

# The Abstraction Layer (v.1.6.1)

The Abstraction Layer (AL) is a library to interface a DTN application with the Bundle Protocol independently of the actual Bundle Protocol (BP) implementation. By decoupling the application code from the BP implementation, it is possible to reuse the same application code in different DTN environments, with significant advantages in terms of application portability, maintenance and interoperability. A possible drawback is the dependence of the AL on more than one BP implementation. At present, the AL supports DTN2, ION, and IBR-DTN BP implementations.

The AL consists of two elements:

- the AL Types;
- the AL API.

As the present AL version has been created to support the DTNperf\_3 application, only the types and the functions necessary for this purpose have been “abstracted”. Other DTN applications could require the abstraction of others elements as well.

The present release includes a set of new functions, called “extB” (extensions by Bisacchi), which extends the previous version, trying to provide the programmer with an interface closer to the TCP/UDP socket syntax for C (BSD version); they will be described apart as their use is optional. The API documentation refers to AL ver: 1.6.1, released in May 2019.

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# 1 ABSTRACTION LAYER TYPES

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AL Types are an abstraction of DTN2, ION, and IBR-DTN types. They are denoted by the “al\_bp” prefix and defined in file “al\_bp\_types.h”.

The types are divided into four groups: general, registration EID, bundle, status report types.

For each group, the table below show the correspondence between AL, DTN2, ION, and IBR-DTN types. Empty cells mean that there is not any direct correspondence to the implementation specific types.

Note that, as the AL, the DTN2 API, and the ION API are written in C while the IBR-DTN API is written in C++ and object-oriented, the correspondence presented in this document between the IBR-DTN API and the other ones is approximate.

Abstraction Layer	DTN2	ION	IBR-DTN
<b>General Types</b>			
al_bp_handle_t int *	dtm_handle_t int*	BpSAP bpsap_st *{ VEndpoint* vpoint; MetaEid endpointMetaEid; sm_SemId recvSemaphore; }	dtm::api::Client
al_bp_endpoint_id_t {char uri[AL_BP_MAX_ENDPOINT_ID]}	dtm_endpoint_id_t {char uri[DTN_MAX_ENDPOINT_ID]}	char *	dtm::data::EID
al_bp_timeval_t u32_t	dtm_timeval_t u_int	DtmTime { unsigned long seconds; unsigned long nanosec; }	dtm::data::Number

<pre>al_bp_timestamp_t {   u32_t secs;   u32_t seqno; }</pre>	<pre>dtn_timestamp_t {   u_hyper secs;   u_hyper seqno; }</pre>	<pre>BpTimestamp {   unsigned long seconds;   unsigned long count; }</pre>	<pre>dtn::data::Timestamp dtn::data::Number</pre>
<pre>al_bp_error_t { BP_SUCCESS   BP_ERRBASE;   BP_ENOBPI;   BP_EINVAL;   BP_ENULLPNTR;   BP_EUNREG;   BP_ECONNECT;   BP_ETIMEOUT;   BP_ESIZE;   BP_ENOTFOUND;   BP_EINTERNAL;   BP_EBUSY;   BP_ENOSPACE;   BP_ENOTIMPL;   BP_EATTACH;   BP_EBUILDEID   BP_EOPEN;   BP_EREQ;   BP_EPARSEID;   BP_ESEND;   BP_ERECD;   BP_ERECDINT;}</pre>			
<b>Registration EID Types</b>			
<pre>al_bp_reg_token_t u32_t</pre>	<pre>dtn_reg_token_t u_hyper</pre>		
<pre>al_bp_reg_id_t u32_t</pre>	<pre>dtn_reg_id_t u_int</pre>		

<pre>al_bp_reg_info_t { al_bp_endpoint_id_t endpoint;   al_bp_reg_id_t regid;   u32_t flags;   u32_t replay_flags;   al_bp_timeval_t expiration;   boolean_t init_passive;   al_bp_reg_token_t reg_token;   struct {     u32_t script_len;     char *script_val;} script; }</pre>	<pre>dtm_reg_info_t { dtm_endpoint_id_t endpoint;   dtm_reg_id_t regid;   u_int flags;   u_int replay_flags;   dtm_timeval_t expiration;   bool_t init_passive;   dtm_reg_token_t reg_token;   struct {     u_int script_len;     char *script_val;} script; }</pre>		
<pre>al_bp_reg_flags_t { BP_REG_DROP = 1,   BP_REG_DEFER = 2,   BP_REG_EXEC = 3,   BP_SESSION_CUSTODY = 4,   BP_SESSION_PUBLISH = 8,   BP_SESSION_SUBSCRIBE = 16,   BP_DELIVERY_ACKS = 32 }</pre>	<pre>dtm_reg_flags_t { DTN_REG_DROP = 1,   DTN_REG_DEFER = 2,   DTN_REG_EXEC = 3,   DTN_SESSION_CUSTODY = 4,   DTN_SESSION_PUBLISH = 8,   DTN_SESSION_SUBSCRIBE = 16,   DTN_DELIVERY_ACKS = 32 }</pre>	<pre>BpRecvRule {DiscardBundle,   EnqueueBundle, }</pre>	
<b>Bundle Types</b>			
<pre>al_bp_bundle_delivery_opts_t {   BP_DOPTS_NONE = 0,   BP_DOPTS_CUSTODY = 1,   BP_DOPTS_DELIVERY_RCPT = 2,   BP_DOPTS_RECEIVE_RCPT = 4,   BP_DOPTS_FORWARD_RCPT = 8,   BP_DOPTS_CUSTODY_RCPT = 16,   BP_DOPTS_DELETE_RCPT = 32,   BP_DOPTS_SINGLETON_DEST = 64,   BP_DOPTS_MULTINODE_DEST = 128,   BP_DOPTS_DO_NOT_FRAGMENT = 256, }</pre>	<pre>dtm_bundle_delivery_opts_t {   DOPTS_NONE = 0,   DOPTS_CUSTODY = 1,   DOPTS_DELIVERY_RCPT = 2,   DOPTS_RECEIVE_RCPT = 4,   DOPTS_FORWARD_RCPT = 8,   DOPTS_CUSTODY_RCPT = 16,   DOPTS_DELETE_RCPT = 32,   DOPTS_SINGLETON_DEST = 64,   DOPTS_MULTINODE_DEST = 128,   DOPTS_DO_NOT_FRAGMENT = 256, }</pre>	<pre>int {   BP_DELIVERED_RPT;   BP_RECEIVED_RPT;   BP_FORWARDED_RPT;   BP_CUSTODY_RPT;   BP_DELETED_RPT; }</pre>	<pre>dtm::data::PrimaryBlock::FLAGS {   FRAGMENT = 0x01,   APPDATA_IS_ADMRECORD = 0x02,   DONT_FRAGMENT = 0x04,   CUSTODY_REQUESTED = 0x08,   DESTINATION_IS_SINGLETON = 0x10,   ACKOFAPP_REQUESTED = 0x20,   REQUEST_REPORT_OF_BUNDLE_RECE PTION = 0x4000,   REQUEST_REPORT_OF_CUSTODY_AC CEPTANCE = 0x8000,   REQUEST_REPORT_OF_BUNDLE_FOR WARDING = 0x10000,   REQUEST_REPORT_OF_BUNDLE_DELI VERY = 0x20000,   REQUEST_REPORT_OF_BUNDLE_DELE TION = 0x40000 }</pre>

<pre>al_bp_bundle_priority_t {   al_bp_bundle_priority_enum priority   {     BP_PRIORITY_BULK = 0,     BP_PRIORITY_NORMAL = 1,     BP_PRIORITY_EXPEDITED = 2,     BP_PRIORITY_RESERVED = 3,   }   u32_t ordinal; }</pre>	<pre>dtn_bundle_priority_t {   COS_BULK = 0,   COS_NORMAL = 1,   COS_EXPEDITED = 2,   COS_RESERVED = 3, }</pre>	<pre>int {   BP_BULK_PRIORITY (0)   BP_STD_PRIORITY (1)   BP_EXPEDITED_PRIORITY (2) }</pre>	<pre>dtn::data::PrimaryBlock::PRIORITY {   PRIO_LOW = 0,   PRIO_MEDIUM = 1,   PRIO_HIGH = 2 }</pre>
<pre>al_bp_extension_block_t {   u32_t type;   u32_t flags;   struct {     u32_t data_len;     char *data_val;   } data; }</pre>			<pre>dtn::data::ExtensionBlock {   block_t blocktype;   Bitset&lt;ProcFlags&gt; _procflags;   ibrccommon::BLOB::Reference   _blobref; }</pre>

