
Ethernet MAC library

The Ethernet MAC library provides a complete, software defined, Ethernet MAC that supports 10/100/1000 Mb/s data rates and is designed to IEEE Std 802.3-2002 specifications.

Features

- 10/100/1000 Mb/s full-duplex operation
- Media Independent Interface (MII) and Reduced Gigabit Media Independent Interface (RGMII) to the physical layer
- Configurable Ethertype and MAC address filters for unicast, multicast and broadcast addresses
- Frame alignment, CRC, and frame length error detection
- IEEE 802.1Q Audio Video Bridging priority queueing and credit based traffic shaper
- Support for VLAN-tagged frames
- Transmit and receive frame timestamp support for IEEE 1588 and 802.1AS
- Management Data Input/Output (MDIO) Interface for physical layer management

Components

- 10/100 Mb/s Ethernet MAC
- 10/100 Mb/s Ethernet MAC with real-time features
- 10/100/1000 Mb/s Ethernet MAC with real-time features (xCORE-200 XE/XEF)
- Raw MII interface

Software version and dependencies

This document pertains to version 3.0.3 of this library. It is known to work on version 14.0.2 of the xTIMEcomposer tools suite, it may work on other versions.

This library depends on the following other libraries:

- lib_logging ($\geq 2.0.0$)
- lib_locks ($\geq 2.0.0$)
- lib_xassert ($\geq 2.0.0$)
- lib_gpio ($\geq 1.0.0$)

Typical Resource Usage

This following table shows typical resource usage in some different configurations. Exact resource usage will depend on the particular use of the library by the application.

Configuration	Pins	Ports	Clocks	Ram	Logical cores
10/100 Mb/s	13	5 (1-bit), 2 (4-bit), 1 (any-bit)	2	~15.9K	2
10/100 Mb/s real-time	13	5 (1-bit), 2 (4-bit)	2	~22.6K	4
10/100/1000 Mb/s	12	8 (1-bit), 2 (4-bit), 2 (8-bit)	4	~101.4K	8
Raw MII	13	5 (1-bit), 2 (4-bit)	2	~10.0K	1
SMI (MDIO)	2	2 (1-bit) or 1 (multi-bit)	0	~0.7K	0

Related application notes

The following application notes use this library:

- AN00120 - How to use the Ethernet MAC library

1 External signal description

1.1 MII: Media Independent Interface

MII is an interface standardized by IEEE 802.3 that connects different types of PHYs to the same Ethernet Media Access Control (MAC). The MAC can interact with any PHY using the same hardware interface, independent of the media the PHYs are connected to.

The MII transfers data using 4 bit words (nibbles) in each direction, clocked at 25 MHz to achieve 100 Mb/s data rate.

An enable signal (TXEN) is set active to indicate start of frame and remains active until it is completed. A clock signal (TXCLK) clocks nibbles (TXD[3:0]) at 2.5 MHz for 10 Mb/s mode and 25 MHz for 100 Mb/s mode. The RXDV signal goes active when a valid frame starts and remains active throughout a valid frame duration. A clock signal (RXCLK) clocks the received nibbles (RXD[3:0]). Table 1 below describes the MII signals:

Port Requirement	Signal Name	Description
4-bit port [Bit 3]	TXD3	Transmit data bit 3
4-bit port [Bit 2]	TXD2	Transmit data bit 2
4-bit port [Bit 1]	TXD1	Transmit data bit 1
4-bit port [Bit 0]	TXD0	Transmit data bit 0
1-bit port	TXCLK	Transmit clock (2.5/25 MHz)
1-bit port	TXEN	Transmit data valid
1-bit port	RXCLK	Receive clock (2.5/25 MHz)
1-bit port	RXDV	Receive data valid
1-bit port	RXERR	Receive data error
4-bit port [Bit 3]	RX3	Receive data bit 3
4-bit port [Bit 2]	RX2	Receive data bit 2
4-bit port [Bit 1]	RX1	Receive data bit 1
4-bit port [Bit 0]	RX0	Receive data bit 0

Table 1: MII signals

Any unused 1-bit and 4-bit xCORE ports can be used for MII providing that they are on the same Tile and there is enough resource to instantiate the relevant Ethernet MAC component on that Tile.

1.2 RGMII: Reduced Gigabit Media Independent Interface

RGMII requires half the number of data pins used in GMII by clocking data on both the rising and the falling edges of the clock, and by eliminating non-essential signals (carrier sense and collision indication).

xCORE-200 XE/XEF devices have a set of pins that are dedicated to communication with a Gigabit Ethernet PHY or switch via RGMII, designed to comply with the timings in the RGMII v1.3 specification:

http://www.hp.com/rnd/pdfs/RGMIIv1_3.pdf

RGMII supports Ethernet speeds of 10 Mb/s, 100 Mb/s and 1000 Mb/s.

The pins and functions are listed in Table 2. When the 10/100/1000 Mb/s Ethernet MAC is instantiated these pins can no longer be used as GPIO pins, and will instead be driven directly from a Double Data Rate RGMII block, which in turn is interfaced to a set of ports on Tile 1.

Mandatory Pin	Signal Name	Description
X1D40	TX3	Transmit data bit 3
X1D41	TX2	Transmit data bit 2
X1D42	TX1	Transmit data bit 1
X1D43	TX0	Transmit data bit 0
X1D26	TX_CLK	Transmit clock (2.5/25/125 MHz)
X1D27	TX_CTL	Transmit data valid/error
X1D28	RX_CLK	Receive clock (2.5/25/125 MHz)
X1D29	RX_CTL	Receive data valid/error
X1D30	RX3	Receive data bit 3
X1D31	RX2	Receive data bit 2
X1D32	RX1	Receive data bit 1
X1D33	RX0	Receive data bit 0

Table 2: RGMII pins and signals

The RGMII block is connected to the ports on Tile 1 as shown in Figure 1. When the 10/100/1000 Mb/s Ethernet MAC is instantiated, the ports and IO pins shown can only be used by the MAC component. Other IO pins and ports are unaffected.

