SF_RSRC_LOST_ARP_CACHE	Some network ARP cache	resources lost.
NET_DBG_SF_RSRC_LOST_TCP_CONN	Some network TCP connection	resources lost.
NET_DBG_SF_RSRC_LOST_SOCK	Some network socket	resources lost.

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_rsrc_lost;
CPU_BOOLEAN     net_rsrc_lost_tmr;
CPU_BOOLEAN     net_rsrc_lost_conn;
CPU_BOOLEAN     net_rsrc_lost_sock;


net_status         = NetDbg_ChkStatusRsrcLost();
net_rsrc_lost      = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LOST);
net_rsrc_lost_tmr  = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LOST_TMR);
net_rsrc_lost_conn = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LOST_CONN);
net_rsrc_lost_sock = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LOST_SOCK);
```

10.02.03 Check Network Resources Low Status, NetDbg_ChkStatusRsrcLow()

This function returns whether any µC/TCP-IP resources are currently low. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED or when the Debug Monitor Task itself is enabled (see section 10.30). The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatusRsrcLow (void)
```

The function returns NET_DBG_STATUS_OK if no network resources are low. Otherwise, the function returns the following resources low condition codes logically OR'd :

NET_DBG_SF_RSRC_LO	Some network	resources low.
NET_DBG_SF_RSRC_LO_BUF_SMALL	Network SMALL buffer	resources low.
NET_DBG_SF_RSRC_LO_BUF_LARGE	Network LARGE buffer	resources low.
NET_DBG_SF_RSRC_LO_TMR	Network timer	resources low.
NET_DBG_SF_RSRC_LO_CONN	Network connection	resources low.
NET_DBG_SF_RSRC_LO_ARP_CACHE	Network ARP cache	resources low.
NET_DBG_SF_RSRC_LO_TCP_CONN	Network TCP connection	resources low.
NET_DBG_SF_RSRC_LO_SOCK	Network socket	resources low.

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_rsrc_lo;
CPU_BOOLEAN     net_rsrc_lo_tmr;
CPU_BOOLEAN     net_rsrc_lo_conn;
CPU_BOOLEAN     net_rsrc_lo_sock;


net_status       = NetDbg_ChkStatusRsrcLo();
net_rsrc_lo      = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LO);
net_rsrc_lo_tmr  = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LO_TMR);
net_rsrc_lo_conn = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LO_CONN);
net_rsrc_lo_sock = DEF_BIT_IS_SET(net_status, NET_DBG_SF_RSRC_LO_SOCK);
```

10.02.04 Check Network Buffers Status, NetDbg_ChkStatusBufs()

This function returns the current run-time status of µC/TCP-IP buffers. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED. The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatusBufs (void)
```

The function returns NET_DBG_STATUS_OK if all network buffers are OK; i.e. no buffer faults currently exist. Otherwise, the function returns the following network buffer fault codes logically OR'd :

NET_DBG_SF_BUF	Some network buffer management fault(s).
NET_DBG_SF_BUF_SMALL_TYPE	Small buffer invalid type.
NET_DBG_SF_BUF_SMALL_ID	Small buffer invalid ID.
NET_DBG_SF_BUF_SMALL_LINK_TYPE	Small buffer invalid link type.
NET_DBG_SF_BUF_SMALL_LINK_UNUSED	Small buffer link unused.
NET_DBG_SF_BUF_SMALL_LINK_BACK_TO_BUF	Small buffer invalid link back to same buffer.
NET_DBG_SF_BUF_SMALL_LINK_NOT_TO_BUF	Small buffer invalid link NOT back to same buffer.
NET_DBG_SF_BUF_SMALL_LINK_TO_BUF	Small buffer invalid link back to buffer.
NET_DBG_SF_BUF_SMALL_POOL_TYPE	Small buffer invalid pool buffer type.
NET_DBG_SF_BUF_SMALL_POOL_ID	Small buffer invalid pool buffer ID.
NET_DBG_SF_BUF_SMALL_POOL_DUP	Small buffer pool contains duplicate buffer(s).
NET_DBG_SF_BUF_SMALL_POOL_NBR_MAX	Small buffer pool number of buffers greater than maximum number of small buffers.
NET_DBG_SF_BUF_SMALL_USED_IN_POOL	Small buffer used but in pool.
NET_DBG_SF_BUF_SMALL_UNUSED_NOT_IN_POOL	Small buffer unused but NOT in pool.
NET_DBG_SF_BUF_LARGE_TYPE	Large buffer invalid type.
NET_DBG_SF_BUF_LARGE_ID	Large buffer invalid ID.
NET_DBG_SF_BUF_LARGE_LINK_TYPE	Large buffer invalid link type.
NET_DBG_SF_BUF_LARGE_LINK_UNUSED	Large buffer link unused.
NET_DBG_SF_BUF_LARGE_LINK_BACK_TO_BUF	Large buffer invalid link back to same buffer.
NET_DBG_SF_BUF_LARGE_LINK_NOT_TO_BUF	Large buffer invalid link NOT back to same buffer.
NET_DBG_SF_BUF_LARGE_LINK_TO_BUF	Large buffer invalid link back to buffer.
NET_DBG_SF_BUF_LARGE_POOL_TYPE	Large buffer invalid pool buffer type.
NET_DBG_SF_BUF_LARGE_POOL_ID	Large buffer invalid pool buffer ID.
NET_DBG_SF_BUF_LARGE_POOL_DUP	Large buffer pool contains duplicate buffer(s).
NET_DBG_SF_BUF_LARGE_POOL_NBR_MAX	Large buffer pool number of buffers greater than maximum number of large buffers.
NET_DBG_SF_BUF_LARGE_USED_IN_POOL	Large buffer used but in pool.
NET_DBG_SF_BUF_LARGE_UNUSED_NOT_IN_POOL	Large buffer unused but NOT in pool.