<pre> al_bp_bundle_spec_t {     al_bp_endpoint_id_t source;     al_bp_endpoint_id_t dest;     al_bp_endpoint_id_t replyto;     al_bp_bundle_priority_t priority;     al_bp_bundle_delivery_opts_t dopts;     al_bp_timeval_t expiration;     al_bp_timestamp_t creation_ts;     al_bp_reg_id_t delivery_regid;     struct {         u32_t blocks_len;          al_bp_extension_block_t *blocks_val;     } blocks;     struct {         u32_t metadata_len;          al_bp_extension_block_t *metadata_val;     } metadata;     boolean_t unreliable;     boolean_t critical;     u32_t flow_label; } </pre>	<pre> dtn_bundle_spec_t {     dtn_endpoint_id_t source;     dtn_endpoint_id_t dest;     dtn_endpoint_id_t replyto;     dtn_bundle_priority_t priority;     int dopts;     dtn_timeval_t expiration;     dtn_timestamp_t creation_ts;     dtn_reg_id_t delivery_regid;     dtn_sequence_id_t sequence_id;     dtn_sequence_id_t obsoletes_id;     struct {         u_int blocks_len;         dtn_extension_block_t *blocks_val;     } blocks;     struct {         u_int metadata_len;         dtn_extension_block_t *metadata_val;     } metadata; } </pre>		<pre> dtn::data::Bundle {     EID source;     Timestamp timestamp;     Number sequencenumber;     Number fragmentoffset;     Bitset&lt;FLAGS&gt; proclags;     Number lifetime;     Number appdatalength;     EID destination;     EID reportto;     EID custodian;     block_list_blocks; } </pre>
<pre> al_bp_bundle_payload_location_t {     BP_PAYLOAD_FILE = 0,     BP_PAYLOAD_MEM = 1,     BP_PAYLOAD_TEMP_FILE = 2, } </pre>	<pre> dtn_bundle_payload_location_t {     DTN_PAYLOAD_FILE = 0,     DTN_PAYLOAD_MEM = 1,     DTN_PAYLOAD_TEMP_FILE = 2, } </pre>		

<pre> al_bp_bundle_id_t {     al_bp_endpoint_id_t source;     al_bp_timestamp_t creation_ts;     u32_t frag_offset;     u32_t orig_length; } </pre>	<pre> dtn_bundle_id_t {     dtn_endpoint_id_t source;     dtn_timestamp_t creation_ts;     u_int frag_offset;     u_int orig_length; } </pre>	<pre> BundleId {     EndpointId source;     BpTimestamp creationTime;     unsigned long fragmentOffset; } </pre>	<pre> dtn::data::BundleID {     EID source;     Timestamp timestamp;     Number sequencenumber;     Number fragmentoffset; } </pre>
<pre> al_bp_bundle_payload_t {     al_bp_bundle_payload_location_t location;     struct     {         u32_t filename_len;         char *filename_val;     } filename;     struct     {         u32_t buf_len;         char *buf_val;     } buf;     al_bp_bundle_status_report_t *status_report; } </pre>	<pre> dtn_bundle_payload_t {     dtn_bundle_payload_location_t location;     struct {         u_int filename_len;         char *filename_val;     } filename;     struct {         u_int buf_len;         char *buf_val;     } buf;     dtn_bundle_status_report_t *status_report; } </pre>	<pre> Payload {     unsigned long length;     Object content; } </pre>	<pre> dtn::data::PayloadBlock {     block_t blocktype;     Bitset&lt;ProcFlags&gt; _procflags;     ibrcommon::BLOB::Reference _blobref; } </pre>
<pre> al_bp_bundle_object_t {     al_bp_bundle_id_t * id;     al_bp_bundle_spec_t * spec;     al_bp_bundle_payload_t * payload; } </pre>			

**Status Report Types**

<pre>al_bp_status_report_reason_t {   BP_SR_REASON_NO_ADDTL_INFO = 0x00,   BP_SR_REASON_LIFETIME_EXPIRED = 0x01,   BP_SR_REASON_FORWARDED_UNID IR_LINK = 0x02,   BP_SR_REASON_TRANSMISSION_CA NCELED = 0x03,   BP_SR_REASON_DEPLETED_STORAG E = 0x04,   BP_SR_REASON_ENDPOINT_ID_UNI NTELLIGIBLE = 0x05,   BP_SR_REASON_NO_ROUTE_TO_DES T = 0x06,   BP_SR_REASON_NO_TIMELY_CONTA CT = 0x07,   BP_SR_REASON_BLOCK_UNINTELLIG IBLE = 0x08, }</pre>	<pre>dtn_status_report_reason_t {   REASON_NO_ADDTL_INFO = 0x00,   REASON_LIFETIME_EXPIRED = 0x01,   REASON_FORWARDED_UNIDIR_LINK = 0x02,   REASON_TRANSMISSION_CANCELE D = 0x03,   REASON_DEPLETED_STORAGE = 0x04,   REASON_ENDPOINT_ID_UNINTELLIG IBLE = 0x05,   REASON_NO_ROUTE_TO_DEST = 0x06,   REASON_NO_TIMELY_CONTACT = 0x07,   REASON_BLOCK_UNINTELLIGIBLE = 0x08, }</pre>	<pre>BpSrReason {   SrLifetimeExpired = 1,   SrUnidirectionalLink,   SrCanceled,   SrDepletedStorage,   SrDestinationUnintelligible,   SrNoKnownRoute,   SrNoTimelyContact,   SrBlockUnintelligible }</pre>	<pre>dtn::data::StatusReportBlock::TYPE {   NO_ADDITIONAL_INFORMATION = 0x00,   LIFETIME_EXPIRED = 0x01,   FORWARDED_OVER_UNIDIRECTIONA L_LINK = 0x02,   TRANSMISSION_CANCELED = 0x03,   DEPLETED_STORAGE = 0x04,   DESTINATION_ENDPOINT_ID_UNINTE LLIGIBLE = 0x05,   NO_KNOWN_ROUTE_TO_DESTINATIO N_FROM_HERE = 0x06,   NO_TIMELY_CONTACT_WITH_NEXT_N ODE_ON_ROUTE = 0x07,   BLOCK_UNINTELLIGIBLE = 0x08 }</pre>
<pre>al_bp_status_report_flags_t {   BP_STATUS_RECEIVED = 0x01,   BP_STATUS_CUSTODY_ACCEPTED = 0x02,   BP_STATUS_FORWARDED = 0x04,   BP_STATUS_DELIVERED = 0x08,   BP_STATUS_DELETED = 0x10,   BP_STATUS_ACKED_BY_APP = 0x20, }</pre>	<pre>dtn_status_report_flags_t {   STATUS_RECEIVED = 0x01,   STATUS_CUSTODY_ACCEPTED = 0x02,   STATUS_FORWARDED = 0x04,   STATUS_DELIVERED = 0x08,   STATUS_DELETED = 0x10,   STATUS_ACKED_BY_APP = 0x20, }</pre>	<pre>int {   BP_STATUS_RECEIVE 0   BP_STATUS_ACCEPT 1   BP_STATUS_FORWARD 2   BP_STATUS_DELIVER 3   BP_STATUS_DELETE 4   BP_STATUS_STATS 5 }</pre>	<pre>dtn::data::StatusReportBlock::TYPE {   RECEIPT_OF_BUNDLE = 0x01,   CUSTODY_ACCEPTANCE_OF_BUNDLE = 0x02,   FORWARDING_OF_BUNDLE = 0x04,   DELIVERY_OF_BUNDLE = 0x08,   DELETION_OF_BUNDLE = 0x10 }</pre>