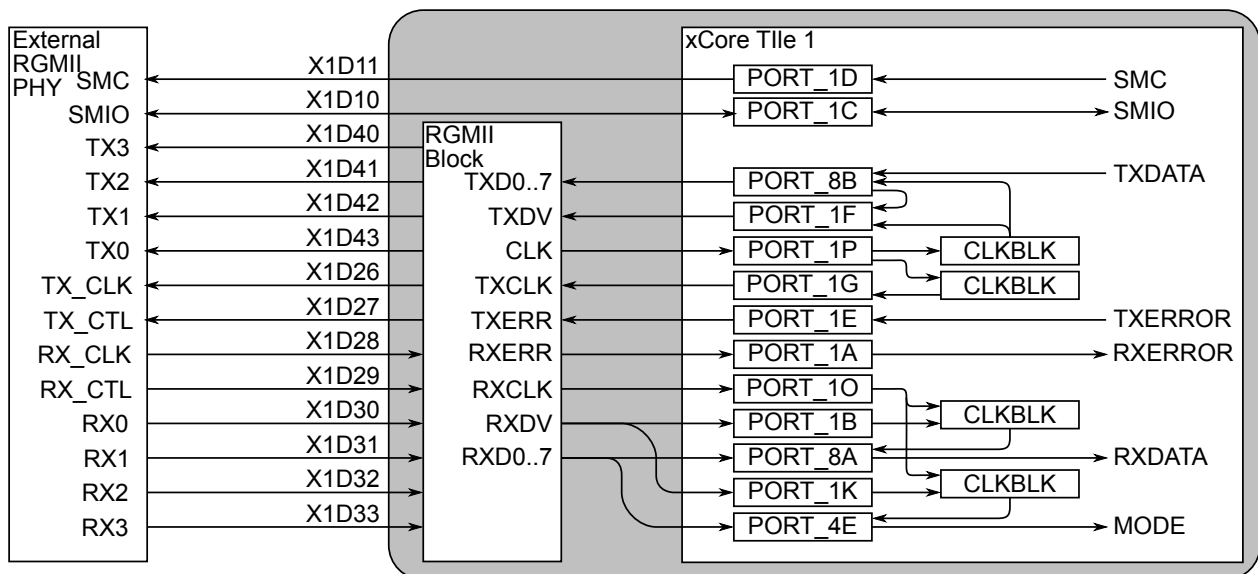


Figure 1: RGMII port structure

1.3 PHY Serial Management Interface (MDIO)

The MDIO interface consists of clock (MDC) and data (MDIO) signals. Both should be connected to two one-bit ports that are configured as open-drain IOs, using external pull-ups to either 3.3V or 2.5V (RGMII).

2 Usage

2.1 10/100 Mb/s Ethernet MAC operation

There are two types of 10/100 Mb/s Ethernet MAC that are optimized for different feature sets. Both connect to a standard 10/100 Mb/s Ethernet PHY using the same MII interface described in §1.1.

The resource-optimized MAC described here is provided for applications that do not require real-time features, such as those required by the Audio Video Bridging standards.

The same API is shared across all configurations of the Ethernet MACs. Additional API calls are available in the configuration interface of the real-time MACs that will cause a run-time assertion if called by the non-real-time configuration.

Ethernet MAC components are instantiated as parallel tasks that run in a par statement. The application can connect via a transmit, receive and configuration interface connection using the `ethernet_tx_if`, `ethernet_rx_if` and `ethernet_cfg_if` interface types:

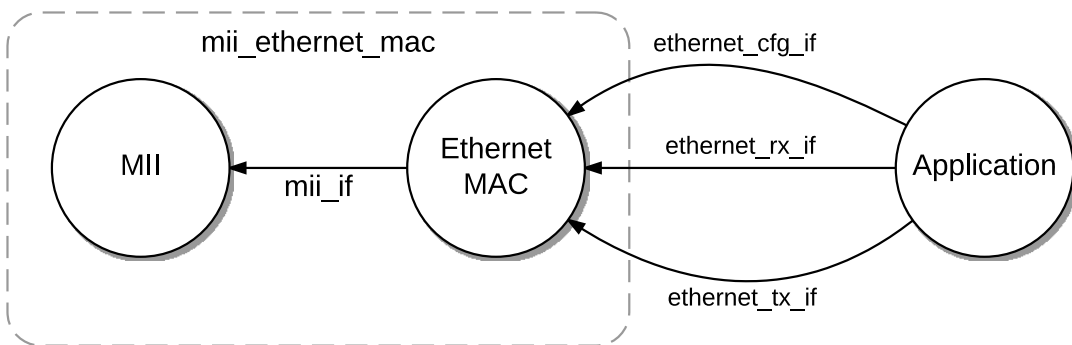


Figure 2: 10/100 Mb/s Ethernet MAC task diagram

For example, the following code instantiates a standard Ethernet MAC component and connects to it:

```

port p_eth_rxc1k = XS1_PORT_1J;
port p_eth_rxd   = XS1_PORT_4E;
port p_eth_txd   = XS1_PORT_4F;
port p_eth_rxdv  = XS1_PORT_1K;
port p_eth_txen  = XS1_PORT_1L;
port p_eth_txc1k = XS1_PORT_1I;
port p_eth_rxerr = XS1_PORT_1P;
port p_eth_timing = XS1_PORT_8C;
clock eth_rxc1k  = XS1_CLKBLK_1;
clock eth_txc1k  = XS1_CLKBLK_2;

int main()
{
    ethernet_cfg_if i_cfg[1];
    ethernet_rx_if i_rx[1];
    ethernet_tx_if i_tx[1];
    par {
        mii_ethernet_mac(i_cfg, 1, i_rx, 1, i_tx, 1,
                        p_eth_rxc1k, p_eth_rxerr, p_eth_rxd, p_eth_rxdv,
                        p_eth_txc1k, p_eth_txen, p_eth_txd, p_eth_timing,
                        eth_rxc1k, eth_txc1k, 1600);
        application(i_cfg[0], i_rx[0], i_tx[0]);
    }
    return 0;
}

```

Note that the connections are arrays of interfaces, so several tasks can connect to the same component instance.

The application can use the client end of the interface connections to perform Ethernet MAC operations e.g.:

```

void application(client ethernet_cfg_if i_cfg,
                client ethernet_rx_if i_rx,
                client ethernet_tx_if i_tx)
{
    ethernet_macaddr_filter_t macaddr_filter;
    size_t index = i_rx.get_index();
    for (int i = 0; i < 6; i++)
        macaddr_filter.addr[i] = i;
    i_cfg.add_macaddr_filter(index, 0, macaddr_filter);

    while (1) {
        select {
            case i_rx.packet_ready():
                uint8_t rxbuf[ETHERNET_MAX_PACKET_SIZE];
                ethernet_packet_info_t packet_info;
                i_rx.get_packet(packet_info, rxbuf, ETHERNET_MAX_PACKET_SIZE);
                i_tx.send_packet(rxbuf, packet_info.len, ETHERNET_ALL_INTERFACES);
                break;
        }
    }
}

```

2.2 10/100 Mb/s real-time Ethernet MAC

The real-time 10/100 Mb/s Ethernet MAC supports additional features required to implement, for example, an AVB Talker and/or Listener endpoint, but has additional xCORE resource requirements compared to the non-real-time MAC.

