VNETI
Virtual NETwork Interface

Version 2.6
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(changes w.r.t. version 2.5 are in blue [pages 10 and 13])

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Preamble

The purpose of VNETI (which stands for Versatile NETwork Interface) is to provide a simple collection of API, independent of the underlying implementation of networking, which, in addition to enabling a rapid deployment of networked application for microcontrollers would make it easy to develop testbeds using emulated radio interfaces. To avoid the protocol layering problems haunting small footprint solutions, the presented interface is essentially layer-less and its semi-complete generic functionality can be redefined by plugins. Also, the actual implementation of the physical interface to the network can be encapsulated as a relatively simple and easily exchangeable module. To facilitate development, testing, and experiments, multiple plugins and physical interfaces can coexist within the same system configuration.

1. The structure

The structure of VNETI and its relationship to other system components is shown in Figure 1. In essence, the module implements transparent management of buffer (packet) storage organized into a dynamic number of queues, timeouts definable on a per-packet basis, multiple application access points (roughly equivalent to connections or sessions), and provides a unified set of functions for interfacing plugins and physical modules.

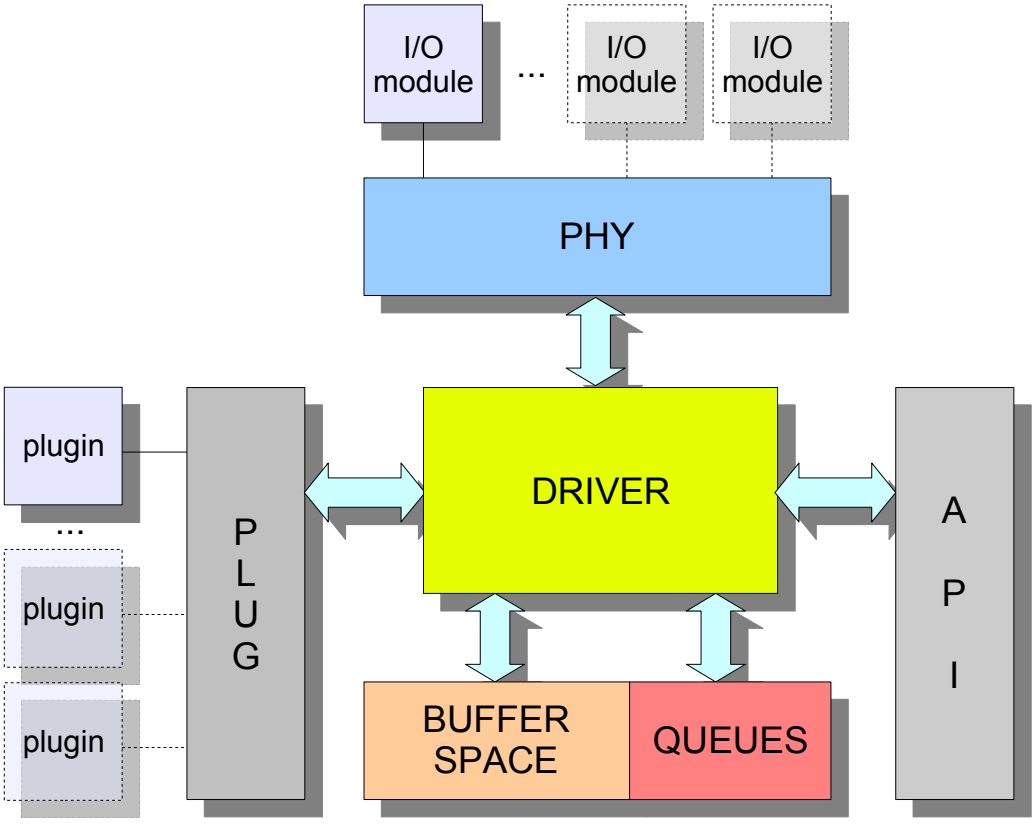


Figure 1: VNETI structure.

A workable VNETI setup involves at least one physical I/O module (PHY) and at least one plugin. The application can open a connection, receive and transmit packets over a connection, close a connection, without having to worry about details, like

allocation/deallocation of buffer space, header/trailer processing, and possibly error recovery, which operations are performed transparently by the plugin(s). A single plugin can cooperate with multiple physical modules; multiple plugins can claim frames delivered by different physical modules for their specific processing, and so on. Regardless of the actual configuration of plugins and physical modules configured into the system, the API provided by VNETI is essentially fixed; thus, we can say that VNETI, in addition to being open-ended (on the physical end) is open-sided (on the plugin side), while being closed with respect to the API.