<pre> al_bp_bundle_status_report_t {     al_bp_bundle_id_t bundle_id;     al_bp_status_report_reason_t reason;     al_bp_status_report_flags_t flags;     al_bp_timestamp_t receipt_ts;     al_bp_timestamp_t custody_ts;     al_bp_timestamp_t forwarding_ts;     al_bp_timestamp_t delivery_ts;     al_bp_timestamp_t deletion_ts;     al_bp_timestamp_t ack_by_app_ts; } </pre>	<pre> dtn_bundle_status_report_t {     dtn_bundle_id_t bundle_id;     dtn_status_report_reason_t reason;     dtn_status_report_flags_t flags;     dtn_timestamp_t receipt_ts;     dtn_timestamp_t custody_ts;     dtn_timestamp_t forwarding_ts;     dtn_timestamp_t delivery_ts;     dtn_timestamp_t deletion_ts;     dtn_timestamp_t ack_by_app_ts; } </pre>	<pre> BpStatusRpt {     BpTimestamp creationTime;     unsigned long fragmentOffset;     unsigned long fragmentLength;     char *sourceEid;     unsigned char isFragment;     unsigned char flags;     BpSrReason reasonCode;     DtnTime receiptTime;     DtnTime acceptanceTime;     DtnTime forwardTime;     DtnTime deliveryTime;     DtnTime deletionTime; } </pre>	<pre> dtn::data::StatusReportBlock {     char status;     char reasoncode;     DTNTime timeof_receipt;     DTNTime timeof_custodyaccept;     DTNTime timeof_forwarding;     DTNTime timeof_delivery;     DTNTime timeof_deletion;     BundleID bundleid; } </pre>
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## 2 ABSTRACTION LAYER API

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The AL API aims to decouple the application code from the API of a specific BP implementation. The scheme below summarizes the use of the most important functions of the basic layer of AL\_BP (al\_bp prefix). The al\_bp\_unregister must be called only when the active implementation is ION.

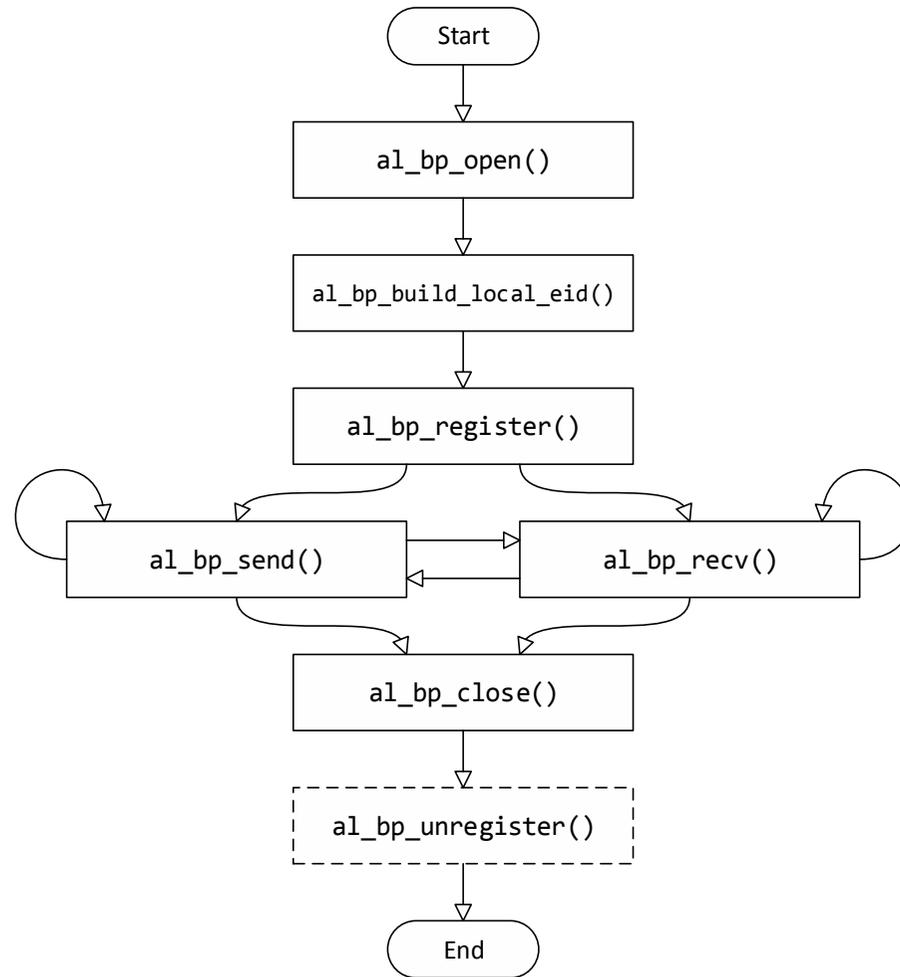


Figure 1. Typical flow of the most significant AL\_BP basic (al\_bp) functions.

The AL API functions are denoted by the “al\_bp” prefix and are defined in file “al\_bp\_api.h”. Every AL function calls the corresponding function of the specific BP implementation. APIs of DTN2, ION, and IBR-DTN are called by specific functions, denoted as bp\_xxx (xxx=, dtn, ion, ibr), declared in files “al\_bp\_dtn.h”, “al\_bp\_ion.h”, and “al\_bp\_ibr.h”.

The AL functions are divided into three groups: basic, utility and bundle functions.

## 2.1 BASIC AND UTILITY FUNCTIONS

In the table below the correspondence between AL, DTN2, ION and IBR-DTN APIs is presented for the basic functions and utility functions. The former are a direct abstraction of one or more implementation-specific functions, as shown in the table below. The latter have a looser correspondence (if any) and perform auxiliary tasks.

Bundle functions are not listed in the table because they do not correspond to any DTN2, ION, or IBR-DTN function. In fact, they are designed to manage errors and to have a better control of the bundle as an object and will be examined in the next section.

Abstraction Layer	DTN2	ION	IBR-DTN
<b>Basic functions</b>			
al_bp_open( al_bp_handle_t* handle )	dtm_open( dtm_handle_t* handle )	bp_attach( )	ibrcommon::vaddress::vaddress( const std::string &address, const int port ) ibrcommon::tcpsocket::tcpsocket( const ibrcommon::vaddress &destination ) ibrcommon::socketstream::socketstream( ibrcommon::socket *sock )
al_bp_open_with_ip( char *daemon_api_IP, int daemon_api_port, al_bp_handle_t* handle )	dtm_open_with_IP( char *daemon_api_IP, int daemon_api_port, dtm_handle_t* handle )		ibrcommon::vaddress::vaddress( const std::string &address, const int port ) ibrcommon::tcpsocket::tcpsocket( const ibrcommon::vaddress &destination ) ibrcommon::socketstream::socketstream( ibrcommon::socket *sock )
al_bp_errno( al_bp_handle_t handle )	dtm_errno( dtm_handle_t handle )	system_error_msg( )	

<pre>al_bp_build_local_eid(   al_bp_handle_t handle,   al_bp_endpoint_id_t* local_eid,   const char* service_tag,   al_bp_scheme_t type )</pre>	<pre>dtm_build_local_eid(   dtm_handle_t handle,   dtm_endpoint_id_t* local_eid,   const char* service_tag )</pre>		
<pre>al_bp_register(   al_bp_handle_t * handle,   al_bp_reg_info_t * reginfo,   al_bp_reg_id_t * newregid )</pre>	<pre>dtm_register(   dtm_handle_t handle,   dtm_reg_info_t* reginfo,   dtm_reg_id_t* newregid )</pre>	<pre>addEndpoint(   char *endpointName,   BpRecvRule recvAction,   char *recvScript)  bp_open(   char * eid,   BpSAP * ionptr )</pre>	<pre>dtm::api::Client::Client(   const std::string &amp;app,   ibrccommon::socketstream &amp;stream )</pre>
<pre>al_bp_unregister(   al_bp_handle_t handle,   al_bp_reg_id_t regid,   al_bp_endpoint_id_t eid )</pre>	<pre>dtm_unregister(   dtm_handle_t handle,   dtm_reg_id_t regid )</pre>	<pre>removeEndpoint(   char *endpointName )</pre>	<pre>dtm::api::Client::~~Client()</pre>
<pre>al_bp_find_registration(   al_bp_handle_t handle,   al_bp_endpoint_id_t * eid,   al_bp_reg_id_t * newregid )</pre>	<pre>dtm_find_registration(   dtm_handle_t handle,   dtm_endpoint_id_t* eid,   dtm_reg_id_t* newregid )</pre>	<pre>findEndpoint(   char *schemeName,   char *nss,   VScheme *vscheme,   VEndpoint **vpoint,   PsmAddress *elt )</pre>	