It is instantiated similarly to the non-real-time Ethernet MAC, with additional streaming channels for sending and receiving high-priority Ethernet traffic:

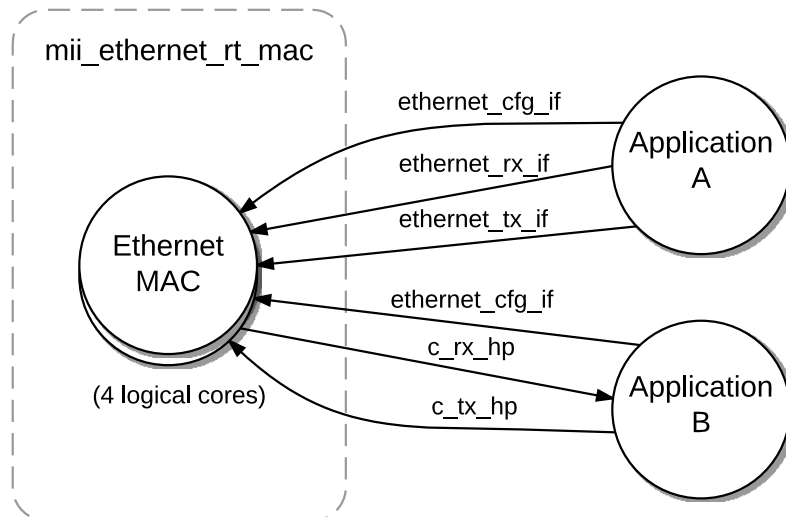


Figure 3: 10/100 Mb/s real-time Ethernet MAC task diagram

For example, the following code instantiates a real-time Ethernet MAC component with high and low-priority interfaces and connects to it:

```

port p_eth_rxcclk = XS1_PORT_1J;
port p_eth_rxd    = XS1_PORT_4E;
port p_eth_txd    = XS1_PORT_4F;
port p_eth_rxdv   = XS1_PORT_1K;
port p_eth_txen   = XS1_PORT_1L;
port p_eth_txcclk = XS1_PORT_1I;
port p_eth_rxerr  = XS1_PORT_1P;
clock eth_rxcclk  = XS1_CLKBLK_1;
clock eth_txcclk  = XS1_CLKBLK_2;

int main()
{
    ethernet_cfg_if i_cfg[1];
    ethernet_rx_if i_rx_lp[1];
    ethernet_tx_if i_tx_lp[1];
    streaming_chan c_rx_hp;
    streaming_chan c_tx_hp;
    par {
        mii_ethernet_rt_mac(i_cfg, 1, i_rx_lp, 1, i_tx_lp, 1,
                           c_rx_hp, c_tx_hp, p_eth_rxcclk, p_eth_rxerr,
                           p_eth_rxd, p_eth_rxdv, p_eth_txcclk,
                           p_eth_txen, p_eth_txd, eth_rxcclk, eth_txcclk,
                           4000, 4000, ETHERNET_ENABLE_SHAPER);
        application(i_cfg[0], i_rx_lp[0], i_tx_lp[0], c_rx_hp, c_tx_hp);
    }
}

```

The application can use the other end of the streaming channels to send and receive high-priority traffic e.g.:

```

void application(client ethernet_cfg_if i_cfg,
                client ethernet_rx_if i_rx,
                client ethernet_tx_if i_tx,
                streaming_chanend c_rx_hp,
                streaming_chanend c_tx_hp)
{
    ethernet_macaddr_filter_t macaddr_filter;
    size_t index = i_rx.get_index();
    for (int i = 0; i < 6; i++)
        macaddr_filter.addr[i] = i;
    i_cfg.add_macaddr_filter(index, 1, macaddr_filter);

    while (1) {
        uint8_t rxbuf[ETHERNET_MAX_PACKET_SIZE];
        ethernet_packet_info_t packet_info;
        select {
            case ethernet_receive_hp_packet(c_rx_hp, rxbuf, packet_info):
                ethernet_send_hp_packet(c_tx_hp, rxbuf, packet_info.len,
                                       ETHERNET_ALL_INTERFACES);
                break;
        }
    }
}

```


2.3 10/100/1000 Mb/s real-time Ethernet MAC

The 10/100/1000 Mb/s Ethernet MAC supports the same feature set and API as the 10/100 Mb/s real-time MAC but with higher throughput and lower end-to-end latency. The component connects to a Gigabit Ethernet PHY via an RGMII interface as described in §1.2.

It is instantiated similarly to the real-time Ethernet MAC, with an additional combinable task that allows the configuration interface to be shared with another slow interface such as SMI/MDIO. It must be instantiated on Tile 1 and the user application run on Tile 0:

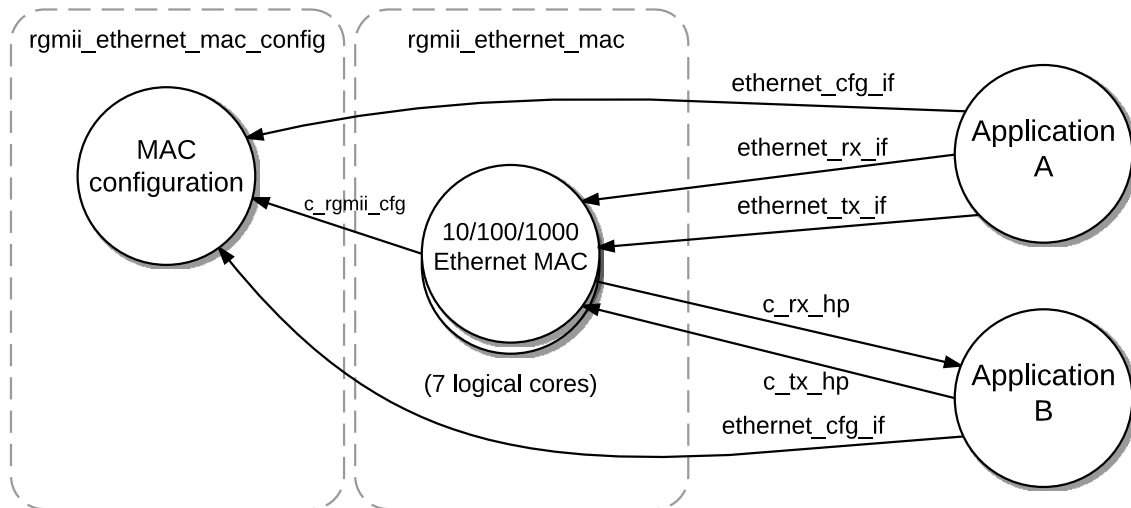


Figure 4: 10/100/1000 Mb/s Ethernet MAC task diagram

For example, the following code instantiates a 10/100/1000 Mb/s Ethernet MAC component with high and low-priority interfaces and connects to it:

```
rgmii_ports_t rgmii_ports = on tile[1]: RGMII_PORTS_INITIALIZER;

int main()
{
    ethernet_cfg_if i_cfg[1];
    ethernet_rx_if i_rx_lp[1];
    ethernet_tx_if i_tx_lp[1];
    streaming chan c_rx_hp;
    streaming chan c_tx_hp;
    streaming chan c_rgmii_cfg;
    par {
        on tile[1]: rgmii_ethernet_mac(i_rx, 1, i_tx, 1,
                                     c_rx_hp, c_tx_hp,
                                     c_rgmii_cfg, rgmii_ports,
                                     ETHERNET_ENABLE_SHAPER);
        on tile[1]: rgmii_ethernet_mac_config(i_cfg, 1, c_rgmii_cfg);
        on tile[0]: application(i_cfg[0], i_rx_lp[0], i_tx_lp[0], c_rx_hp, c_tx_hp);
    }
}
```

2.4 Raw MII interface

The raw MII interface implements a MII layer component with a basic buffering scheme that is shared with the application. It provides a direct access to the MII pins as described in §1.1. It does not implement the buffering and filtering required by a compliant Ethernet MAC layer, and defers this to the application.