2. Physical interface

Physical I/O modules (typically RF devices) are interfaced to VNETI via five functions whose headers are defined in *tcvphys.h* (in directory PicOS). This interface is dubbed *phy*. During initialization, a physical module registers itself with VNETI by executing this function:

```
int tcvphy_reg (int id, ctrlfun_t cfun, int info)
```

whose first argument is a small integer number uniquely identifying the module within the current praxis.[1] The second argument points to the module's *control function* for setting various operating parameters of the module. The third argument provides the so-called interface *information* attribute i.e., an integer value that is supposed to be globally unique among all possible interfaces, and whose role is to identify the module unambiguously (regardless of its short and possibly ambiguous **id**) for the plugin or application.

The short module identifier (**id**) will allow a plugin to recognize one of possibly several physical modules, e.g., as the source of an inbound packet. Also, by passing it as a parameter to the **open** function (see below), the praxis will be able to associate a specific session with a specific physical module. Module identifiers are usually very small. They are indexes into an array of physical modules, whose maximum size is determined by a configuration parameter (**TCV_MAX_PHYS** with the default value of 3 and the maximum of 8).

The control function pointed to by **cfun** should have the following header:

```
int cntrlfun (int option, address value)
```

with the first argument identifying the option of the physical module, and the second providing its (new) value (which can be a structure pointed to by the specified address). Some options can be considered standard (e.g., switching on and off the receiver/transmitter), while some others may be interface-specific (e.g., switching on the promiscuous mode of the Ethernet chip). Some calls to the control function may be intended to read the value of an option rather than changing it. This value can be returned via the function value or via the parameter (viewed as a pointer). The VNETI API gives the application access to the control functions of the physical modules handling its connections. If the application decides to take advantage of an exotic option, it is expected to know what is doing.

A registered physical module is assigned a single queue of outgoing packets, which is handled automatically by VNETI. The value returned by **tcvphy_reg** is a 16-bit integer number identifying the *queue event* that will be triggered by VNETI whenever the outgoing queue becomes nonempty. The physical module can acquire the top packet from its outgoing queue via this function:

[1] This is PicOS's term for “application.”

```
address tcvphy_get (int id, int *len)
```

The first argument is the module identifier that was specified with **tcvphy_reg**. If there is a packet queued for transmission by the physical module, the function removes the first packet from the queue and returns a pointer to it, while the length of this packet (in bytes) is returned via the second argument. Note that packets (as perceived by physical modules) are always word-aligned, although their length is expressed in bytes (and it doesn't have to be even). The function returns **NULL**, if there is no packet to transmit at this time. Typically, **tcvphy_get** is called from a process of the physical module, e.g., after receiving the queue event.

The queue event is triggered when the outgoing queue of packets becomes nonempty, and also when an *urgent* packet (see section 3) is put into the (possibly nonempty) queue, necessarily at the front.

It is possible to peek at the topmost packet in the outgoing queue (without removing it) by calling this function:

```
address tcvphy_top (int id)
```

with the module identifier as the argument. The function returns the pointer to the first packet in the queue, or **NULL** if the queue is empty.

The packet whose pointer is returned by **tcvphy_get** is stored in the dynamic buffer pool handled by VNETI. This means that the physical module must tell VNETI when it is done with the packet (note that a physical packet transmission may involve blocking and take a nontrivial amount of time), such that its buffer can be deallocated. This is accomplished by the following function:

```
void tcvphy_end (address packet)
```

which accepts the original packet pointer that was produced by **tcvphy_get** and notifies VNETI that the packet has been transmitted. This does not automatically result in the deallocation of the packet's storage. Determining the fate of the packet that has been transmitted by the physical module is up to the plugin, and **tcvphy_end** will consult a plugin function (**tcv_xmt** – see section 4) to decide what to do with the packet. For example, the plugin may decide to keep the packet for a possible retransmission until it is acknowledged by the recipient.

A packet indicated by **tcvphy_top**, i.e., one that has not been removed from the outgoing queue, can also be marked as "transmitted" by **tcvphy_end**. If the plugin decides to deallocate such a packet, it will be automatically dequeued before deletion.

The reception end is handled in a very simple manner. When the physical module receives a packet that should be passed to VNETI, it calls the following function:

```
int tcvphy_rcv (int id, address buf, int len)
```

whose last two arguments describe the location of the packet in memory. Note that the physical module is responsible for allocating and handling its own reception buffer (pointed to by **buf**). The above operation never blocks and it expects that VNETI is able to copy the packet to its internal buffer storage, furnishing it with internal attributes based on the decision of the plugin. If no memory is available to accommodate the packet into a queue, it will be dropped and ignored, in which case the function returns zero. This will also happen if the plugin decides to drop the packet (e.g., considered irrelevant); thus, a

zero value does not necessarily mean memory problems. If the packet has been stored for reception by the praxis (it has not been dropped), the function returns 1.

```
int tcvphy_erase (int id)
```

This operation drains the output queue of the interface module and returns the number of erased packets. The packets are removed from the queue and deallocated without notifying the plugin.

