Host Identity Protocol   M. Komu
Internet-Draft   Helsinki Institute for Information
Intended status: Standards Track   Technology
Expires: September 8, 2007   March 7, 2007

Native Application Programming Interfaces for SHIM Layer Prococols
draft-ietf-hip-native-api-01

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Abstract

This document proposes extensions to the current networking APIs for protocols based on identifier/locator split. Currently, the document focuses on HIP, but the extensions can be used also by other protocols implementing identifier locator split. Using the API extensions, new SHIM aware applications can gain a better control of the SHIM layer and endpoint identifiers. For example, the applications can query and set SHIM related attributes, or specify their own endpoint identifiers for a host. In addition, a new indirection element called endpoint descriptor is defined for SHIM aware applications that can be used for implementing opportunistic mode in a clean way.

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1. Introduction

The extensions defined in this draft can be used also by other protocols based on the identifier/locator split. However, this documented focuses mainly to HIP.

Host Identity Protocol proposes a new cryptographic namespace and a new layer to the TCP/IP architecture. Applications can see these new changes in the networking stacks with varying degrees of visibility. [I-D.henderson-hip-applications] discusses the lowest levels of visibility in which applications are either completely or partially unaware of HIP. In this document, we discuss about the highest level of visibility. The applications are completely HIP aware and can control the HIP layer and Host Identifiers. The applications aquery and set security related attributes and even create their own Host Identifiers.

Existing applications can be used with HIP as described in [I-D.henderson-hip-applications]. The reason why HIP can be used in a backwards compatible way lies in the identifiers. A HIP enabled system can support the use of LSIs, HITs and even IP addresses as upper layer identifiers to accomodate varying application requirements. However, these types of identifiers are not forwards compatible. The length of HIT may turn out insecure in the future. There may be a need to change the HITs on the fly to an already connected socket for dynamic session mobility. Or, the socket is going to be associated to multiple HITs for HIP based multicast.

To support forwards compatibility, we introduce a new, generalized identifier called the endpoint descriptor (ED). The ED acts as a handle to the actual identifier that separates application layer indentifiers from the lower layer identifiers.

The ED can already now be used for implementing HIP opportunistic mode in a clean way. The problem with implementing HIP opportunistic mode is that e.g. sockets API connect() call should be bound to a HIT in order to use HIP, but the HIT is unknown until the reception the R1 packet. At this point it is too late to change the binding e.g. from a IP to HIT. However, the ED has to property of late binding and therefore provides a cleaner way to implement the opportunistic mode.

The ED socket address structure does not reveal the transport layerport number to the application even though it is possible to request it explicitly. This makes it possible to change the port number dynamically without affecting the application. Also, it seems that the port number is irrelevant, or even misleading, in todays NATted networks to the application.

The document also introduces a new address family, PF_SHIM, for sockets that use EDs. The new family is a direct consequence of introducing a new address type (ED) to the sockets API. It can also be used for quick detection of SHIM support in the localhost. This is especially useful discover when SHIM aware applications are tried on a host that does not support SHIM.

The ED concept is similar to Local Scope Identifier [I-D.henderson-hip-applications] in the sense that it is also valid only within a host. However, it has some differences. A minor difference is that two LSIs are the same when they refer to the same endpoint, but ED does not have this constraint. LSIs have a prefix to separate them from IP addresses, but ED do not. However, the main reason why ED is not denoted as LSI in this document is that the LSIs are bound to AF_INET sockets whereas EDs are bound to PF_SHIM sockets.

2. Design Architecture

In this section, the native SHIM API design is described from an architectural point of view. We introduce the ED concept, which is a central idea in the API. We describe the layering and namespace models along with the socket bindings. We conclude the discussion with a description of the endpoint identifier resolution mechanism.

2.1. Endpoint Descriptor

The representation of endpoints is hidden from the applications. The ED is a ``handle'' to a HI. A given ED serves as a pointer to the corresponding HI entry in the HI database of the host. It should be noticed that the ED cannot be used as a referral that is passed from one host to another because it has only local significance.