The buffering of this task is shared with the application it is connected to. It sets up an interrupt handler on the logical core the application is running on (via the `init` function on the `mii_if` interface connection) and also consumes some of the MIPs on that core in addition to the core `mii` is running on.

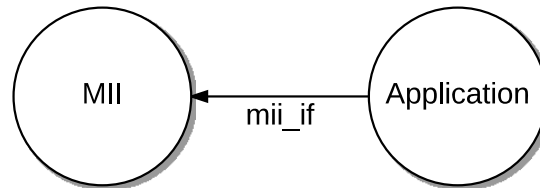


Figure 5: MII task diagram

For example, the following code instantiates a MII component and connects to it:

```
port p_eth_rxc1k = XS1_PORT_1J;
port p_eth_rxd  = XS1_PORT_4E;
port p_eth_txd  = XS1_PORT_4F;
port p_eth_rxdv = XS1_PORT_1K;
port p_eth_txen = XS1_PORT_1L;
port p_eth_txc1k = XS1_PORT_1I;
port p_eth_rxerr = XS1_PORT_1P;
port p_eth_timing = XS1_PORT_8C;
clock eth_rxc1k  = XS1_CLKBLK_1;
clock eth_txc1k  = XS1_CLKBLK_2;

int main()
{
    mii_if i_mii;
    par {
        mii(i_mii, p_eth_rxc1k, p_eth_rxerr, p_eth_rxd, p_eth_rxdv,
            p_eth_txc1k, p_eth_txen, p_eth_txd, p_eth_timing,
            eth_rxc1k, eth_txc1k, 4096);
        application(i_mii);
    }
    return 0;
}
```

More information on interfaces and tasks can be found in the XMOS Programming Guide (see [XM-004440-PC](#)).

3 API

All Ethernet functions can be accessed via the `ethernet.h` header:

```
#include <ethernet.h>
```

You will also have to add `lib_ethernet` to the `USED_MODULES` field of your application Makefile.

3.1 Creating a 10/100 Mb/s Ethernet MAC instance

Function	<code>mii_ethernet_mac</code>
Description	10/100 Mb/s Ethernet MAC component that connects to an MII interface. This function implements a 10/100 Mb/s Ethernet MAC component connected to an MII interface. Interaction to the component is via the connected configuration and data interfaces.
Type	<pre>void mii_ethernet_mac(server ethernet_cfg_if i_cfg[n_cfg], static const unsigned n_cfg, server ethernet_rx_if i_rx[n_rx], static const unsigned n_rx, server ethernet_tx_if i_tx[n_tx], static const unsigned n_tx, in port p_rxclk, in port p_rxer, in port p_rxd, in port p_rxdv, in port p_txclk, out port p_txen, out port p_txd, port p_timing, clock rxclk, clock txclk, static const unsigned rx_bufsize_words)</pre>

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Parameters		
	i_cfg	Array of client configuration interfaces
	n_cfg	The number of configuration clients connected
	i_rx	Array of receive clients
	n_rx	The number of receive clients connected
	i_tx	Array of transmit clients
	n_tx	The number of transmit clients connected
	p_rxc1k	MII RX clock port
	p_rxer	MII RX error port
	p_rxd	MII RX data port
	p_rxdv	MII RX data valid port
	p_txc1k	MII TX clock port
	p_txen	MII TX enable port
	p_txd	MII TX data port
	p_timing	Internal timing port - this can be any xCORE port that is not connected to any external device.
	rxclk	Clock used for MII receive timing
	txclk	Clock used for MII transmit timing
	rx_bufsize_words	The number of words to used for a receive buffer. This should be at least 1500 words.

3.2 Creating a 10/100 Mb/s real-time Ethernet MAC instance

Function	<code>mii_ethernet_rt_mac</code>
Description	10/100 Mb/s real-time Ethernet MAC component to connect to an MII interface. This function implements a 10/100 Mb/s Ethernet MAC component, connected to an MII interface, with real-time features (priority queuing and traffic shaping). Interaction to the component is via the connected configuration and data interfaces.
Type	<pre>void mii_ethernet_rt_mac(server ethernet_cfg_if i_cfg[n_cfg], static const unsigned n_cfg, server ethernet_rx_if i_rx_lp[n_rx_lp], static const unsigned n_rx_lp, server ethernet_tx_if i_tx_lp[n_tx_lp], static const unsigned n_tx_lp, streaming_chanend ?c_rx_hp, streaming_chanend ?c_tx_hp, in port p_rxclk, in port p_rxer, in port p_rxd, in port p_rxdv, in port p_txclk, out port p_txen, out port p_txd, clock rxclk, clock txclk, static const unsigned rx_bufsize_words, static const unsigned tx_bufsize_words, enum ethernet_enable_shaper_t shaper_enabled)</pre>

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Parameters	
<code>i_cfg</code>	Array of client configuration interfaces
<code>n_cfg</code>	The number of configuration clients connected
<code>i_rx_lp</code>	Array of low priority receive clients
<code>n_rx_lp</code>	The number of low priority receive clients connected
<code>i_tx_lp</code>	Array of low priority transmit clients
<code>n_tx_lp</code>	The number of low priority transmit clients connected
<code>c_rx_hp</code>	Streaming channel end for high priority receive data
<code>c_tx_hp</code>	Streaming channel end for high priority transmit data
<code>p_rxc1k</code>	MII RX clock port
<code>p_rxer</code>	MII RX error port
<code>p_rxd</code>	MII RX data port
<code>p_rxdv</code>	MII RX data valid port
<code>p_txc1k</code>	MII TX clock port
<code>p_txen</code>	MII TX enable port
<code>p_txd</code>	MII TX data port
<code>rxclk</code>	Clock used for MII receive timing
<code>txclk</code>	Clock used for MII transmit timing
<code>rx_bufsize_words</code>	The number of words to used for a receive buffer. This should be at least 500 words.
<code>tx_bufsize_words</code>	The number of words to used for a transmit buffer. This should be at least 500 words.
<code>shaper_enabled</code>	This should be set to <code>ETHERNET_ENABLE_SHAPER</code> or <code>ETHERNET_DISABLE_SHAPER</code> to either enable or disable the 802.1Qav traffic shaper within the MAC.