3. API: the praxis interface

Before the praxis can use the services offered by VNETI (in collaboration with its registered plugins and physical modules), it must open a session. The exact semantics of what it means to "*open a session*" depends on the plugin. In the simplest case, as implemented in the trivial *null* plugin (see file **plug_null.c** in *PicOS/Libs/Lib/*), there can be only a single session per physical interface representing a more or less direct connection to the network, but nonetheless, this session must be explicitly set up, i.e., opened. This is accomplished by the following operation:

```
int tcv_open (word state, int phid, int plid, ...)
```

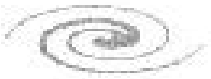
whose exact configuration of arguments depends on the capabilities of the plugin responsible for handling the session. The first argument identifies a state in the calling process. Depending on how the session is organized (e.g., the operation may involve setting up a some kind of a connection to a remote host), the open request may block. In such a case, the first argument indicates the state in which the process will be restarted when it makes sense to re-try the operation. The state argument can be **NONE**, in which case the operation never blocks, but returns its status. If the value returned by **tcv_open** is −2 (constant **BLOCKED**), it means that the open operation has started but the request has not been completed. The function must be called again at a later time. The state of a pending open request is maintained by VNETI (and the plugin), so it is legal to re-execute a previously blocked **tcv_open** at any time to check whether it has completed. When **state** is not **NONE**, the process is automatically blocked and restarted at the indicated state when the session status has changed.

The remaining two fixed arguments of **tcv_open** identify the physical module and the plugin responsible for handling the session. Similar to the physical identifier, the plugin identifier is a small integer number uniquely assigned to a single plugin interfaced to VNETI by the praxis.

Upon a successful completion, **tcv_open** returns a small integer value (starting from zero), which identifies the session resembling a file descriptor (in UNIX terminology). If the value returned by the function is −1 (constant **ERROR**), it means that the attempt to set up the session has failed. The reason for this failure is not formal (in which case the program would simply crash on a system error), but may have resulted from a lack of resources (too many sessions) or a higher-level problem encountered by the plugin.

The maximum number of sessions that can be opened simultaneously at any moment is determined by **TCV_MAX_DESC** with the default value of 16. The maximum setting of this symbol, which can be redefined in **options.h**, is 128. Each session is assigned an incoming queue of packets from which the application can receive data. Outgoing packets are passed to VNETI without being explicitly queued within the session context.

Once opened a session can be closed with the following function:



```
int tcv_close (word state, int fd)
```

whose second argument is a session descriptor[2] that was returned by **tcv_open**. The operation can legitimately block, in which case the first argument indicates the state to be assumed when it makes sense to reissue the request. As in the case of **tcv_open**, the half closed state of a connection is stored by VNETI. In those circumstances when the operation can possibly block, such a half-closed state will remain pending (rendering the session descriptor wasted) until the application executes **tcv_close** successfully.

The function returns 0 upon success, −2 (**BLOCKED**) when the close request is pending (this is only possible if **state** is **NONE**), and −1 (**ERROR**) when there has been a high-level error determined by the plugin.

The operations of reading from and writing to the session descriptor deal with packets, while making it possible to extract/send information in smaller chunks. This simple way, the structure of packets is made visible enough to account for those circumstances when the application prefers to see them explicitly, and transparent enough to view a session descriptor as a stream-like device handling (almost) unpackaged sequences of bytes.

The following operation acquires the next packet queued for reception at the session:

```
address tcv_rnp (word state, int fd)
```

and returns the packet handle (a word-aligned pointer to the first byte of the packet). The operation will block if no packet is available in the session's incoming queue, in which case the **state** argument is interpreted in the usual way. If **state** is **NONE**, the function returns **NULL** if there's no packet to read.

The packet handle returned by **tcv_rnp**, besides providing immediate access to the packet string, additionally represents a more elaborate data structure maintained by VNETI to keep track of various packet attributes. In particular, although the length of the received packet is not directly returned by **tcv_rnp**, this (and some other) information is readily accessible through the packet handle (see below).

The packet acquired by **tcv_rnp** is removed from the session's queue. This has two implications. First, it is possible to read (extract from the queue) multiple packets before actually processing them (e.g., from multiple processes). Second, the handle returned by **tcv_rnp** becomes the only reference to the received packet. Consequently, the application is responsible for indicating explicitly the moment when the packet has been processed and is not needed any more. This is accomplished by the following function:

```
void tcv_endp (address packet)
```

where the argument is a packet handle. If the handle has been acquired by **tcv_rnp** (i.e., it describes an incoming packet), it means that the application is completely done with the packet and it should be deallocated.