2.2. Layering Model

The application layer accesses the transport layer via the socket interface. The application layer uses the traditional TCP/IP IPv4 or IPv6 interface, or the new native SHIM API interface provided by the socket layer. The layering model is illustrated in Figure 1. For simplicity, the IPsec layer has been excluded from the figure.

```
                          +-----------------------------------+
      Application Layer   |           Application             |
                          +----------+----------+-------------+
           Socket Layer   | IPv4 API | IPv6 API | SHIM API |
                          +----------+----+-----+----------+
        Transport Layer   |      TCP      |      UDP       |
                          +---------------+----------------+
             SHIM Layer   |       HIP and other SHIMs      |
                          +---------------+----------------+
          Network Layer   |     IPv4      |     IPv6       |
                          +---------------+----------------+
             Link Layer   |   Ethernet    |     Etc        |
                          +---------------+----------------+
```

Figure 1

The SHIM layer is as a shim/wedge layer between the transport and network layers. The datagrams delivered between the transport and network layers are intercepted in the SHIM layer to see if the datagrams are SHIM related and require SHIM intervention.

2.3. Namespace Model

The namespace model is shown in from HIP view point. The namespace identifiers are described in this section.

Layer	Identifier
User Interface	FQDN
Application Layer	ED, port and protocol
Transport Layer	HI, port
SHIM Layer	HI
Network Layer	IP address

Table 1

People prefer human-readable names when referring to network entities. The most commonly used identifier in the User Interface is the FQDN, but there are also other ways to name network entities. The FQDN format is still the preferred UI level identifier in the context of the native SHIM API.

In the current API, connection associations in the application layer are uniquely distinguished by the source IP address, destination IP address, source port, destination port, and protocol. HIP changes this model by using HIT in the place of IP addresses. The HIP model

is further expanded in the native HIP API model by using ED instead of HITs. Now, the application layer uses source ED, destination ED, source port, destination port, and transport protocol type, to distinguish between the different connection associations.

Basically, the difference between the application and transport layer identifiers is that the transport layer uses HIs instead of EDs. The TLI is named with source HI, destination HI, source port, and destination port at the transport layer.

Correspondingly, the HIP layer uses HIs as identifiers. The HIP security associations are based on source HI and destination HI pairs.

The network layer uses IP addresses, i.e., locators, for routing purposes. The network layer interacts with the HIP layer to exchange information about changes in the local interfaces addresses and peer addresses.

2.4. Socket Bindings

A HIP based SHIM socket is associated with one source and one destination ED, along with their port numbers and protocol type. The relationship between a socket and ED is a many-to-one one. Multiple EDs can be associated with a single HI. Further, the source HI is associated with a set of network interfaces at the local host. The destination HI, in turn, is associated with a set of destination addresses of the peer. The socket bindings are visualized in Figure 2.

```
                     1 +---------+ *  * +--------+ *  * +-----------+
                   +---+ Src EID +------+ Src HI +------+ Src Iface |
+--------+ *       |   +---------+      +--------+      +-----------+
|  HIP   +-------+
|        |
| Socket +-------+
+--------+ *       |   +---------+      +--------+      +-----------+
                   +---+ Dst EID +------+ Dst HI +------+  Dst IP   |
                     1 +---------+ *  * +--------+ *  * +-----------+
```

Figure 2

The relationship between a source ED and a source HI is usually many-to-one one, but it can be also many-to-many on certain cases. There are two refinements to the relationship. First, a listening socket is allowed to accept connections from all local HIs of the host. Second, the opportunistic mode allows the base exchange to be initiated to an unknown destination HI. In a way, the relationship

between the local ED and local HI is a many-to-undefined relationship momentarily in both of the cases, but once the connection is established, the ED will be permanently associated with a certain HI.

The DNS based endpoint discovery mechanism is illustrated in Figure 3. The application calls the resolver (step a.) to resolve an FQDN (step b.). The DNS server responds with a ED and a set of locators (step c.). The resolver does not directly pass the ED and the locators to the application, but sends them to the SHIM module (step d.). Finally, the resolver receives an ED from the SHIM module (step e.) and passes the ED to the application (step f.).

```
                             +----------+
                             |          |
                             |   DNS    |
                             |          |
                             +----------+
                                 ^  |
                      b. <FQDN> |  | c. <EID, locator>
                                 |  v
   +-------------+ a. <FQDN>  +----------+
   |             |----------->|          |
   | Application |            | Resolver |
   |             |<-----------|          |
   +-------------+  f. <ED>   +----------+
                                 ^  |
                       e. <ED>  |  | d. <EID, locator>
                                 |  v
                             +----------+
                             |          |
                             |   SHIM   |
                             |          |
                             +----------+
```

Figure 3

The application can also receive multiple EDs from the resolver when the FQDN is associated with multiple EIDs. The endpoint discovery mechanism is still almost the same. The difference is that the DNS returns a set of EIDs (along with the associated locators) to the resolver. The resolver sends all of them to the SHIM module and receives a set of EDs in return, each ED corresponding to a single HI. Finally, the EDs are sent to the application.