3.3 Real-time supporting typedefs

Type	ethernet_enable_shaper_t
Description	Enum representing a flag to enable or disable the 802.1Qav credit based traffic shaper on the egress MAC port.
Values	<p>ETHERNET_ENABLE_SHAPER Enable the credit based shaper.</p> <p>ETHERNET_DISABLE_SHAPER Disable the credit based shaper.</p>

3.4 Creating a 10/100/1000 Mb/s Ethernet MAC instance

Type	<code>rgmii_ports_t</code>
Description	Structure representing the port and clock resources required by RGMII. A macro to initialize this structure is provided: <pre>rgmii_ports_t rgmii_ports = on tile[1]: RGMII_PORTS_INITIALIZER;</pre>
Fields	<pre>in port p_rxc1k RX clock port. in buffered port:1 p_rxer RX error port. in buffered port:32 p_rxd_1000 1Gb RX data port in buffered port:32 p_rxd_10_100 10/100Mb RX data port in buffered port:4 p_rxd_interframe Interframe RX data port. in port p_rxdv RX data valid port. in port p_rxdv_interframe Interframe RX data valid port. in port p_txclk_in TX clock input port. out port p_txclk_out TX clock output port. out port p_txer TX error port. out port p_txen TX enable port. out buffered port:32 p_txd TX data port. clock rxc1k Clock used for receive timing.</pre>

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	<p>clock rxclk_interframe Clock used for interframe receive timing.</p> <p>clock txclk Clock used for transmit timing.</p> <p>clock txclk_out Second clock used for transmit timing.</p>
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Function	rgmii_ethernet_mac
Description	10/100/1000 Mb/s Ethernet MAC component to connect to an RGMII interface. This function implements a 10/100/1000 Mb/s Ethernet MAC component, connected to an RGMII interface, with real-time features. Interaction to the component is via the connected configuration and data interfaces.
Type	<pre>void rgmii_ethernet_mac(server ethernet_rx_if i_rx_lp[n_rx_lp], static const unsigned n_rx_lp, server ethernet_tx_if i_tx_lp[n_tx_lp], static const unsigned n_tx_lp, streaming_chanend ?c_rx_hp, streaming_chanend ?c_tx_hp, streaming_chanend c_rgmii_cfg, rgmii_ports_t &rgmii_ports, enum ethernet_enable_shaper_t shaper_enabled)</pre>

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Parameters	<code>i_rx_lp</code>	Array of low priority receive clients
	<code>n_rx_lp</code>	The number of low priority receive clients connected
	<code>i_tx_lp</code>	Array of low priority transmit clients
	<code>n_tx_lp</code>	The number of low priority transmit clients connected
	<code>c_rx_hp</code>	Streaming channel end for high priority receive data
	<code>c_tx_hp</code>	Streaming channel end for high priority transmit data
	<code>c_rgmii_cfg</code>	A streaming channel end connected to rgmii_ethernet_mac_config()
	<code>rgmii_ports</code>	A <code>rgmii_ports_t</code> structure initialized with the <code>RGMII_PORTS_INITIALIZER</code> macro
<code>shaper_enabled</code>	This should be set to <code>ETHERNET_ENABLE_SHAPER</code> or <code>ETHERNET_DISABLE_SHAPER</code> to either enable or disable the 802.1Qav traffic shaper within the MAC.	

Function	<code>rgmii_ethernet_mac_config</code>
Description	RGMII Ethernet MAC configuration task. This function implements the server side of the <code>ethernet_cfg_if</code> interface and communicates internally with the RGMII Ethernet MAC via a streaming channel end. The function can be combined with SMI from within the top level par.
Type	[[combinable]] void <code>rgmii_ethernet_mac_config(server ethernet_cfg_if i_cfg[n], unsigned n, streaming chanend c_rgmii_cfg)</code>
Parameters	<code>i_cfg</code> Array of client configuration interfaces <code>n</code> The number of configuration clients connected <code>c_rgmii_cfg</code> A streaming channel end connected to rgmii_ethernet_mac()

3.5 The Ethernet MAC configuration interface

Type	ethernet_cfg_if																																																	
Description	Ethernet MAC configuration interface. This interface allows clients to configure the Ethernet MAC.																																																	
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Continued on next page

Type	ethernet_cfg_if (continued)	
	Function	add_macaddr_filter
	Description	Add MAC addresses to the filter.
	Type	<code>ethernet_macaddr_filter_result_t</code> <code>add_macaddr_filter(size_t client_num,</code> <code>int is_hp,</code> <code>ethernet_macaddr_filter_t entry)</code>
	Parameters	<p><code>client_num</code> The index into the set of RX clients. Can be acquired by calling the <code>get_index()</code> method.</p> <p><code>is_hp</code> Indicates whether the RX client is high priority. There is only one high priority client, so <code>client_num</code> must be 0 when <code>is_hp</code> is set.</p> <p><code>entry</code> The filter entry to add.</p>
	Returns	ETHERNET_MACADDR_FILTER_SUCCESS when the entry is added or ETHERNET_MACADDR_FILTER_TABLE_FULL on failure.
	Function	del_macaddr_filter
	Description	Delete MAC addresses from the filter.
	Type	<code>void</code> <code>del_macaddr_filter(size_t client_num,</code> <code>int is_hp,</code> <code>ethernet_macaddr_filter_t entry)</code>
	Parameters	<p><code>client_num</code> The index into the set of RX clients. Can be acquired by calling the <code>get_index()</code> method.</p> <p><code>is_hp</code> Indicates whether the RX client is high priority. There is only one high priority client, so <code>client_num</code> must be 0 when <code>is_hp</code> is set.</p> <p><code>entry</code> The filter entry to delete.</p>

Continued on next page

Type	ethernet_cfg_if (continued)	
	Function	del_all_macaddr_filters
	Description	Delete all MAC addresses from the filter registered for this client.
	Type	void del_all_macaddr_filters(size_t client_num, int is_hp)
	Parameters	client_num The index into the set of RX clients. Can be acquired by calling the get_index() method. is_hp Indicates whether the RX client is high priority. There is only one high priority client, so client_num must be 0 when is_hp is set.
	Function	add_ethertype_filter
	Description	Add an Ethertype to the filter.
	Type	void add_ethertype_filter(size_t client_num, uint16_t ethertype)
	Parameters	client_num The index into the set of RX clients. Can be acquired by calling the get_index() method. ethertype A two-octet Ethertype value to filter.
	Function	del_ethertype_filter
	Description	Delete an Ethertype from the filter.
	Type	void del_ethertype_filter(size_t client_num, uint16_t ethertype)
	Parameters	client_num The index into the set of RX clients. Can be acquired by calling the get_index() method. ethertype A two-octet Ethertype value to delete from filter.

Continued on next page

Type	ethernet_cfg_if (continued)	
	Function	get_tile_id_and_timer_value
	Description	Get the tile ID that the Ethernet MAC is running on and the current timer value on that tile.
	Type	void get_tile_id_and_timer_value(unsigned &tile_id, unsigned &time_on_tile)
	Parameters	tile_id The tile ID returned from the Ethernet MAC time_on_tile The current timer value from the Ethernet MAC
	Function	set_egress_qav_idle_slope
	Description	Set the high-priority TX queue's credit based shaper idle slope.
	Type	void set_egress_qav_idle_slope(size_t ifnum, unsigned slope)
	Parameters	ifnum The index of the MAC interface to set the slope slope The slope value

Continued on next page

Type	ethernet_cfg_if (continued)							
	Function	set_ingress_timestamp_latency						
	Description	<p>Set the ingress latency to correct for the offset between the timestamp measurement plane relative to the reference plane. See 802.1AS 8.4.3.</p> <p>This latency can change at different PHY speeds, thus requires a latency value to be set for each speed in the ethernet_speed_t enum.</p> <p>All ingress timestamps received by the client will be corrected with the set value. The latency is initialized to 0 for all speeds.</p>						
	Type	void set_ingress_timestamp_latency(size_t ifnum, ethernet_speed_t speed, unsigned value)						
	Parameters	<table border="0"> <tr> <td>ifnum</td> <td>The index of the MAC interface to set the latency</td> </tr> <tr> <td>speed</td> <td>The speed to set the latency for</td> </tr> <tr> <td>value</td> <td>The latency value in nanoseconds</td> </tr> </table>	ifnum	The index of the MAC interface to set the latency	speed	The speed to set the latency for	value	The latency value in nanoseconds
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	Type	void set_egress_timestamp_latency(size_t ifnum, ethernet_speed_t speed, unsigned value)						
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ifnum	The index of the MAC interface to set the latency							
speed	The speed to set the latency for							
value	The latency value in nanoseconds							