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_fault_buf;


net_status    = NetDbg_ChkStatusBufs();
net_fault_buf = DEF_BIT_IS_SET(net_status, NET_DBG_SF_BUF);
```

10.02.05 Check Network Timers Status, NetDbg_ChkStatusTmrs()

This function returns the current run-time status of µC/TCP-IP timers. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED. The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatusTmrs (void)
```

The function returns NET_DBG_STATUS_OK if all network timers are OK; i.e. no timer faults currently exist. Otherwise, the function returns the following network timer fault codes logically OR'd :

NET_DBG_SF_TMR	Some network timer management fault(s).
NET_DBG_SF_TMR_TYPE	Network timer invalid type.
NET_DBG_SF_TMR_ID	Network timer invalid id.
NET_DBG_SF_TMR_LINK_TYPE	Network timer invalid link type.
NET_DBG_SF_TMR_LINK_UNUSED	Network timer link unused.
NET_DBG_SF_TMR_LINK_BACK_TO_TMR	Network timer invalid link back to same timer.
NET_DBG_SF_TMR_LINK_TO_TMR	Network timer invalid link back to timer.
NET_DBG_SF_TMR_POOL_TYPE	Network timer invalid pool type.
NET_DBG_SF_TMR_POOL_ID	Network timer invalid pool ID.
NET_DBG_SF_TMR_POOL_DUP	Network timer pool contains duplicate timer(s).
NET_DBG_SF_TMR_POOL_NBR_MAX	Network timer pool number of timers greater than maximum number of timers.
NET_DBG_SF_TMR_LIST_TYPE	Network timer task list invalid type.
NET_DBG_SF_TMR_LIST_ID	Network timer task list invalid ID.
NET_DBG_SF_TMR_LIST_DUP	Network timer task list contains duplicate timer(s).
NET_DBG_SF_TMR_LIST_NBR_MAX	Network timer task list number of timers greater than maximum number of timers.
NET_DBG_SF_TMR_LIST_NBR_USED	Network timer task list number of timers NOT equal to number of used timers.
NET_DBG_SF_TMR_USED_IN_POOL	Network timer used but in pool.
NET_DBG_SF_TMR_UNUSED_NOT_IN_POOL	Network timer unused but NOT in pool.
NET_DBG_SF_TMR_UNUSED_IN_LIST	Network timer unused but in timer task list.

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_fault_tmr;


net_status    = NetDbg_ChkStatusTmrs();
net_fault_tmr = DEF_BIT_IS_SET(net_status, NET_DBG_SF_TMR);
```

10.02.06 Check Network Connections Status, NetDbg_ChkStatusConns()

This function returns the current run-time status of µC/TCP-IP connections. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED and when the Network Connections module itself is enabled. The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatusConns (void)
```

The function returns NET_DBG_STATUS_OK if all network connections are OK; i.e. no connection faults currently exist. Otherwise, the function returns the following network connection fault codes logically OR'd :

NET_DBG_SF_CONN	Some network connection management fault(s).
NET_DBG_SF_CONN_TYPE	Network connection invalid type.
NET_DBG_SF_CONN_FAMILY	Network connection invalid family.
NET_DBG_SF_CONN_ID	Network connection invalid ID.
NET_DBG_SF_CONN_ID_NONE	Network connection with NO connection IDs.
NET_DBG_SF_CONN_ID_UNUSED	Network connection linked to unused connection.
NET_DBG_SF_CONN_LINK_TYPE	Network connection invalid link type.
NET_DBG_SF_CONN_LINK_UNUSED	Network connection link unused.
NET_DBG_SF_CONN_LINK_BACK_TO_CONN	Network connection invalid link back to same connection.
NET_DBG_SF_CONN_LINK_NOT_TO_CONN	Network connection invalid link NOT back to same connection.
NET_DBG_SF_CONN_LINK_NOT_IN_LIST	Network connection NOT in appropriate connection list.
NET_DBG_SF_CONN_POOL_TYPE	Network connection invalid pool type.
NET_DBG_SF_CONN_POOL_ID	Network connection invalid pool ID.
NET_DBG_SF_CONN_POOL_DUP	Network connection pool contains duplicate connection(s).
NET_DBG_SF_CONN_POOL_NBR_MAX	Network connection pool number of connections greater than maximum number of connections.
NET_DBG_SF_CONN_LIST_IX_NBR_MAX	Network connection invalid list index number.
NET_DBG_SF_CONN_LIST_NBR_NOT_SOLITARY	Network connection lists number of connections NOT equal to solitary connection.
NET_DBG_SF_CONN_USED_IN_POOL	Network connection used but in pool.
NET_DBG_SF_CONN_USED_NOT_IN_LIST	Network connection used but NOT in list.
NET_DBG_SF_CONN_UNUSED_IN_LIST	Network connection unused but in list.
NET_DBG_SF_CONN_UNUSED_NOT_IN_POOL	Network connection unused but NOT in pool.
NET_DBG_SF_CONN_IN_LIST_IN_POOL	Network connection in list & in pool.
NET_DBG_SF_CONN_NOT_IN_LIST_NOT_IN_POOL	Network connection NOT in list & NOT in pool.