3. Interface Syntax and Description

In this section, we describe the native SHIM API using the syntax of

the C programming language and present only the ``external'' interfaces and data structures that are visible to the applications. We limit the description to those interfaces and data structures that are either modified or completely new, because the native SHIM API is otherwise identical to the sockets API [POSIX].

3.1. Data Structures

We introduce a new protocol family, PF_SHIM, for the sockets API. The AF_SHIM constant is an alias for it. The use of the PF_SHIM constant is mandatory with the socket function if the native SHIM API is to be used in the application. The PF_SHIM constant is given as the first argument (domain) to the socket function.

The ED abstraction is realized in the sockaddr_ed structure, which is shown in Figure 4. The family of the socket, ed_family, is set to PF_SHIM. The port number ed_port is two octets and the ED value ed_val is four octets. The ED value is just an opaque number to the application. The application should not try to associate it directly to a EID or even compare it to other ED values, because there are separate functions for those purposes. The ED family is stored in host byte order. The ED value is stored in network byte order. It should be noticed that the port number is not present in the socket address structure, but it can be queried with the functions in section Section 3.2.2.

```
struct sockaddr_ed {
        unsigned short int ed_family;
        sa_ed_t ed_val;
}
```

Figure 4

The ed_val field is usually set by special native SHIM API functions, which are described in the following section. However, three special macros can be used to directly set a value into the ed_val field. The macros are SHIM_ED_ANY, SHIM_ED_ANY_PUB and SHIM_ED_ANY_ANON. They denote an ED value associated with a wildcard HI of any, public, or anonymous type. They are useful to a ``server'' application that is willing to accept connections to all of the HIs of the host. The macros correspond to the sockets API macros INADDR_ANY and IN6ADDR_ANY_INIT, but they are applicable on the SHIM layer. It should be noted that only one process at a time can bind with the SHIM_ED_*ANY macro on a certain port to avoid ambiguous bindings.

The native SHIM API has a new resolver function which is used for querying both endpoint identifiers and locators. The resolver introduces a new data structure, which is used both as the input and

output argument for the resolver. We reuse the existing resolver datastructure shown in Figure 5.

```
struct addrinfo {
    int    ai_flags;           /* e.g. AI_ED */
    int    ai_family;          /* e.g. PF_SHIM */
    int    ai_socktype;        /* e.g. SOCK_STREAM */
    int    ai_protocol;        /* usually just zero */
    size_t ai_addrlen;         /* length of the endpoint */
    struct sockaddr *ai_addr; /* endpoint socket address */
    char   *ai_canonname;      /* canon. name of the host */
    struct addrinfo *ai_next; /* next endpoint */
};
```

Figure 5

In addrinfo structures, the family field is set to PF_SHIM when the socket address structure contains an ED that refers to a SHIM identifier, such as HI.

The flags in the addrinfo structure control the behavior of the resolver and describe the attributes of the endpoints and locators:

- The flag AI_ED must be set, or otherwise the resolver does not return EDs to guarantee that legacy applications won't break. When AI_ED is set, the resolver returns a linked list which contains first the sockaddr_ed structures for SHIM identifiers if any was found. After that, any other type of socket addresses are returned except that HITs in sockaddr_in6 format are excluded because they were already included in the returned sockaddr_ed structures.

- When querying local identifiers, the AI_ED_ANON flag forces the resolver to query only local anonymous identifiers. The default action is first to resolve the public endpoints and then the anonymous endpoints.

- Some applications may prefer configuring the locators manually and can set the AI_ED_NOLOCATORS flag to prohibit the resolver from resolving any locators.

- The AI_ED_ANY, AI_ED_ANY_PUB and AI_ED_ANY_ANON flags cause the resolver to output only a single socket address containing an ED that would be received using the corresponding SHIM_ED_*ANY macro. When these flags are used for resolving local addresses, they allow wildcard late binding to certain types of local idenfiers. When the flags are used for peer resolving, they allow to contact the peer using opportunistic mode.

o The getaddrinfo resolver does not return IP addresses belonging to a SHIM rendezvous server unless AI_ED is defined. AI_ED_RVS, can appear both in the input and output arguments of the resolver. In the input, it can be used for resolving only rendezvous server addresses. On the output, it denotes that the address is a rendezvous rather than end-point address.