Outgoing packets are handled in a similar way, i.e., by requesting a packet handle from VNETI. This is done by the calling following function:

```
address tcv_wnp (word state, int fd, int length)
```

The operation builds a new packet **length** bytes long and returns its handle. The only possible reason for blocking is the lack of memory to accommodate the new packet.

[2] In all subsequent occurrences, **fd** will stand for a session descriptor.

When this happens, the invoking process will be resumed in the indicated state when some memory becomes available. As usual, if **state** is **NONE**, the function never blocks but returns **NULL** on failure.

When the packet is filled out and complete, the application can use **tcv_endp** (see above) to notify VNETI that it should be accepted as a new ready outgoing packet. Note that VNETI is able to tell the difference between the two invocations of **tcv_endp** (i.e., for an incoming and an outgoing packet). This is possible because the complete data structure encompassing the packet stores its "nature," which is different for a received packet (one acquired by **tcv_rnp**) and for an outgoing packet (one produced by **tcv_wnp**).

Here is another variant of the function:

```
address tcv_wnpu (word state, int fd, int length)
```

which acts exactly as **tcv_wnp**, except that it additionally marks the packet as urgent. This is a special flag, e.g., made available to the plugin. When an urgent packet is queued for output at the physical module, it is stored at the head of the module's outgoing queue. Needless to say that normal (non-urgent) packets are appended at the end.

Packets handled by **tcv_rnp**/**tcv_wnp** are complete in terms of their overall size, i.e., they include room for the possible headers and/or trailers. While those headers and trailers need not be used by the praxis (the plugin may be solely responsible for interpreting them and filling them in), the application must be aware of them if it insists on interpreting directly the raw packet contents made accessible via handles. If the headers/trailers are processed by the plugin, the **length** parameter of **tcv_wnp** refers to the *logical* component of the packet (the application payload) excluding the parts that are not meant for the praxis. VNETI will obtain the total required length of the packet frame by consulting the plugin. However, when the application stores its payload within the packet, it has to bypass the header explicitly. If the above sounds confusing, just keep reading.

All this hassle can be avoided by accessing the packet contents (the payload) via some other functions provided by VNETI. In particular, this one:

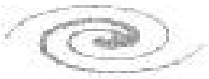
```
int tcv_read (address packet, char *buf, int len)
```

extracts up to **len** payload bytes from the incoming packet pointed to by the specified handle and stores them in **buf**. It uses internal pointers maintained by VNETI which are updated after every extraction. The function returns the number of extracted bytes, which can be less than **len** (if there are not that many bytes left in the packet). In particular, if the function returns zero, it means that all the payload has been extracted from the packet. Note that **tcv_read** is intended for incoming packets, i.e., ones that have been acquired with **tcv_rnp**, and it should never be called for an outgoing packet.

Similarly, the payload of an outgoing packet can be filled using the following function:

```
int tcv_write (address packet, const char *buf, int len)
```

whose semantics is obvious. The function returns the number of bytes stored within the payload section of the packet. When it returns zero or less than **len**, it means that the entire payload has been filled.



Another function in this group is the following one, which can also be used to determine the length of a packet acquired by **tcv_rnp**:

```
int tcv_left (address packet)
```

It returns the number of payload bytes still left within the packet. For an incoming packet, this means the number of bytes left for extraction. Immediately after the packet has been acquired by **tcv_rnp**, this number is equal to the total length of the payload; then it is decremented after each call to **tcv_read**. For an outgoing packet, this number starts with the length specified for **tcv_wnp**, and then it is decremented by **tcv_write**.

The urgent attribute of a packet (it only makes sense for an outgoing packet) can be set explicitly with this operation:

```
void tcv_urgent (address packet)
```

Here is the way to tell whether a packet is urgent:

```
bool tcv_isurgent (address packet)
```

The last function is a predicate returning nonzero when the urgent attribute of the packet is set.

The praxis is able to monitor the size of packet queues with help of the following operation:

```
int tcv_qsize (int fd, int disp)
```

where **disp** is the so-called disposition code (see section 4), which, in this case can have one of these four values:

TCV_DSP_RCV the function returns the total number of packets awaiting reception by the praxis. These are the packets that have been received by the physical module and queued for extraction via **tcv_rnp**.

TCV_DSP_RCVU the function returns the number of urgent packets awaiting reception by the praxis.

TCV_DSP_XMT the function returns the total number of packets awaiting transmission by the physical module responsible for handling the output from this session.