<pre>al_bp_send(   al_bp_handle_t handle,   al_bp_reg_id_t regid,   al_bp_bundle_spec_t* spec,   al_bp_bundle_payload_t* payload,   al_bp_bundle_id_t* id )</pre>	<pre>dtm_send(   dtm_handle_t handle,   dtm_reg_id_t regid,   dtm_bundle_spec_t* spec,   dtm_bundle_payload_t* payload,   dtm_bundle_id_t* id )</pre>	<pre>bp_send(   BpSAP sap,   int mode,   char * destEid,   char * reportToEid,   int lifespan,   int classOfService,   BpCustodySwitch custodySwitch,   unsigned char srrFlags,   int ackRequested,   BpExtendedCOS* extendedCOS,   Object adu,   Object *newBundle )</pre>	<pre>void dtm::api::Client::operator&lt;&lt;(   const dtm::data::Bundle &amp;b )</pre>
<pre>al_bp_recv(   al_bp_handle_t handle,   al_bp_bundle_spec_t* spec,   al_bp_bundle_payload_location_t location,   al_bp_bundle_payload_t* payload,   al_bp_timeval_t timeout )</pre>	<pre>dtm_recv(   dtm_handle_t handle,   dtm_bundle_spec_t* spec,   dtm_bundle_payload_location_t location,   dtm_bundle_payload_t* payload,   dtm_timeval_t timeout )</pre>	<pre>bp_receive(   BpSAP sap,   BpDelivery *dlvBuffer,   int timeoutSeconds )</pre>	<pre>dtm::data::Bundle dtm::api::Client::getBundle(   const dtm::data::Timeout timeout = 0 )</pre>
<pre>al_bp_close(   al_bp_handle_t handle )</pre>	<pre>dtm_close(   dtm_handle_t handle )</pre>	<pre>bp_close(   BpSAP ionptr )</pre>	<pre>ibrccommon::socketstream::close()</pre>
<b>Utility functions</b>			
<pre>al_bp_get_implementation()</pre>			
<pre>void al_bp_copy_eid(   al_bp_endpoint_id_t* dst,   al_bp_endpoint_id_t* src )</pre>	<pre>void dtm_copy_eid(   dtm_endpoint_id_t* dst,   dtm_endpoint_id_t* src )</pre>		
<pre>al_bp_error_t al_bp_parse_eid_string(   al_bp_endpoint_id_t* eid,   const char* str )</pre>	<pre>int dtm_parse_eid_string(   dtm_endpoint_id_t* eid,   const char* str )</pre>	<pre>int parseEidString(   char *eidString,   MetaEid *metaEid,   VScheme **scheme,   PsmAddress *schemeElt )</pre>	<pre>dtm::data::EID::EID(   const std::string &amp;value )</pre>

al_bp_error_t al_bp_get_none_endpoint( al_bp_endpoint_id_t *eid_none )			
al_bp_error_t al_bp_set_payload( al_bp_bundle_payload_t* payload, al_bp_bundle_payload_location_t location, char* val, int len )	int dtn_set_payload( dtn_bundle_payload_t* payload, dtn_bundle_payload_location_t location, char* val, int len )		
void al_bp_free_payload( al_bp_bundle_payload_t* payload )	int dtn_free_payload( dtn_bundle_payload_t* payload )	zco_destroy_file_ref( Sdr sdr, Object fileRef )	
void al_bp_free_extension_blocks( al_bp_bundle_spec_t* spec )			
void al_bp_free_metadata_blocks( al_bp_bundle_spec_t* spec )			
const char* al_bp_status_report_reason_to_str( al_bp_status_report_reason_t err )	const char* dtn_status_report_reason_to_str( dtn_status_report_reason_t err)		
char* al_bp_strerror(int err)			

Below we provide the reader with some basic information about the three most important “basic” AL functions, by pointing out the differences in case they run on top of DTN2, ION, or IBR-DTN BP implementations.

#### 2.1.1.1 *al\_bp\_open*

*al\_bp\_error\_t al\_bp\_open(al\_bp\_handle\_t\* handle)*

Opens the connection between the application and the BP daemon. In DTN2 and IBR-DTN this function also initializes the handle.

#### 2.1.1.2 *al\_bp\_build\_local\_eid*

*al\_bp\_error\_t al\_bp\_build\_local\_eid(al\_bp\_handle\_t handle, al\_bp\_endpoint\_id\_t\* local\_eid, const char\* service\_tag, al\_bp\_scheme\_t type);*

Creates the local EID. In DTN2 and IBR-DTN the local EID is retrieved from the handle. In ION the local eid is built with specific rules, depending on the type value, (CBHE or DTN).

if CBHE, the “ipn” scheme is used and the local EID will be **ipn:<own\_number>:<own\_pid>**

if DTN the “dtn” scheme is used and the local EID will be **dtn://<local\_hostname>/<service\_tag>**.

### *2.1.1.3 al\_bp\_register*

*al\_bp\_error\_t al\_bp\_register(al\_bp\_handle\_t \* handle, al\_bp\_reg\_info\_t\* reginfo, al\_bp\_reg\_id\_t\* newregid)*

Registers the local EID to the BP daemon. In ION it also calls the API bp\_open() that initializes the handle and allows the application to start sending and receiving bundles.

## 2.2 BUNDLE FUNCTIONS

2.2.1.1 *Bundle functions aim to manage the bundle as an “object” (in brackets as C lacks the concept of object), with “get” and “set” functions for almost every bundle object parameter. Bundle functions are declared in the “al\_bp\_api.h” file as basic and utility functions, but can be distinguished by the “al\_bp\_bundle” prefix. In a few significant cases, they can be considered as a second layer of abstraction (e.g. for al\_bp\_bundle\_send/receive that abstract the al\_bp\_send/receive by making use of the concept of the bundle “object”). This second layer of abstraction does not involve the initial and the final phases, left unaltered (see the figure below, where the use of the al\_bp\_bundle is highlighted).*

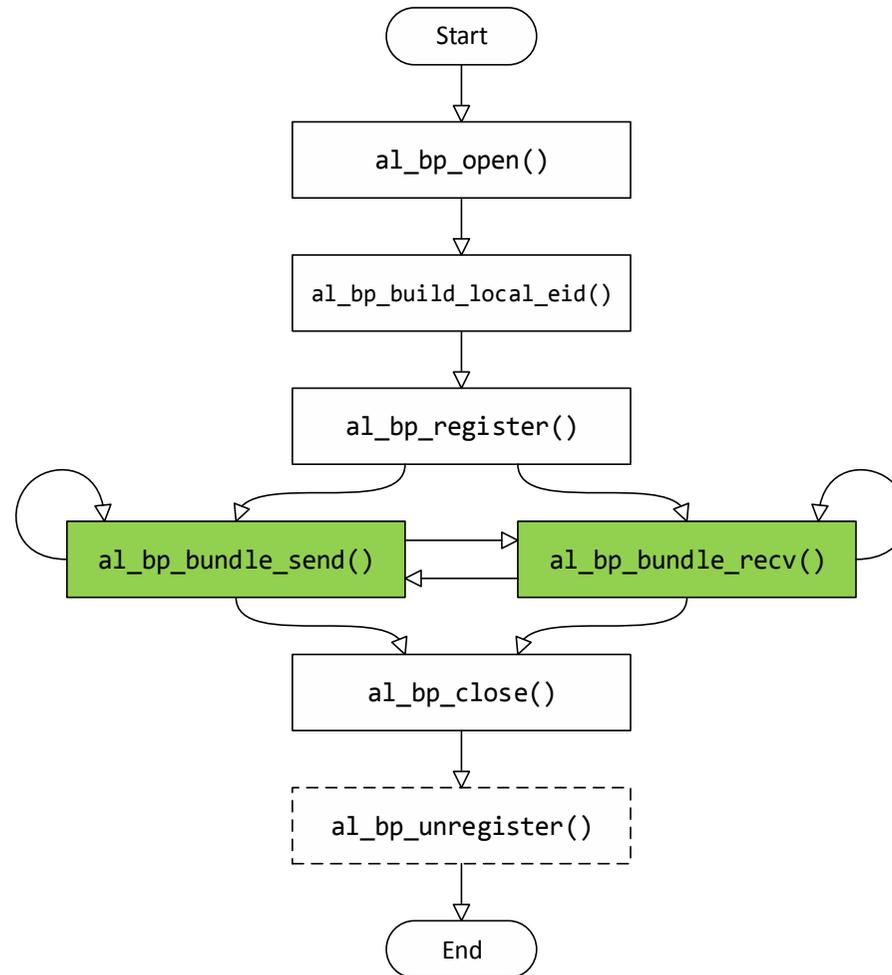


Figure 2. Typical flow of the most significant AL\_BP functions when the *al\_bp\_bundle* (second layer of abstraction) is used by the DTN application. Note that only the send and receive functions are changed (highlighted in green or grey).