Application specified endpoint identifiers are essentially private keys. To support application specified identifiers in the API, we introduce new data structures for storing the private keys. The private keys need an uniform format so that they can be easily used in the API calls. The keys are stored in the endpoint structures as shown in Figure 6.

```
struct endpoint {
        se_length_t   length;
        se_family_t   family;
};
struct endpoint_hip {
        se_length_t length;
        se_family_t family; /* EF_HI in the case of HIP */
        se_hip_flags_t flags;
        union {
                struct hip_host_id host_id;
                hit_t hit;
        } id;
};
```

Figure 6

The endpoint structure represents a generic endpoint and the endpoint_hip structure represents a HIP specific endpoint. The family field distinguishes whether the identifier is HIP or other protocol related. The HIP endpoint is public by default unless SHIM_ENDPOINT_FLAG_ANON flag is set in the structure to anonymize the endpoint. The id union contains the HI in the host_id member in the format specified in [I-D.ietf-hip-base]. If the key is private, the material is appended to the host_id with the length adjusted accordingly. The flag SHIM_ENDPOINT_FLAG_PRIVATE is also set. The hit member of the union is used only when the SHIM_ENDPOINT_FLAG_HIT flag is set.

3.2. Functions

In this section, some existing sockets API functions are reintroduced along with their additions. Also, some new auxiliary functions are defined.

3.2.1. Resolver Interface

The native SHIM API does not introduce changes to the interface syntax of the primitive sockets API functions bind, connect, send, sendto, sendmsg, recv, recvfrom, and recvmsg. However, the application usually calls the functions with sockaddr_ed structures instead of sockaddr_in or sockaddr_in6 structures. The source of the sockaddr_ed structures in the native SHIM API is the resolver function getaddrinfo [RFC3493] which is shown in Figure 7.

```
int getaddrinfo(const char *nodename,
                const char *servname,
                const struct addrinfo *hints,
                struct addrinfo **res)
void free_addrinfo(struct addrinfo *res)
```

Figure 7

The getaddrinfo function takes the nodename, servname, and hints as its input arguments. It places the result of the query into the res argument. The return value is zero on success, or a non-zero error value on error. The nodename argument specifies the host name to be resolved; a NULL argument denotes the local host. The servname parameter sets the port number to be set in the socket addresses in the res output argument. Both the nodename and servname cannot be NULL.

The output argument res is dynamically allocated by the resolver. The application must free res argument with the free_addrinfo function. The res argument contains a linked list of the resolved endpoints. The input argument hints acts like a filter that defines the attributes required from the resolved endpoints. For example, setting the flag SHIM_ENDPOINT_FLAG_ANON in the hints forces the resolver to return only anonymous endpoints in the output argument res. A NULL hints argument indicates that any kind of endpoints are acceptable.

3.2.2. Application Specified Identities

Application specified local and peer endpoints can be retrieved from files using the function shown in Figure 8. The function shim_endpoint_load_pem is used for retrieving a private or public key from a given file filename. The file must be in PEM encoded format. The result is allocated dynamically and stored into the endpoint argument. The return value of the function is zero on success, or a non-zero error value on failure. The result is deallocated with the free system call.

```
        int shim_endpoint_pem_load(const char *filename,
                                   struct endpoint **endpoint)
```

Figure 8

Alternatively, the application can load the image directly from memory as shown in Figure 9

```
        int shim_endpoint_pem_load_str(const char *pem_str,
                                       struct endpoint **endpoint);
```

Figure 9

The endpoint structure cannot be used directly in the sockets API function calls. The application must convert the endpoint into an ED first. Local endpoints are converted with the getlocaled function and peer endpoints with getpeered function. The functions are illustrated in Figure 10.

```
     struct sockaddr_ed *getlocaled(const struct endpoint *endpoint,
                                   const char *servname,
                                   const struct addrinfo *addrs,
                                   const struct if_nameindex *ifaces,
                                   int flags)
     struct sockaddr_ed *getpeered(const struct endpoint *endpoint,
                                   const char *servname,
                                   const struct addrinfo *addrs,
                                   int flags)
```

Figure 10

The result of the conversion, an ED socket address, is returned by both of the functions. A failure in the conversion causes a NULL return value to be returned and the errno to be set accordingly. The caller of the functions is responsible of freeing the returned socket address structure.

The application can retrieve the endpoint argument e.g. with the shim_endpoint_load_pem function. If the endpoint is NULL, the system selects an arbitrary EID and associates it with the ED value of the return value.

The servname argument is the service string. The function converts it to a numeric port number and fills the port number into the returned ED socket structure for the convenience of the application.