TCV_DSP_XMTU the function returns the number of urgent packets awaiting transmission by the physical module.

It is also possible to empty the respective queues by calling:

```
int tcv_erase (int fd, int disp)
```

where **disp** is exactly as for **tcv_qsize**. For **TCV_DSP_RCVU** and **TCV_DSP_XMTU**, the function completely clears the respective queues, while for the remaining two values it erases all non-urgent packets. Note that there is no way to erase all urgent packets leaving the non-urgent ones in the queue. A single packet available via a handle can be erased (unconditionally removed from any queue it may be in) with this function:

```
void tcv_drop (address packet)
```

VNETI provides a way to invoke the control function of the underlying physical module of a session from the praxis. This is accomplished by calling:

```
int tcv_control (int fd, int option, address value)
```

which function is in essence a link to the control function declared by the physical module (see section 2). The primary difference is that from the application, the physical module is identifiable through the session descriptor, rather than directly (or via the module identifier). Additionally, two special option values, **PHYSOPT_PLUGINFO** and **PHYSOPT_PHYSINFO**, are processed by the plugin, rather than being passed to the physical module's control function. With **PHYSOPT_PLUGINFO**, the **fd** argument is interpreted as a plugin **id**, and the function returns the plugin *information* attribute (see the next section). With **PHYSOPT_PHYSINFO**, **fd** is interpreted as a physical module identifier, and the function returns the *information* descriptor of the respective physical module (see section 2). In both cases, if the specified identifier does not correspond to an existing plugin/module, the function returns zero.

The last application-level function provided by VNETI is the one for configuring plugins:

```
void tcv_plug (int id, tcvplug_t *plugin)
```

The first argument is the numerical plugin identifier whose purpose is to uniquely identify all plugins configured by the praxis, e.g., for reference with **tcv_open**. The second argument points to a data structure containing seven function pointers. This structure and the roles of all those functions are described in the next section.

4. Plugin interface

A plugin is described by a set of seven functions and one integer value, which are collectively provided via the following structure:

```
typedef struct {
    int (*tcv_ope) (int phid, int fd, va_list ap);
    int (*tcv_clo) (int phid, int fd);
    int  (*tcv_rcv)  (int  phid,  address  buf,  int  len,  int  *ses,
        tcvadp_t *frm);
    int (*tcv_frm) (address packet, int ses, tcvadp_t *frm);
    int (*tcv_out) (address packet, int ses);
    int (*tcv_xmt) (address packet, int ses);
    int (*tcv_tmt) (address packet, int ses);
    int tcv_info;
} tcvplug_t;
```

The single numerical attribute (**tcv_info**) provides the plugin's global *information* descriptor intended to be globally unique among all plugins.

The plugin functions may reference a number of operations offered by VNETI to be used exclusively by plugins. In addition, the plugin functions can also call those functions of VNETI that are intended for the application (section 3).

We start from describing the roles and responsibilities of the plugin functions.

→ **tcv_ope**

This function is called to handle the plugin end of the session open operation. Its first two arguments are, respectively, the physical module identifier and the session descriptor allocated by VNETI to the new session. The third argument is a pointer to the list of all the extra arguments (the ones represented by dots in the header) that were passed to **tcv_open**.

The value returned by the function is interpreted in the following way: zero indicates success and means that the new session has been accepted by the plugin; −1 means error, i.e., the session has been rejected by the plugin; any other value means that the request has been accepted by the plugin, but the session hasn't been set up immediately. In the last case, VNETI interprets the value returned by **tcv_ope** as the identifier of the event that will be triggered by the plugin when it makes sense to retry the operation. The process calling **tcv_open** will be blocked waiting for that event (unless the **state** argument of **tcv_open** was **NONE**).

The only reason why **tcv_open** (the praxis-level open function) may block is when the plugin **tcv_ope** function decides to block. By itself, VNETI never blocks on opening a new session.

→ **tcv_clo**

This function is called to close the plugin end of a session being closed by **tcv_close**. The two arguments are, respectively, the physical module identifier and the session descriptor. The values returned by **tcv_clo** are interpreted as for **tcv_ope**.

→ **tcv_rcv**

This function is called by VNETI when a packet is received from a physical module. The first three (input) arguments are: the physical module identifier, the packet buffer pointer (word aligned), and the total received length of the packet. The value returned by the function indicates whether the plugin has claimed the packet, and what should be done with the packet (the so-called disposition code).

Having received a packet from a physical module (see operation **tcvphy_rcv**), VNETI examines all the registered plugins calling their **tcv_rcv** functions in turn). The plugins are examined in the reverse order of their numerical identifiers, and the first plugin whose **tcv_rcv** returns nonzero is assumed to have claimed the packet. This way the plugins with low identifiers are treated as fall-back (or default) plugins for servicing the types of packets unclaimed by the higher-numbered plugins.