Type	ethernet_link_state_t
Description	Type representing link events.
Values	<p>ETHERNET_LINK_DOWN Ethernet link down event.</p> <p>ETHERNET_LINK_UP Ethernet link up event.</p>

Type	ethernet_speed_t
Description	Type representing the PHY link speed and duplex.
Values	<p>LINK_10_MBPS_FULL_DUPLEX 10 Mbps full duplex</p> <p>LINK_100_MBPS_FULL_DUPLEX 100 Mbps full duplex</p> <p>LINK_1000_MBPS_FULL_DUPLEX 1000 Mbps full duplex</p> <p>NUM_ETHERNET_SPEEDS Count of speeds in this enum.</p>

Type	ethernet_macaddr_filter_t
Description	Structure representing MAC address filter data that is registered with the Ethernet MAC.
Fields	<p>uint8_t addr Six-octet destination MAC address to filter to the client that registers it.</p> <p>unsigned appdata An optional word of user data that is stored by the Ethernet MAC and returned to the client when a packet is received with the destination MAC address indicated by the addr field.</p>

Type	ethernet_macaddr_filter_result_t
Description	Type representing the result of adding a filter entry to the Ethernet MAC.

Continued on next page

Values	ETHERNET_MACADDR_FILTER_SUCCESS The filter entry was added successfully. ETHERNET_MACADDR_FILTER_TABLE_FULL The filter entry was not added because the filter table is full.
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3.6 The Ethernet MAC data handling interface

Type	ethernet_tx_if																			
Description	Ethernet MAC data transmit interface. This interface allows clients to send packets to the Ethernet MAC for transmission																			
Functions	<table border="1"> <tr> <td>Function</td> <td>_init_send_packet</td> </tr> <tr> <td>Description</td> <td>Internal API call. Do not use.</td> </tr> <tr> <td>Type</td> <td>void _init_send_packet(size_t n, size_t ifnum)</td> </tr> </table> <table border="1"> <tr> <td>Function</td> <td>_complete_send_packet</td> </tr> <tr> <td>Description</td> <td>Internal API call. Do not use.</td> </tr> <tr> <td>Type</td> <td>void _complete_send_packet(char packet[n], unsigned n, int request_timestamp, size_t ifnum)</td> </tr> </table> <table border="1"> <tr> <td>Function</td> <td>_get_outgoing_timestamp</td> </tr> <tr> <td>Description</td> <td>Internal API call. Do not use.</td> </tr> <tr> <td>Type</td> <td>unsigned _get_outgoing_timestamp()</td> </tr> </table>		Function	_init_send_packet	Description	Internal API call. Do not use.	Type	void _init_send_packet(size_t n, size_t ifnum)	Function	_complete_send_packet	Description	Internal API call. Do not use.	Type	void _complete_send_packet(char packet[n], unsigned n, int request_timestamp, size_t ifnum)	Function	_get_outgoing_timestamp	Description	Internal API call. Do not use.	Type	unsigned _get_outgoing_timestamp()
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Description	Internal API call. Do not use.																			
Type	unsigned _get_outgoing_timestamp()																			

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Type	ethernet_tx_if (continued)		
	Function	send_packet	
	Description	Function to send an Ethernet packet on the specified interface. The call will block until a transmit buffer is available and the packet has been copied to the Ethernet MAC.	
	Type	void send_packet(char packet[n], unsigned n, unsigned ifnum)	
	Parameters	packet	A byte-array containing the Ethernet packet to send. Must include a valid Ethernet frame header.
		n	The number of bytes in the packet array to send
		ifnum	The index of the MAC interface to send the packet Use the ETHERNET_ALL_INTERFACES define to send to all interfaces.
	Function	send_timed_packet	
	Description	Function to send an Ethernet packet on the specified interface and return a timestamp when the packet was sent by the MAC. The call will block until the packet has been sent and the egress timestamp retrieved.	
Type	unsigned send_timed_packet(char packet[n], unsigned n, unsigned ifnum)		
Parameters	packet	A byte-array containing the Ethernet packet to send. Must include a valid Ethernet frame header.	
	n	The number of bytes in the packet array to send	
	ifnum	The index of the MAC interface to send the packet Use the ETHERNET_ALL_INTERFACES define to send to all interfaces.	
Returns	A 32-bit timestamp off a 100 MHz reference clock that represents the egress time. May be corrected for egress latency, see set_egress_timestamp_latency() on the ethernet_cfg_if interface.		

Type	ethernet_rx_if	
Description	Ethernet MAC data receive interface. This interface allows clients to receive packets from the Ethernet MAC.	
Functions	Function	get_index
	Description	Get the index of a given receiver client.
	Type	size_t get_index()
	Function	packet_ready
	Description	Packet ready notification. This notification will fire when a packet has been queued for this client and is ready to be received using get_packet(). The event can be selected upon e.g.: <pre>select { case i_eth_rx.packet_ready(): ... // Get and handle the packet break; }</pre>
	Type	[[notification]] slave void packet_ready()
	Function	get_packet
	Description	Function to receive an Ethernet packet or status/control data from the MAC. Should be called after a packet_ready() notification.
	Type	[[clears_notification]] void get_packet(ethernet_packet_info_t &desc, char packet[n], unsigned n)
	Parameters	desc A descriptor containing metadata about the packet contents.
		packet A byte-array containing the packet data.
		n The number of bytes to receive. The data array must be large enough to receive the number of bytes specified.

Type	eth_packet_type_t
Description	Type representing the type of packet from the MAC.
Values	<p>ETH_DATA A packet containing data.</p> <p>ETH_IF_STATUS A control packet containing interface status information.</p> <p>ETH_OUTGOING_TIMESTAMP_INFO A control packet containing an outgoing timestamp.</p> <p>ETH_NO_DATA A packet containing no data.</p>

Type	ethernet_packet_info_t
Description	Structure representing a received data or control packet from the Ethernet MAC.
Fields	<p>eth_packet_type_t type Type representing the type of packet from the MAC.</p> <p>unsigned len Length of the received packet in bytes.</p> <p>unsigned timestamp The local time the packet was received by the MAC.</p> <p>unsigned src_ifnum The index of the MAC interface that received the packet.</p> <p>unsigned filter_data A word of user data that was registered with the MAC address filter.</p>

3.7 The Ethernet MAC high-priority data handling interface

Function	ethernet_send_hp_packet	
Description	Function to send a priority-queued packet over a high priority channel from the 10/100 Mb/s real-time MAC.	
Type	<pre>void ethernet_send_hp_packet(streaming_chanend c_tx_hp, char packet[n], unsigned n, unsigned ifnum)</pre>	
Parameters	c_tx_hp	A streaming channel end connected to the MAC.
	packet	A byte-array containing the Ethernet packet to send. Must include a valid Ethernet frame header.
	n	The number of bytes in the packet array to send
	ifnum	The index of the MAC interface to send the packet Use the ETHERNET_ALL_INTERFACES define to send to all interfaces.