The addrs argument defines the initial IP addresses of the local host or peer host. The argument is a pointer to a linked list of addrinfo structures containing the initial addresses of the peer. The list pointer can be obtained with a getaddrinfo [RFC3493] function call. A NULL pointer indicates that the application trusts the host to already know the locators of the peer. We recommend that a NULL pointer is not given to the getpeered function to ensure reachability with the peer.

The getlocaled function accepts also a list of network interface indexes in the ifaces argument. The list can be obtained with the if_nameindex [RFC3493] function call. A NULL list pointer indicates all the interfaces of the local host. Both the IP addresses and interfaces can be combined to select a specific address from a specific interface.

The last argument is the flags. The following flags are valid only for the getlocaled function:

o Flags SHIM_ED_REUSE_UID, SHIM_ED_REUSE_GID and SHIM_ED_REUSE_ANY allow the EID (e.g. a large private key) to be reused for processes with the same UID, GID or any UID as the calling process.

o Flags SHIM_ED_IPV4 and SHIM_ED_IPV6 can be used for limiting the address family scope of the local interface.

It should noticed that the SHIM_ED_ANY, SHIM_ED_ANY_PUB and SHIM_ED_ANY_ANON macros can be implemented as calls to the getlocaled call with a NULL endpoint, NULL interface, NULL address argument and the flag corresponding to the macro name set.

3.2.3. Querying Endpoint Related Information

The getlocaled and getpeered functions have also their reverse counterparts. Given an ED, the getlocaledinfo and getpeeredinfo functions search for the EID (e.g. a HI) and the current set of locators associated with the ED. The first argument is the ED to be searched for. The functions write the results of the search, the transport layer port number of the occupied by the correponding HIT, the HIs and locators, to the rest of the function arguments. The function interfaces are depicted in Figure 11. The caller of the functions is responsible for freeing the memory reserved for the search results.

```
int getlocaledinfo(const struct sockaddr_ed *my_ed,
                   struct in_port_t **port
                   struct endpoint **endpoint,
                   struct addrinfo **addrs,
                   struct if_nameindex **ifaces)
int getpeeredinfo(const struct sockaddr_ed *peer_ed,
                  struct in_port_t **port
                  struct endpoint **endpoint,
                  struct addrinfo **addrs)
```

Figure 11

The getlocaledinfo and getpeeredinfo functions are especially useful for an advanced application that receives multiple EDs from the resolver. The advanced application can query the properties of the EDs using getlocaledinfo and getpeeredinfo functions and select the ED that matches the desired properties.

3.2.4. HIP Related Policy Attributes

Multihoming related attributes are defined in [I-D.ietf-shim6-multihome-shim-api]. It also specifies an event driven API for application, which can be used for listening for changes in locators.

HIP related policy attributes are accessed using the definitions in [I-D.komu-btns-api]

Some of the policy attributes must be set before the hosts have established connection. The implementation may refuse to accept the option when there is already an existing connection and dynamic renegotiation of the option is not possible. In addition, the SHIM may return an error value if the corresponding SHIM protocol does not support the given option.

Table 2shows HIP related policy attributes that are accessed with the APIs defined in [I-D.komu-btns-api].

Attribute	Purpose
IPSEC_ESP_TRANSFORM	Preferred ESP transform
IPSEC_SA_LIFETIME	Preferred IPsec SA lifetime in seconds
SHIM_PROTOCOL	Get or set current SHIM protocol. Currently only PF_HIP is defined.
SHIM_CHALLENGE_SIZE	Puzzle challenge size
SHIM_SHIM_TRANSFORM	Preferred SHIM transform
SHIM_DH_GROUP_IDS	The preferred Diffie-Hellman Group
SHIM_AF_FAMILY	The preferred locator family. The default family is AF_ANY.
SHIM_FAST_FALLBACK	If set to one, use the extensions in [I-D.lindqvist-hip-opportunistic]
SHIM_FAST_HANDSHAKE	If set to one, use the extensions in [I-D.lindqvist-hip-tcp-piggybacking]

Table 2

4. IANA Considerations

No IANA considerations.

5. Security Considerations

To be done.

6. Acknowledgements

Jukka Ylitalo and Pekka Nikander have contributed many ideas, time and effort to the native HIP API. Thomas Henderson, Kristian Slavov, Julien Laganier, Jaakko Kangasharju, Mika Kousa, Jan Melen, Andrew McGregor, Sasu Tarkoma, Lars Eggert, Joe Touch, Antti Jaervinen, Anthony Joseph, Teemu Koponen and Juha-Matti Tapio have also provided valuable ideas and feedback.

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Acknowledgment

Funding for the RFC Editor function is provided by the IETF Administrative Support Activity (IASA).