Having claimed a packet, **tcv_rcv** is expected to return some additional information via the last two arguments. The first of them is the descriptor of the session to which the packet should be assigned. This does not automatically imply that the packet will be queued for reception at that session. At this level, the session descriptor can be viewed as a tag assigned to the packet. The second return argument points to a simple structure consisting of two 16-bit numbers which determine the portion of the received packet that should be extracted and stored by VNETI. The first of these numbers is interpreted as the offset from the beginning of the received packet, while the second one is viewed as the offset from the end. In particular, if the entire received packet should be passed to VNETI, both numbers should be zero. Note that any truncation at this level is not meant to identify and isolate the application level payload, but rather to eliminate those components of the

physical header/trailer that the plugin considers useless and uninteresting. This can also be done by the physical module, which decides on the portion of the received packet that should be presented to VNETI. A special plugin function, **tcv_frm** (see below), is provided to identify application-level payloads within packets, once they get past the reception/acceptance stage.

Note that the packet pointer passed to **tcv_rcv** is not a packet handle, i.e., it represents a raw sequence of bytes rather than a structure kept in a VNETI buffer and adorned with the standard set of internal attributes. This is in contrast to the remaining four plugin functions, which accept packet handles. One should remember that operations like cloning packets, changing their attributes, assigning them to sessions, and so on, are only defined on packet handles.

The concept of a disposition code, as returned by **tcv_rcv**, is general and applicable to some other plugin functions and VNETI operations available to plugins. Here is the complete list of those codes:

(0) TCV_DSP_PASS

This code means *skip* or *do nothing*. For example, it is used as the *no claim* indication by **tcv_rcv**.

(1) TCV_DSP_DROP

The packet should be dropped and ignored.

(2) TCV_DSP_RCV

The packet should be queued for reception at the session with which it is associated. If the packet is urgent, it will be queued at the front of the session's queue, otherwise, it will be queued at the end.

(3) TCV_DSP_RCVU

Make the packet urgent and queue it at the session (necessarily at the front of the queue).

(4) TCV_DSP_XMT

Queue the packet for transmission by the physical module with which the packet is associated. If the packet is urgent, it will be queued at the front of the interface's outgoing queue, otherwise, it will be queued at the end.

(5) TCV_DSP_XMTU

Make the packet urgent and queue it for transmission by the respective physical module.

Note that an outgoing packet created by the application is automatically associated with a physical module (the one that was assigned to the session when it was opened). Similarly, a received packet may be immediately associated with a session by **tcv_rcv**. If its immediate disposition is 2 or 3, the packet must be assigned to a legitimate (opened) session.

→ **tcv_frm**

This function is given a packet handle and the session descriptor, and returns (via the third argument) the offsets of the header and trailer within the packet which separate the framing information from the application payload. The structure pointed to by the third argument is the same as for **tcv_rcv** (see **sysio.h** for its declaration). The first word of this structure specifies the header offset from the beginning of the packet, while the second word gives the trailer offset from the end. The payload length is determined as total length – header offset – trailer offset.

The function must be prepared to be called with the first argument equal **NULL**. This happens when (and only when) VNETI attempts to allocate a new outgoing packet buffer for **tcv_wnp**/**tcv_wnpu**. Note that in that case, to know how much memory should be requested for the new packet, VNETI must query **tcv_frm** before the handle can sensibly point to anything. Thus the function must be able to tell the framing parameters based exclusively on the session descriptor, possibly accounting for the worst possible case.

The integer value returned by the function should be normally zero. A nonzero value returned when the function has been invoked by **tcv_wnp** (or **tcv_wnpu**) means that the attempt to acquire a new packet buffer for transmission should fail (in the same way as if no memory were available). The integer value of **tcv_frm** then identifies the event that will be triggered when another acquisition attempt (call to **tcv_wnp**/**tcv_wnpu**) can be made. The function can tell that it has been called by **tcv_wnp** or **tcv_wnpu**) by examining its second parameter and finding it to be **NULL**.

→ **tcv_out**

This function is called whenever a new outgoing packet is ready (the application executes **tcv_endp**) and its return value determines what should be done with the packet – according to the disposition codes listed above. The second argument gives the session ID for the packet pointed to by the first argument.

→ **tcv_xmt**

This function is called whenever a packet has been transmitted by a physical module. Its return value determines the fate of this packet. The arguments are as for **tcv_out**.

→ **tcv_tmt**

This function is called for a packet whose timer goes off. Its return value determines the fate of the packet.