### 2.2.1.2 *al\_bp\_bundle\_send*

*al\_bp\_error\_t* *al\_bp\_bundle\_send*(*al\_bp\_handle\_t* handle, *al\_bp\_reg\_id\_t* regid, *al\_bp\_bundle\_object\_t* \* bundle\_object)

Sends the bundle object.

### 2.2.1.3 *al\_bp\_bundle\_receive*

*al\_bp\_error\_t al\_bp\_bundle\_receive(al\_bp\_handle\_t handle, al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_bundle\_payload\_location\_t payload\_location, al\_bp\_timeval\_t timeout)*

Receives a bundle object.

### 2.2.1.4 *al\_bp\_bundle\_create*

*al\_bp\_error\_t al\_bp\_bundle\_create(al\_bp\_bundle\_object\_t \* bundle\_object)*

Creates an empty bundle object.

### 2.2.1.5 *al\_bp\_bundle\_free*

*al\_bp\_error\_t al\_bp\_bundle\_free(al\_bp\_bundle\_object\_t \* bundle\_object)*

Deletes the bundle object from memory.

### 2.2.1.6 *al\_bp\_bundle\_get\_id*

*al\_bp\_error\_t al\_bp\_bundle\_get\_id(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_bundle\_id\_t \*\* bundle\_id)*

Retrieves the bundle Id from the bundle object.

### 2.2.1.7 *al\_bp\_bundle\_set\_payload\_location*

*al\_bp\_error\_t al\_bp\_bundle\_set\_payload\_location(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_bundle\_payload\_location\_t location)*

Sets the bundle payload location: either memory or file.

### 2.2.1.8 *al\_bp\_bundle\_get\_payload\_location*

*al\_bp\_error\_t al\_bp\_bundle\_get\_payload\_location(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_bundle\_payload\_location\_t \* location)*

Returns the bundle payload location.

#### *2.2.1.9 al\_bp\_bundle\_get\_payload\_size*

*al\_bp\_error\_t al\_bp\_bundle\_get\_payload\_size(al\_bp\_bundle\_object\_t bundle\_object, u32\_t \* size)*

Returns the bundle payload size.

#### *2.2.1.10 al\_bp\_bundle\_get\_payload\_file*

*al\_bp\_error\_t al\_bp\_bundle\_get\_payload\_file(al\_bp\_bundle\_object\_t bundle\_object, char\_t \*\* filename, u32\_t \* filename\_len)*

Returns the value of the payload if it is saved in a file.

#### *2.2.1.11 bp\_bundle\_get\_payload\_mem*

*al\_bp\_error\_t al\_bp\_bundle\_get\_payload\_mem(al\_bp\_bundle\_object\_t bundle\_object, char \*\* buf, u32\_t \* buf\_len)*

Returns the value of the payload if it is stored in memory.

#### *2.2.1.12 al\_bp\_bundle\_set\_payload\_file*

*al\_bp\_error\_t al\_bp\_bundle\_set\_payload\_file(al\_bp\_bundle\_object\_t \* bundle\_object, char\_t \* filename, u32\_t filename\_len)*

Sets the value of the payload if it is saved in a file.

#### *2.2.1.13 al\_bp\_bundle\_set\_payload\_mem*

*al\_bp\_error\_t al\_bp\_bundle\_set\_payload\_mem(al\_bp\_bundle\_object\_t \* bundle\_object, \* buf, u32\_t buf\_len)*

Sets the value of the payload if it is saved in memory.

#### *2.2.1.14 al\_bp\_bundle\_get\_source*

*al\_bp\_error\_t al\_bp\_bundle\_get\_source(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_endpoint\_id\_t \* source)*

Returns the bundle's source EID.

#### *2.2.1.15 al\_bp\_bundle\_set\_source*

*al\_bp\_error\_t al\_bp\_bundle\_set\_source(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_endpoint\_id\_t source)*

Sets the bundle's source EID.

#### *2.2.1.16 al\_bp\_bundle\_get\_dest*

*al\_bp\_error\_t al\_bp\_bundle\_get\_dest(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_endpoint\_id\_t \* dest)*

Returns the bundle's destination EID.

#### *2.2.1.17 al\_bp\_bundle\_set\_dest*

*al\_bp\_error\_t al\_bp\_bundle\_set\_dest(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_endpoint\_id\_t dest)*

Sets the bundle's destination EID.

#### *2.2.1.18 al\_bp\_bundle\_get\_replyto*

*al\_bp\_error\_t al\_bp\_bundle\_get\_replyto(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_endpoint\_id\_t \* replyto)*

Returns the status report's destination EID.

#### *2.2.1.19 al\_bp\_bundle\_set\_replyto*

*al\_bp\_error\_t al\_bp\_bundle\_set\_replyto(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_endpoint\_id\_t replyto)*

Sets the status report's destination EID.

#### *2.2.1.20 al\_bp\_bundle\_get\_priority*

*al\_bp\_error\_t al\_bp\_bundle\_get\_priority(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_bundle\_priority\_t \* priority)*

Returns the bundle's priority.

#### *2.2.1.21 al\_bp\_bundle\_set\_priority*

*al\_bp\_error\_t al\_bp\_bundle\_set\_priority(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_bundle\_priority\_t priority)*

Sets the bundle's priority.

#### *2.2.1.22 al\_bp\_bundle\_get\_expiration*

*al\_bp\_error\_t al\_bp\_bundle\_get\_expiration(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_timeval\_t \* exp)*

Return the bundle's expiration time.

#### *2.2.1.23 al\_bp\_bundle\_set\_expiration*

*al\_bp\_error\_t al\_bp\_bundle\_set\_expiration(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_timeval\_t exp)*

Sets the bundle's expiration time.

#### *2.2.1.24 al\_bp\_bundle\_get\_creation\_timestamp*

*al\_bp\_error\_t al\_bp\_bundle\_get\_creation\_timestamp(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_timestamp\_t \* ts)*

Returns the bundle's creation timestamp.

#### *2.2.1.25 al\_bp\_bundle\_set\_creation\_timestamp*

*al\_bp\_error\_t al\_bp\_bundle\_set\_creation\_timestamp(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_timestamp\_t ts)*

Sets the bundle's creation timestamp.

#### *2.2.1.26 al\_bp\_bundle\_get\_delivery\_opts*

*al\_bp\_error\_t al\_bp\_bundle\_get\_delivery\_opts(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_bundle\_delivery\_opts\_t \* dopts)*

Returns the bundle's delivery options.

#### 2.2.1.27 *al\_bp\_bundle\_set\_delivery\_opts*

*al\_bp\_error\_t al\_bp\_bundle\_set\_delivery\_opts(al\_bp\_bundle\_object\_t \* bundle\_object, al\_bp\_bundle\_delivery\_opts\_t dopts)*

Sets the bundle's delivery options.

#### 2.2.1.28 *al\_bp\_bundle\_get\_status\_report*

*al\_bp\_error\_t al\_bp\_bundle\_get\_status\_report(al\_bp\_bundle\_object\_t bundle\_object, al\_bp\_bundle\_status\_report\_t \*\* status\_report)*

Returns the bundle's status report.

## 3 FILE AND API STRUCTURE

---

The organization of AL files is the following:

- `dtncperf/al_bp/src`: contains the declaration files and the implementation of the interface, in `al_bp_api.h` and `al_bp_api.c`;
- `dtncperf/al_bp/src/bp_implementations`: contains the interfaces to DTN2, ION, and IBR-DTN APIs (`al_bp_dtn.c`, `al_bp_ion.c`, `al_bp_ibr.cpp`, and corresponding ".h")

Note that the AL is compiled for a BP implementation if the path to this implementation directory is provided as a parameter after the "make" command. Multiple choices are allowed, so that AL can be compiled for whatever combination of BP implementations. The most relevant cases are for one implementation only, or for all implementations, but also all possible couples of BP implementations are allowed. The (sole) BP implementation that is on is determined (although multiple BP implementations can be installed, only one BP daemon can be active at a given instant) at run time.