Function	ethernet_receive_hp_packet	
Description	Function to receive a priority-queued packet over a high priority channel from the 10/100 Mb/s real-time MAC. The packet can be split into two transactions due to internal buffering and therefore this function must be used to receive the packet.	
Type	<pre>void ethernet_receive_hp_packet(streaming_chanend c_rx_hp, char packet[], ethernet_packet_info_t &packet_info)</pre>	
Parameters	c_rx_hp	A streaming channel end connected to the MAC.
	packet	A byte-array containing the packet data.
	packet_info	A descriptor containing metadata about the packet contents.

3.8 Creating a raw MII instance

All raw MII functions can be accessed via the `mii.h` header:

```
#include <mii.h>
```

Function	mii
Description	<p>Raw MII component.</p> <p>This function implements a MII layer component with a basic buffering scheme that is shared with the application. It provides a direct access to the MII pins. It does not implement the buffering and filtering required by a compliant Ethernet MAC layer, and defers this to the application.</p> <p>The buffering of this task is shared with the application it is connected to. It sets up an interrupt handler on the logical core the application is running on via the <code>init</code> function on the <code>mii_if</code> interface connection) and also consumes some of the MIPs on that core in addition to the core <code>mii</code> is running on.</p>
Type	<pre>void mii(server mii_if i_mii, in port p_rxclk, in port p_rxer, in port p_rxd, in port p_rxdv, in port p_txclk, out port p_txen, out port p_txd, port p_timing, clock rxclk, clock txclk, static const unsigned rx_bufsize_words)</pre>

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Parameters		
	<code>i_mii</code>	The MII interface to connect to the application.
	<code>p_rxc1k</code>	MII RX clock port
	<code>p_rxer</code>	MII RX error port
	<code>p_rxd</code>	MII RX data port
	<code>p_rxdv</code>	MII RX data valid port
	<code>p_txc1k</code>	MII TX clock port
	<code>p_txen</code>	MII TX enable port
	<code>p_txd</code>	MII TX data port
	<code>p_timing</code>	Internal timing port - this can be any xCORE port that is not connected to any external device.
	<code>rxclk</code>	Clock used for MII receive timing
	<code>txclk</code>	Clock used for MII transmit timing
	<code>rx_bufsize_words</code>	The number of words to used for a receive buffer. This should be at least 1500 words.

3.9 The MII interface

Type	<code>mii_if</code>									
Description	Interface allowing access to the MII packet layer.									
Functions	<table border="1"> <thead> <tr> <th>Function</th> <th>init</th> </tr> </thead> <tbody> <tr> <td>Description</td> <td>Initialize the MII layer. This function initializes the MII layer. In doing so it will setup an interrupt handler on the current logical core that calls the function (so tasks on that core may be interrupted and can no longer rely on the deterministic runtime of the xCORE).</td> </tr> <tr> <td>Type</td> <td><code>mii_info_t</code> <code>init()</code></td> </tr> <tr> <td>Returns</td> <td>state structure to use in subsequent calls to send/receive packets.</td> </tr> </tbody> </table>		Function	init	Description	Initialize the MII layer. This function initializes the MII layer. In doing so it will setup an interrupt handler on the current logical core that calls the function (so tasks on that core may be interrupted and can no longer rely on the deterministic runtime of the xCORE).	Type	<code>mii_info_t</code> <code>init()</code>	Returns	state structure to use in subsequent calls to send/receive packets.
Function	init									
Description	Initialize the MII layer. This function initializes the MII layer. In doing so it will setup an interrupt handler on the current logical core that calls the function (so tasks on that core may be interrupted and can no longer rely on the deterministic runtime of the xCORE).									
Type	<code>mii_info_t</code> <code>init()</code>									
Returns	state structure to use in subsequent calls to send/receive packets.									

Continued on next page

Type	mii_if (continued)	
	Function	get_incoming_packet
	Description	Get incoming packet from MII layer. This function can be called after an event is triggered by the mii_incoming_packet() function. It gets the next incoming packet from the packet buffer of the MII layer.
	Type	{int * unsafe, size_t, unsigned} get_incoming_packet()
	Returns	a tuple containing a pointer to the data (which is owned by the application until the <code>release_packet()</code> function is called), the number of bytes in the packet and a timestamp. If no packet is available then the first element will be a NULL pointer.
	Function	release_packet
	Description	Release a packet back to the MII layer. This function will release a packet back to the MII layer to be used for buffering.
	Type	void release_packet(int *unsafe data)
	Parameters	data The pointer to packet to return. This should be the same pointer returned by <code>get_incoming_packet()</code>
	Function	send_packet
	Description	Send a packet to the MII layer. This function will send a packet over MII. It does not block and will return immediately with the MII layer now owning the memory of the packet. The function mii_packet_sent() should be subsequently called to determine when the packet has been transmitted and the application can use the buffer again.
	Type	void send_packet(int *unsafe buf, size_t n)
	Parameters	buf The pointer to the packet to be transferred to the MII layer. n The number of bytes in the packet to send.

Function	mii_incoming_packet
Description	<p>Event on/wait for an incoming packet. This function waits for an incoming packet from the MII layer. It can be used in a select to detect an incoming packet e.g</p> <pre> mii_info_t mii_info = i_mii.init(); select { case mii_incoming_packet(mii_info): ... break; ... </pre>
Type	unsafe void mii_incoming_packet(mii_info_t info)

Function	mii_packet_sent
Description	<p>Event on/wait for a packet send to complete. This function will wait for a packet transmitted with the send_packet function on the mii_interface to complete. It can be used in a select to event when the transmission is complete e.g</p> <pre> mii_info_t mii_info = i_mii.init(); select { case mii_packet_sent(mii_info): ... break; ... </pre>
Type	unsafe void mii_packet_sent(mii_info_t info)

Type	mii_info_t
Description	<p>Type containing internal state of the mii task. This type contains internal state of the MII tasks. It is given to the application via the init() function of the 'mii_if' interface and its main use is to allow eventing on incoming packets via the mii_incoming_packet() function.</p>

3.10 Creating an SMI/MDIO instance

All SMI functions can be accessed via the `smi.h` header:

```
#include <smi.h>
```

Function	<code>smi</code>						
Description	SMI component that connects to an Ethernet PHY or switch via MDIO on separate ports. This function implements a SMI component that connects to an Ethernet PHY/ switch via MDIO/MDC connected on separate ports. Interaction to the component is via the connected SMI interface.						
Type	[[distributable]] void <code>smi</code> (server interface <code>smi_if</code> <code>i_smi</code> , port <code>p_mdio</code> , port <code>p_mdc</code>)						
Parameters	<table> <tr> <td><code>i_smi</code></td> <td>Client register read/write interface</td> </tr> <tr> <td><code>p_mdio</code></td> <td>SMI MDIO port</td> </tr> <tr> <td><code>p_mdc</code></td> <td>SMI MDC port</td> </tr> </table>	<code>i_smi</code>	Client register read/write interface	<code>p_mdio</code>	SMI MDIO port	<code>p_mdc</code>	SMI MDC port
<code>i_smi</code>	Client register read/write interface						
<code>p_mdio</code>	SMI MDIO port						
<code>p_mdc</code>	SMI MDC port						