Each of the last three functions (returning disposition codes) accepts a packet handle as the first argument and the session ID as the second argument. Let us emphasize once again that although **tcv_rcv** also returns a disposition code, it (exceptionally) deals with a raw sequence of bytes as opposed to a packet buffer accessible via a handle.

The names of those VNETI functions that are intended to be used solely by plugins start with "**tcvp_**". Below we list those functions in the somewhat accidental order of their subjective relevance. One should note that, if needed, a plugin may call any of the praxis level functions.

```
address tcvp_new (int length, int dsp, int fd)
```

This function creates a new packet **length** bytes long, associates it with session **fd** and sets its disposition code to **dsp**. The length argument refers to the complete length of the entire packet (including any headers and trailers). The packet is not automatically filled with any contents. The function returns the handle to the new packet or **NULL** if there is not enough memory to accommodate the new buffer.

If **dsp** is **TCV_DSP_PASS**, the packet is not assigned to any queue but left detached (e.g., to be stored by the plugin and used later). In that case, **fd** is not required to indicate a legitimate session (**NONE** is recommended in such circumstances).

Note that operations **tcv_read** and **tcv_write** are only applicable to packets that have been acquired (not necessarily by the application but possibly also by the plugin) via **tcv_rnp** or **tcv_wnp**. In particular, they should not be used for filling out or reading a packet created by **tcvp_new**, unless that packet has been directed to the session queue and extracted from it by **tcv_rnp**.

```
void tcvp_dispose (address packet, int dsp)
```

This operation explicitly sets the disposition code for a packet. It can be used, e.g., for changing the disposition code of a packet created internally by the plugin. Return codes of the plugin functions can be viewed as shortcuts for calling **tcvp_dispose** before their return.

Perhaps it makes sense to mention at this point that VNETI does not implement any default dropping policy that would implicitly and automatically remove old (or less important) packets as to make room for the new (or more important) ones. It is up to the plugin to implement such a policy, if it is desired. Note that any packet can be explicitly discarded by setting its disposition code to **TCV_DSP_DROP**, or by calling **tcv_drop** (section 3).

```
address tcvp_clone (address packet, int dsp)
```

This function creates a copy of the indicated packet, sets its disposition code to **dsp**, and returns a handle to the new packet. All the attributes of the clone are inherited from the original, except for the *urgent* attribute, which is cleared. The function returns **NULL** if there is no buffer space available to accommodate the clone.

```
int tcvp_length (address packet)
```

This function returns the total length of the indicated packet (represented by a handle).

```
void tcvp_assign (address packet, int fd)
```

This function assigns the indicated packet to the given session. The second argument must describe an open session. Additionally and automatically, the packet is also assigned to the physical module associated with the session (which looks like the natural thing to do). However, the following operation:

```
void tcvp_attach (address packet, int phid)
```

assigns the packet to the specified physical module while leaving the session attribute intact. This may lead to inconsistencies (if the packet's session is attached to a different

physical module), but may be also OK, e.g., if the packet is to be transmitted and then dropped.

```
Boolean tcvp_isqueued (address packet)
```

The function returns **YES** if and only if the packet appears in one of the *transit* queues of VNETI, i.e., its is queued for reception (at a session) or for transmission (at a PHY). One can also say that such a packet is scheduled for automated processing by VNETI, as opposed to being removed from the transit queues, which typically means that the packet *is* currently being processed (e.g., by the PHY or by a user process).

```
void tcvp_hook (address packet, address *hook)
```

This operation assigns a hook to the packet by storing the packet handle at the indicated **hook** location and noting this fact among the packet's attributes. If the packet is subsequently deallocated, the hook location will be cleared. This mechanism can be viewed as a means of implementing safe packet deallocation, i.e., recognizing those packets whose handles were once saved (by the plugin) but which have been deallocated in the meantime and are not available any more.

```
void tcvp_unhook (address packet)
```

This operation removes the hook from the packet and also clears (sets to **NULL**) the hook location. If the packet is not hooked, the operation is void.

```
address *tcvp_gethook (address packet)
```

This operation returns the pointer to the hook location of the packet, i.e., the address of the address location where the packet's hook is stored. If the packet is not hooked, the returned value is **NULL**.

```
void tcvp_settimer (address packet, word delay)
```

This function sets the timer for the indicated packet to go off after **delay** milliseconds.[3] When the timer goes off, the **tcv_tmt** plugin function will be called for the packet. It is legal to set timers for packets waiting for reception or transmission. If a packet is deallocated before its timer goes off, nothing will happen, i.e., the timer will be automatically voided.

```
void tcvp_cleartimer (address packet)
```

This function clears (unsets) the packet's timer. Nothing happens if no timer was set for the packet.

```
Boolean tcvp_issettimer (address packet)
```

This function returns **YES** if and only if a timer is running for the packet (in other words, the packet is present in the timer queue). Note that this does not preclude the packet's simultaneous presence in a

```
Boolean tcvp_isdetached (address packet)
```

[3] These are "PicOS milliseconds." One PicOS millisecond = 1/1024 s.