The DTN application uses (directly or through the wrapping "al\_bp\_bundle" functions), the al\_bp basic functions. These interface to the API provided by the specific BP implementation, through an intermediate, implementation specific level, so that we have a chain of calls, as shown below.

Let us explain this with an example, referring to `al_bp_send` (see figure below).

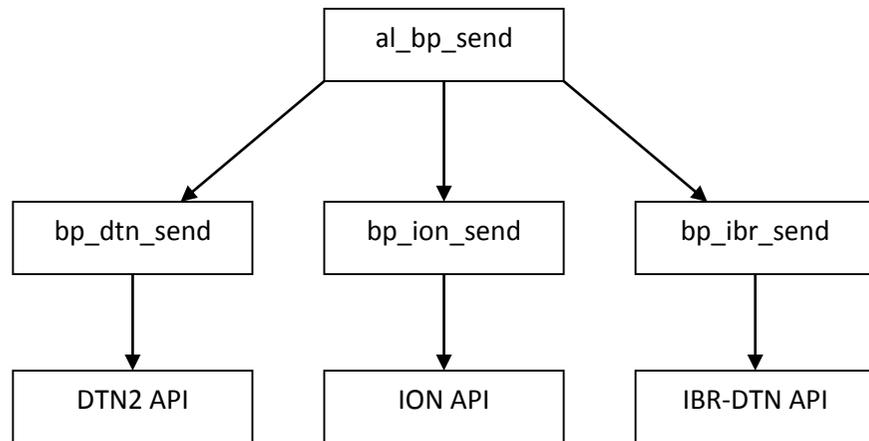


Figure 3. Example of relationship between the “al\_bp” functions and the BP implementation API.

al\_bp\_send is defined in al\_bp\_api.c and is called by the application. It just contains a switch to the BP implementations.

- If DTN2 daemon is on,
  - al\_bp\_send (in al\_bp\_api.c) calls bp\_dtn\_send (in al\_bp\_dtn.c). Note that in bp\_dtn\_send.c there is a real implementation of the API, to be used when the AL is compiled (at least) for DTN2, and a dummy implementation that does not call the API of DTN2, to avoid compilation errors (e.g. due to lack of DTN2 libraries) otherwise.
  - bp\_dtn\_send then calls the DTN2 API.
- If ION is on,
  - al\_bp\_send (in al\_bp\_api.c) calls bp\_ion\_send (in al\_bp\_ion.c). To avoid compilation errors, in al\_bp\_ion.c there are both a real and a dummy implementation of the API, as before.
  - bp\_ion\_send then calls the ION API.
- If IBR-DTN is on,
  - al\_bp\_send (in al\_bp\_api.c) calls bp\_ibr\_send (in al\_bp\_ibr.cpp). To avoid compilation errors, in al\_bp\_ibr.cpp there are both a real and a dummy implementation of the API, as before.
  - bp\_ibr\_send then calls the IBR-DTN API.

Type conversions are in files “al\_bp\_dtn\_conversions.c” and “al\_bp\_ion\_conversions.c”.

For instance, in the set of conversion functions, the prefix “al\_ion” means from “AL to ION”, i.e. that the function takes an abstract type and returns an ION type, while the prefix “ion\_al” means from “ION to AL”, i.e. that the function takes an ION type and returns an abstract type, and analogously for the DTN2 implementations, with “al\_dtn” and “dtn\_al”. By contrast, there are not any dedicated functions to convert between AL and IBR-DTN types. That is due to the lack of correspondence between most of the AL and IBR-DTN types, which results in conversions being performed directly inside the bp\_ibr functions, when needed.

## 4 ABSTRACTION LAYER EXTENSION “B”

---

The present version of the abstraction layer contain an extension, called “B” after the initial of its designer (Andrea Bisacchi). These functions are denoted by the al\_bp\_extB” prefix, are declared in the “al\_bp\_extB.h” file. They leave unaltered all other functions (“al\_bp” and “al\_bp\_bundle”) and their use is optional. The aim of this extension is twofold:

- to provide the user a simple way to manage the high complexity of initial “registration” and final “deregistration” phases when is requested the support of both the “dtn” and “ipn” EID scheme
- second, to promote the use an integer identifier, similar to a Unix “file descriptor” to identify a connection to the BP (or equivalently “registration”).

The former aim has led to two new functions for registering and deregistering and two new functions for sending and receiving a bundle by making use of the new integer identifier. The typical flow when the “al\_bp\_extB” functions are preferred is shown in the figure below.

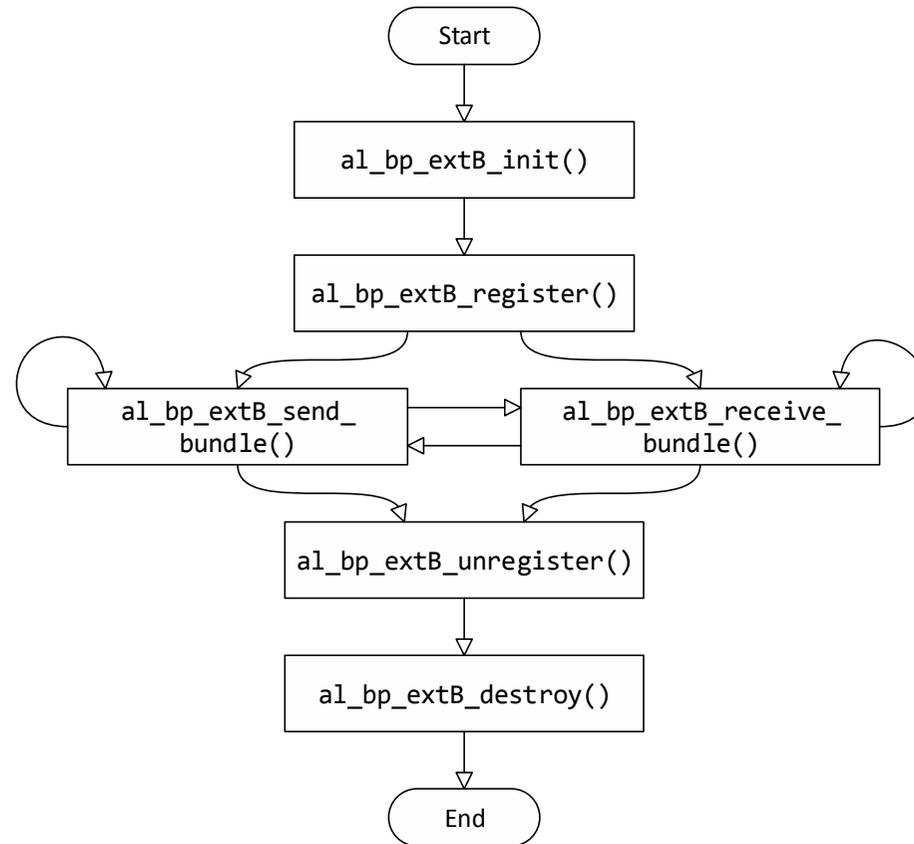


Figure 4. Typical flow of most significant AL\_BP extension (al\_bp\_extB) functions.

The AL extension “B” uses a linked list (called “registration list” in the following) to keep memory of registrations (opened connections to the BP, (one or more)). The AL extension “B” must be initialized by calling the function “al\_bp\_extB\_init”, which creates this “registartion list” and set the EID scheme to be used (default, “dtn” or “ipn”) in registrations. It is worth recalling that in DTN two alternative schemes for EID, “dtn” and “ipn” can be used and all the major implementations are compatible to both, but with different level of support. Thus, in building an application that uses the AL and is destined to run on top of either ION, or DTN2 or IBR-DTN, it is necessary to select the EID scheme to be used in registrations. The al\_bp\_register does this automatically at run time, by exploiting defaults (“dtn” for both DTN2 and IBR-DTN, “ipn” for ION). These defaults can however be overridden by the programmer by “forcing” a specific scheme in the al\_bp\_extB\_init.