Function	<code>smi_singleport</code>								
Description	SMI component that connects to an Ethernet PHY or switch via MDIO on a shared multi-bit port. This function implements a SMI component that connects to an Ethernet PHY/ switch via MDIO/MDC connected on the same multi-bit port. Interaction to the component is via the connected SMI interface.								
Type	[[distributable]] void <code>smi_singleport</code> (server interface <code>smi_if</code> <code>i_smi</code> , port <code>p_smi</code> , unsigned <code>mdio_bit</code> , unsigned <code>mdc_bit</code>)								
Parameters	<table> <tr> <td><code>i_smi</code></td> <td>Client register read/write interface</td> </tr> <tr> <td><code>p_smi</code></td> <td>The multi-bit port with MDIO/MDC pins</td> </tr> <tr> <td><code>mdio_bit</code></td> <td>The MDIO bit position on the multi-bit port</td> </tr> <tr> <td><code>mdc_bit</code></td> <td>The MDC bit position on the multi-bit port</td> </tr> </table>	<code>i_smi</code>	Client register read/write interface	<code>p_smi</code>	The multi-bit port with MDIO/MDC pins	<code>mdio_bit</code>	The MDIO bit position on the multi-bit port	<code>mdc_bit</code>	The MDC bit position on the multi-bit port
<code>i_smi</code>	Client register read/write interface								
<code>p_smi</code>	The multi-bit port with MDIO/MDC pins								
<code>mdio_bit</code>	The MDIO bit position on the multi-bit port								
<code>mdc_bit</code>	The MDC bit position on the multi-bit port								

3.11 The SMI/MDIO PHY interface

Type	smi_if																			
Description	SMI register configuration interface. This interface allows clients to read or write the PHY SMI registers																			
Functions	<table border="1"> <tr> <td>Function</td> <td>read_reg</td> </tr> <tr> <td>Description</td> <td>Read the specified SMI register in the PHY.</td> </tr> <tr> <td>Type</td> <td>uint16_t read_reg(uint8_t phy_address, uint8_t reg_address)</td> </tr> <tr> <td>Parameters</td> <td> phy_address The 5-bit SMI address of the PHY reg_address The 5-bit register address to read </td> </tr> <tr> <td>Returns</td> <td>The 16-bit data value read from the register</td> </tr> <tr> <td>Function</td> <td>write_reg</td> </tr> <tr> <td>Description</td> <td>Write the specified SMI register in the PHY.</td> </tr> <tr> <td>Type</td> <td>void write_reg(uint8_t phy_address, uint8_t reg_address, uint16_t val)</td> </tr> <tr> <td>Parameters</td> <td> phy_address The 5-bit SMI address of the PHY reg_address The 5-bit register address to write val The 16-bit data value to write to the register </td> </tr> </table>		Function	read_reg	Description	Read the specified SMI register in the PHY.	Type	uint16_t read_reg(uint8_t phy_address, uint8_t reg_address)	Parameters	phy_address The 5-bit SMI address of the PHY reg_address The 5-bit register address to read	Returns	The 16-bit data value read from the register	Function	write_reg	Description	Write the specified SMI register in the PHY.	Type	void write_reg(uint8_t phy_address, uint8_t reg_address, uint16_t val)	Parameters	phy_address The 5-bit SMI address of the PHY reg_address The 5-bit register address to write val The 16-bit data value to write to the register
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3.12 SMI PHY configuration helper functions

Function	smi_configure
Description	Function to configure the PHY speed/duplex with or without auto negotiation. The <code>smi_phy_is_powered_down()</code> function should be called to check that the PHY is not powered down before calling this function.
Type	void smi_configure(client <code>smi_if</code> smi, uint8_t phy_address, <code>ethernet_speed_t</code> speed_mbps, <code>smi_autoneg_t</code> auto_neg)
Parameters	<p>smi An interface connection to the SMI component</p> <p>phy_address The 5-bit SMI address of the PHY</p> <p>speed_mbps If auto negotiation is disabled, the specified speed will be forced, otherwise the PHY will be configured to advertise as capable of all full-duplex speeds up to and including the specified speed.</p> <p>auto_neg If set to SMI_ENABLE_AUTONEG auto negotiation is enabled, otherwise disabled if set to SMI_DISABLE_AUTONEG</p>

Type	smi_autoneg_t
Description	Type representing PHY auto negotiation enable/disable flags.
Values	<p>SMI_DISABLE_AUTONEG Enable auto negotiation.</p> <p>SMI_ENABLE_AUTONEG Disable auto negotiation.</p>

Function	smi_set_loopback_mode
Description	Function to enable loopback mode with the Ethernet PHY.
Type	void smi_set_loopback_mode(client <code>smi_if</code> smi, uint8_t phy_address, int enable)

Continued on next page

Parameters	smi	An interface connection to the SMI component
	phy_address	The 5-bit SMI address of the PHY
	enable	Loopback enable flag. If set to 1, loopback is enabled, otherwise 0 to disable

Function	smi_get_id	
Description	Function to retrieve the PHY manufacturer ID number.	
Type	unsigned smi_get_id(client smi_if smi, uint8_t phy_address)	
Parameters	smi	An interface connection to the SMI component
	phy_address	The 5-bit SMI address of the PHY
Returns	The PHY manufacturer ID number	

Function	smi_phy_is_powered_down	
Description	Function to retrieve the power down status of the PHY.	
Type	unsigned smi_phy_is_powered_down(client smi_if smi, uint8_t phy_address)	
Parameters	smi	An interface connection to the SMI component
	phy_address	The 5-bit SMI address of the PHY
Returns	1 if the PHY is powered down, 0 otherwise	

Function	smi_get_link_state	
Description	Function to retrieve the link up/down status.	
Type	ethernet_link_state_t smi_get_link_state(client smi_if smi, uint8_t phy_address)	

Continued on next page

Parameters	<code>smi</code> An interface connection to the SMI component <code>phy_address</code> The 5-bit SMI address of the PHY
Returns	ETHERNET_LINK_UP if the link is up, ETHERNET_LINK_DOWN if the link is down

APPENDIX A - Known Issues

There are no known issues with this library.

APPENDIX B - Ethernet MAC library change log

B.1 3.0.3

- Update RGMII port delays to use best candidate from testing

B.2 3.0.2

- Improve interoperability of PHY speed and link detection via RGMII inter-frame data
- Fix 64-bit alignment of MII lite to prevent crash on XS2

B.3 3.0.1

- Fixed issue with optimisation build flags not being overridden by the module
- Added missing extern declaration for inline interface function send_timed_packet()
- Added ability to override the number of Ethertype filters from the ethernet_conf.h

B.4 3.0.0

- Major rework of structure and API
- Added RGMII Gigabit Ethernet MAC support for xCORE-200