This function returns **YES** if and only if the packet is completely detached, i.e., it isn't stored in any transit queue (so **tcvp_queued** would return **NO**) and it also isn't waiting for a timer (so **tcvp_issettimer** would return **NO** as well).

```
int tcvp_control (int phid, int option, address value)
```

This is the plugin-callable function for accessing the control operation of a physical module by its numerical identifier. It provides a direct link to the control function registered by the respective physical module.

The NULL plugin

For illustration, we present here the minimal plugin needed to make VNETI functional as a raw interface to the network. This plugin can be found in file *plug_null.c* in *PicOS/Libs/Lib*. Its simple role is to pass all incoming packets to the application and send out all packets created by the application.

To use this plugin, the application should include the file *plug_null.h*. For illustration, let us consider the following application fragment, which registers a hypothetical physical module, then the NULL plugin, and finally opens a session.

```
...
   tcvphy_reg (0, ctrlfun, MODULE_INFO);
   tcv_plug (0, &plug_null);
   sfd = tcv_open (NONE, 0, 0);
   if (sfd < 0) {
      diag ("Cannot open tcv interface");
      halt ();
   }
   tcv_control (sfd, PHYSOPT_TXOFF, NULL);
   tcv_control (sfd, PHYSOPT_RXOFF, NULL);
...
```

The second argument of **tcv_plug** is a pointer to the plugin structure (of type **tcvplug_t**) specifying the plugin functions. The **open** operation can never block in this case, so its **state** argument is irrelevant.

When we look into *plug_null.c*, we see these definitions:

```
static int tcv_ope (int, int, va_list);
static int tcv_clo (int, int);
static int tcv_rcv (int, address, int, int*, tcvadp_t*);
static int tcv_frm (address, int, tcvadp_t*);
static int tcv_out (address);
static int tcv_xmt (address);

const tcvplug_t plug_null =
   {tcv_ope, tcv_clo, tcv_rcv, tcv_frm, tcv_out, tcv_xmt,
       NULL};
```

The last function of the plugin (responsible for handling timeouts) is absent (its pointer is **NULL**) as the plugin never uses the timers provided by VNETI and, consequently, that function is never called. The most complex function of the plugin is **tcv_ope** listed below.

```
int *desc = NULL;
```

```
static int tcv_ope (int phy, int fd, va_list plid) {
   int i;
   if (desc == NULL) {
      desc = (int*) umalloc (sizeof (int) * TCV_MAX_PHYS);
      if (desc == NULL)
         syserror (EMALLOC, "plug_null tcv_ope");
      for (i = 0; i < TCV_MAX_PHYS; i++)
         desc [i] = NONE;
   }

   /* phy has been verified by TCV */
   if (desc [phy] != NONE)
      return ERROR;
   desc [phy] = fd;
   return 0;
}
```

The function creates an array indexed by physical interfaces and allows the application to open one session (descriptor) per interface. Note that the values of the session descriptors are determined by VNETI before **tcv_ope** is called. No extra open arguments are used by the plugin. The matching close operation looks like this:

```
static int tcv_clo (int phy, int fd) {
   if (desc == NULL || desc [phy] != fd)
      return ERROR;
   desc [phy] = NONE;
   return 0;
}
```

It just removes the session descriptor from the array. The least trivial among the remaining functions is this one:

```
static int tcv_rcv (int phy, address p, int len, int *ses,
    tcvadp_t *b) {

    if (desc == NULL || (*ses = desc [phy]) == NONE)
      return TCV_DSP_PASS;
    b->head = b->tail = 0;
    return TCV_DSP_RCV;
}
```

which is responsible for claiming packets received by physical modules. It checks if there exists an open session whose physical module identifier matches the physical module that has received the packet. If this is the case, the packet is claimed and received. Its disposition is **TCV_DSP_RCV**, which means that the packet is put at the end of the session's incoming queue. Otherwise, the packet is not claimed by the plugin. The plugin sets both offsets determining the portion of the received string to be turned into the packet to zero, which results in passing the entire received string to VNETI. These are the remaining functions of the plugin:

```
static int tcv_frm (address p, int phy, tcvadp_t *b) {
   return b->head = b->tail = 0;
}

static int tcv_out (address p) {
```


```
   return TCV_DSP_XMT;
}

static int tcv_xmt (address p) {
   return TCV_DSP_DROP;
}
```

Their semantics are trivial and obvious.