After this initialization, the programmer must call the “al\_bp\_extB\_register” function to register the DTN application (an operation equivalent to the TCP/IP binding to a port). This function returns the “al\_bp\_extB\_registration\_descriptor”, i.e. the identifier of the registration (an integer), which is used later on to operate on this registration (e.g. to send or receive a bundle, to unregister) by “al\_bp\_extB” functions. When the application is close, all on going registrations are unregistered and finally the registration list is destroyed.

The “al\_bp\_extB” functions can interface with “al\_bp” basic functions and/or with “al\_bp\_bundle” ones, as shown below.

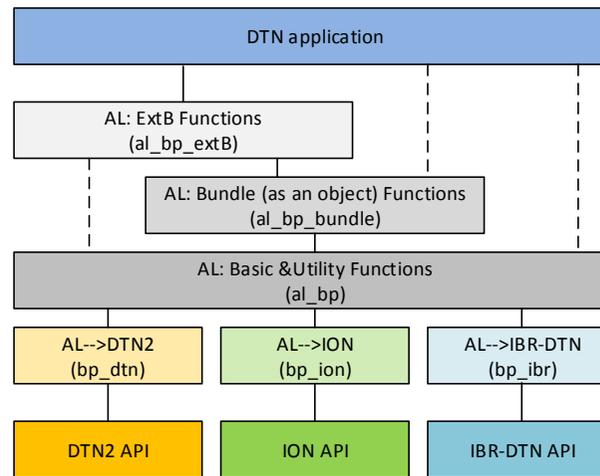


Figure 5. AL\_BP layering.

The extension “B” consists of 8 *high level* functions and a few *backward compatibility* functions, both described below. In al\_bp\_extB.c file there are also a few *private* functions internal to “al\_bp\_extB” (not to be used by programmers).

#### 4.1 HIGH LEVEL FUNCTIONS

In the following table you can see the mapping between the principal “al\_bp\_extB” functions and the standard AL ones (both “al\_bp” and “al\_bp\_bundle”). The programmer is let free of alternatively using the former (left column) or the latter (right column). Note that the mapping is not necessarily one-to-one. For example the 2al\_bp\_extB\_register2 corresponds (and include calls) to “al\_bp\_register2 and “al\_bp\_open”, while the “al\_bp\_extB\_send” is just a wrapping of “al\_bp\_bundle\_send”.

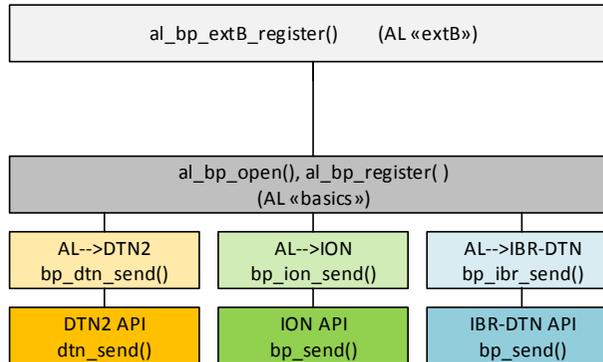


Figure 6. Layering of *al\_bp\_extB\_register*.

For the “send” and “receive” functions the mapping is vice versa one-to-one and implies a new level of abstraction (to use the integer identifier)

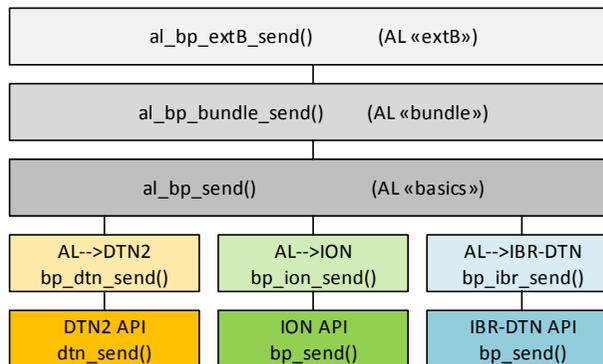


Figure 7. A. Layering of *al\_bp\_extB\_send*.

When using the AL extension “B”, the programmer must include “al\_bp\_api.h” and use the same bundle “object” defined in AL APIs.

Abstraction Layer extension "B"	Abstraction Layer
<pre> al_bp_extB_register (     al_bp_extB_registration_descriptor* registration_descriptor,     int char* dtm_demux_string,     int ipn_demux_number ) </pre>	<pre> al_bp_open(     al_bp_handle_t* handle )  al_bp_register(     al_bp_handle_t * handle,     al_bp_reg_info_t * reginfo,     al_bp_reg_id_t * newregid ) </pre>
<pre> al_bp_extB_send (     al_bp_extB_registration_descriptor registration_descriptor,     al_bp_bundle_object_t* bundle,     al_bp_endpoint_id_t to,     al_bp_endpoint_id_t reply_to ) </pre>	<pre> al_bp_send(     al_bp_handle_t handle,     al_bp_reg_id_t regid,     al_bp_bundle_spec_t* spec,     al_bp_bundle_payload_t* payload,     al_bp_bundle_id_t* id ) </pre>
<pre> al_bp_extB_receive (     al_bp_extB_registration_descriptor registration_descriptor,     al_bp_bundle_object_t bundle,     al_bp_bundle_payload_location_t payload_location,     al_bp_timeval_t timeval ) </pre>	<pre> al_bp_bundle_receive(     al_bp_handle_t handle,     al_bp_bundle_object_t bundle_object,     al_bp_bundle_payload_location_t payload_location,     al_bp_timeval_t timeout ) </pre>

<pre> al_bp_extB_unregister (     al_bp_extB_registration_descriptor registration_descriptor ) </pre>	<pre> al_bp_close(     al_bp_handle_t handle ) al_bp_unregister(     al_bp_handle_t handle,     al_bp_reg_id_t regid,     al_bp_endpoint_id_t eid ) </pre>
---	--

Below the prototypes of the 9 high level functions will be examined one-by-one:

#### 4.1.1.1 *al\_bp\_extB\_init*

*al\_bp\_extB\_error\_t al\_bp\_extB\_init(char force\_eid\_scheme, int ipn\_node\_forDTN2);*

Input:

- *force\_eid\_scheme*: (N|D|I) It is used to specify if the default format of the registration must be overridden (“N” no, i.e. use the default, ‘D’ for “dtn”, ‘I’ for “ipn”)
- *ipn\_node\_forDTN2*: ipn node number used only in case of forced ipn registration on a DTN2 machine

It initializes the Abstraction Layer extension “B” (it has not any correspondence in *al\_bp*):

- it finds the active BP implementation and saves this information in a local variable available to other extB functions (if it does not find any active BP implementation, it returns an error); to find which BP implementation is active (if any), it calls the *al\_bp\_get\_implementation*, which in turns checks if the following processes, specific to each implementation, are running: “dtnd” for DTN2, “rfxclock” for ION, either “/usr/sbin/dtnd” or “/usr/local/sbin/dtnd” or “ibrdtnd” for IBR-DTN. IBR-DTN users are strongly suggested to rename the IBRD-DTN dtnd daemon as ibrdtnd to avoid any ambiguity with the dtnd daemon of DTN2.
- it determines the registration scheme to be used by “*al\_bp\_extB\_register*”, depending on the active implementation and on the *force\_eid\_scheme* value passed; defaults are “ipn” for ION and “dtn” for DTN2 and IBR-DTN.
- it provides the “*al\_bp\_extB\_register*” with the information above, plus the “*ipn\_node\_forDTN2*” if the active implementation is DTN2 and the scheme is forced to ipn.

#### 4.1.1.2 *al\_bp\_extB\_destroy*

```
void al_bp_extB_destroy();
```

It destroys the registration list (it has not any correspondence in al\_bp). After calling this function, “al\_bp\_extB2 functions can no more called, except the “al\_bp\_extB\_init”.

#### 4.1.1.3 *al\_bp\_extB\_register*

```
al_bp_extB_error_t al_bp_extB_register(al_bp_extB_registration_descriptor* registration_descriptor, int char* dtn_demux_string, ipn_demux_number);
```

This function registers a new connection of the application to the BP.