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_fault_conn;


net_status     = NetDbg_ChkStatusConns();
net_fault_conn = DEF_BIT_IS_SET(net_status, NET_DBG_SF_CONN);
```

10.02.07 Check TCP Layer Status, NetDbg_ChkStatusTCP()

This function returns the current run-time status of µC/TCP-IP's TCP layer. This function is enabled by configuring NET_DBG_CFG_DBG_STATUS_EN to DEF_ENABLED and when the TCP layer itself is enabled. The prototype for this function is:

```
NET_DBG_STATUS  NetDbg_ChkStatusTCP (void)
```

The function returns NET_DBG_STATUS_OK if the TCP layer is OK; i.e. no TCP layer faults currently exist. Otherwise, the function returns the following TCP layer fault codes logically OR'd :

NET_DBG_SF_TCP	Some TCP layer fault(s).
NET_DBG_SF_TCP_CONN_TYPE	TCP connection invalid type.
NET_DBG_SF_TCP_CONN_ID	TCP connection invalid ID.
NET_DBG_SF_TCP_CONN_LINK_TYPE	TCP connection invalid link type.
NET_DBG_SF_TCP_CONN_LINK_UNUSED	TCP connection link unused.
NET_DBG_SF_TCP_CONN_POOL_TYPE	TCP connection invalid pool type.
NET_DBG_SF_TCP_CONN_POOL_ID	TCP connection invalid pool ID.
NET_DBG_SF_TCP_CONN_POOL_DUP	TCP connection pool contains duplicate connection(s).
NET_DBG_SF_TCP_CONN_POOL_NBR_MAX	TCP connection pool number of connections greater than maximum number of connections.
NET_DBG_SF_TCP_CONN_USED_IN_POOL	TCP connection used in pool.
NET_DBG_SF_TCP_CONN_UNUSED_NOT_IN_POOL	TCP connection unused NOT in pool.
NET_DBG_SF_TCP_CONN_Q	Some TCP connection queue fault(s).
NET_DBG_SF_TCP_CONN_Q_BUF_TYPE	TCP connection queue buffer invalid type.
NET_DBG_SF_TCP_CONN_Q_BUF_UNUSED	TCP connection queue buffer unused.
NET_DBG_SF_TCP_CONN_Q_LINK_TYPE	TCP connection queue buffer invalid link type.
NET_DBG_SF_TCP_CONN_Q_LINK_UNUSED	TCP connection queue buffer link unused.
NET_DBG_SF_TCP_CONN_Q_BUF_DUP	TCP connection queue contains duplicate buffer(s).

You could use this function as follows:

```
NET_DBG_STATUS  net_status;
CPU_BOOLEAN     net_fault_tcp;


net_status    = NetDbg_ChkStatusTCP();
net_fault_tcp = DEF_BIT_IS_SET(net_status, NET_DBG_SF_TCP);
```

10.03 Network Debug Monitor Task

The Network Debug Monitor Task periodically checks the current run-time status of certain µC/TCP-IP conditions & saves that status to global variables which may be queried by other network modules.

Currently, the Network Debug Monitor Task is only enabled when ICMP Transmit Source Quenches are enabled (see section 9.10.01) because this is the only network functionality that requires a periodic update of certain network status conditions. Applications do not need the Debug Monitor Task functionality since applications have access to the same debug status functions that the Monitor Task calls.

Appendix A

µC/TCP-IP Licensing Policy

You can evaluate the µC/TCP-IP source code for FREE for 45 days, but a license is required when µC/TCP-IP is used commercially. The policy is as follows:

> µC/TCP-IP source and object code can be used by accredited Colleges and Universities without requiring a license, as long as there is no commercial application involved. In other words, no licensing is required if µC/TCP-IP is used for educational use.
>
> You need to obtain an 'Executable Distribution License' to embed µC/TCP-IP in a product that is sold with the intent to make a profit or if the product is not used for education or 'peaceful' research.

For licensing details, contact us at:

Micrium
949 Crestview Circle
Weston, FL 33327-1848
U.S.A.

Phone : +1 954 217 2036
FAX : +1 954 217 2037

WEB : **www.micrium.com**
Email : **licensing@micrium.com**