Output:

- registration\_descriptor: the registration descriptor (>0; 0 in case of error)

Input:

- dtn\_demux\_string: dtn demux token (string);
- ipn\_demux\_number: demux token (number ) to be used in case of an ipn scheme registration (>0)

It returns, in addition to the possible error, the registration\_descriptor (an integer somewhat inspired to file descriptor in sockets, but not passed by the OS) to be given in input to “al\_bp\_extB” functions that work on a specific registration.

#### 4.1.1.4 *al\_bp\_extB\_unregister*

```
al_bp_extB_error_t al_bp_extB_unregister(al_bp_extB_registration_descriptor registration_descriptor);
```

It unregisters the registration identified by the registration descriptor.

#### 4.1.1.5 *al\_bp\_extB\_send*

```
al_bp_extB_error_t al_bp_extB_send(al_bp_extB_registration_descriptor registration_descriptor, al_bp_bundle_object_t* bundle, al_bp_endpoint_id_t destination, al_bp_endpoint_id_t reply_to);
```

This function uses the registration\_descriptor to identify the registration; then it sends a bundle object. It is a wrapper of the al\_bp\_bundle\_send, but the destination and the “reply to” EIDs are passed in input. For the sake of backward compatibility the destination and “reply to” originally contained in the bundle object are saved and restored at the end of the function.

#### 4.1.1.6 *al\_bp\_extB\_receive*

```
al_bp_extB_error_t al_bp_extB_receive(al_bp_extB_registration_descriptor registration_descriptor, al_bp_bundle_object_t bundle,  
al_bp_bundle_payload_location_t payload_location, al_bp_timeval_t timeval);
```

It receives a bundle object destined to the registration\_descriptor passed in input. It is a wrapper of the al\_bp\_bundle\_receive. Payload\_location is a structure passed to al\_bp lower layers. Timeval is a timeout value passed to al\_bp\_lower layers.

#### 4.1.1.7 *al\_bp\_extB\_find\_registration*

```
al_bp_error_t al_bp_extB_find_registration(al_bp_extB_registration_descriptor registration_descriptor, al_bp_endpoint_id_t* eid);
```

It is a wrapper of al\_bp\_find\_registration (it has not any correspondence in al\_bp). It gives in output the registration descriptor corresponding to the EID passed in input.

#### 4.1.1.8 *al\_bp\_extB\_str\_type\_error*

```
char* al_bp_extB_str_type_error(al_bp_extB_error_t error);
```

It returns the string corresponding to a given al\_bp\_extB\_error (it is an auxiliary function).

#### 4.1.1.9 *al\_bp\_extB\_get\_local\_eid*

```
al_bp_endpoint_id_t al_bp_extB_get_local_eid(al_bp_extB_registration_descriptor registration_descriptor);
```

It returns the local EID structure associated to the registration descriptor given in input.

## 4.2 BACKWARD COMPATIBILITY FUNCTIONS

One registration is identified in “al\_bp\_extB” by “al\_bp\_extB\_registration\_descriptor” (an integer), while in “al\_bp” is identified by a 3-ple of structures (al\_bp\_handle\_t, al\_bp\_reg\_info\_t, al\_bp\_reg\_id\_t). The backward compatibility functions are designed to enable the use of the “al\_bp” functions, which use the 3-ple identifier and other parameters, in connections opened by “al\_bp\_extB\_register”. Note that a new application does not need to use “al\_bp”; it just may still use them.

#### 4.2.1.1 *al\_bp\_extB\_get\_handle*

```
al_bp_handle_t al_bp_extB_get_handle(al_bp_extB_registration_descriptor registration_descriptor);
```

It returns the “handle” structure associated to the registration descriptor given in input..

#### 4.2.1.2 *al\_bp\_extB\_get\_reginfo*

*al\_bp\_reg\_info\_t al\_bp\_extB\_get\_reginfo(al\_bp\_extB\_registration\_descriptor registration\_descriptor);*

It returns the “reg\_info” structure associated to the registration descriptor given in input..

#### 4.2.1.3 *al\_bp\_extB\_get\_regid*

*al\_bp\_reg\_id\_t al\_bp\_extB\_get\_regid(al\_bp\_extB\_registration\_descriptor registration\_descriptor);*

It returns the “reg\_id” structure associated to the registration descriptor given in input.

#### 4.2.1.4 *al\_bp\_extB\_get\_eid\_format*

*char al\_bp\_extB\_get\_eid\_format();*

It returns the EID format used in all registrations, found and saved by the “al\_bp\_extB\_init” (“I” for “ipn” and “D” for “dtn”).

#### 4.2.1.5 *al\_bp\_extB\_set\_local\_eid*

*void al\_bp\_extB\_set\_local\_eid(al\_bp\_extB\_registration\_descriptor registration\_descriptor, al\_bp\_endpoint\_id\_t local\_eid);*

It sets the local EID for the corresponding registration descriptor (both in input).

#### 4.2.1.6 *al\_bp\_extB\_errno*

*al\_bp\_error\_t al\_bp\_extB\_errno(al\_bp\_extB\_registration\_descriptor registration\_descriptor);*

It returns (DTN2, IBR-DTN) or prints (ION) the last “errno” given by the BP implementation, corresponding to the registration descriptor passed in input.

#### 4.2.1.7 *al\_bp\_extB\_get\_error*

*al\_bp\_error\_t al\_bp\_extB\_get\_error(al\_bp\_extB\_registration\_descriptor registration\_descriptor);*

It returns the last error (in “al\_bp” format) that occurred in the previous “al\_bp” (not “al\_bp\_extB”) function corresponding to the registration descriptor passed in input.

#### 4.2.1.8 *al\_bp\_extB\_strerror*

*char\* al\_bp\_extB\_strerror(al\_bp\_extB\_registration\_descriptor registration\_descriptor);*

It returns the last error (as a string) that occurred in the previous “al\_bp” (not “al\_bp\_extB”) function corresponding to the registration descriptor passed in input.

### 4.3 PRIVATE FUNCTIONS IN ABSTRACTION LAYER EXTENSION “B”

There are also a few private functions in the extension “B”, used for better code readability and for convenience. As they must be kept invisible to the DTN application programmer, they are not declared in the “al\_bp\_extB.h” and are not associated with any specific prefix. A brief description is reported here for the sake of completeness only.

The al\_bp\_extB uses the “registration list” to keep memory of the registrations. The list elements are “al\_bp\_extB\_registration\_t” type structures, consisting of many fields. The registration identifier (an integer) allows the user to find the corresponding structure in the list. The list library used to manage the list is included in AL\_BP code (in list.h and list.c), but is not specific, as it allows generic types for the elements of the list.

#### 4.3.1.1 *set\_eid\_scheme*

```
al_bp_error_t set_eid_scheme(char force_eid_scheme);
```

It sets the EID scheme used in registration(s).

#### 4.3.1.2 *build\_local\_eid*

```
al_bp_error_t build_local_eid(al_bp_extB_registration_t* registration, char* dtm_demux_string, int ipn_demux_number, int ipn_node_forDTN2);
```

It builds the local EID. Used by al\_bp\_extB\_register.

#### 4.3.1.3 *insert\_registration\_in\_list*

```
void put_registration_in_list(al_bp_extB_registration_t registration);
```

It inserts a registration structure in the linked list.

#### 4.3.1.4 *remove\_registration\_from\_list*

```
void remove_registration_from_list(al_bp_extB_registration_descriptor registration_descriptor);
```

It removes a registration structure from the linked list.

#### 4.3.1.5 *get\_registration\_from\_reg\_des*

```
al_bp_extB_registration_t* get_registration_from_reg_des(al_bp_extB_registration_descriptor registration_descriptor);
```

It gets the pointer to the registration structure from the passed registration descriptor by searching in the registration list. To perform this operation the registration list must know how to compare the elements; this operation is performed by the next function.

#### *4.3.1.6 compare\_registration\_and\_reg\_des*

*int compare\_registration\_and\_reg\_des (void\* data1, size\_t data1\_size, void\* data2, size\_t data2\_size)*

This function check if the current element of the list (an "al\_bp\_extB\_registration\_t2 structure) contains in its "reg\_des" field the registration descriptor passed either in data1 or data2. It is used in the functions "remove\_registration\_from\_list" and "get\_registration\_from\_reg\_des" to find the wanted element of the list. It returns an "int" value, according to standard compare functions.