Nabto Push

NABTO/001/TEN/050

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2 Abstract

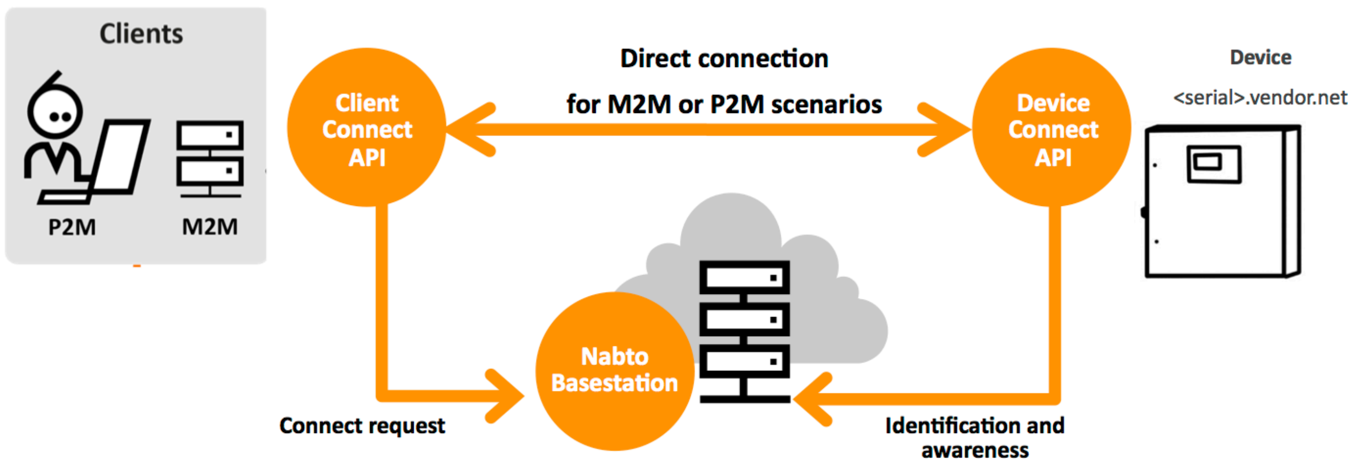
This document describes how to implement solution that use the Nabto Push communication pattern to send information from a uNabto device to an external service (such as a mobile push notification service or a Big Data analysis solution) on initiative of the uNabto device using the secure channel already established between a uNabto device and the Nabto basestation.

This basically enables embedded devices to send push notifications or communicate with a Big Data solution securely without the hassle of embedding an HTTPS client or e.g. using MQTT + TLS.

3 Bibliography

TEN023	NABTO/001/TEN/023: uNabto SDK - Writing a uNabto device application
TEN025	NABTO/001/TEN/025: Writing a Nabto API client application
TEN036	NABTO/001/TEN/036: Security in Nabto Solutions

4 Nabto Platform Basics



The Nabto platform consists of 3 components:

- Nabto **client**: Libraries supplied by Nabto, used by the customer's application
- Nabto **device**: The uNabto SDK - an open source framework supplied by Nabto, integrated with the customer's device application
- Nabto **basestation**: Services supplied by Nabto (Nabto- or self-hosted) that mediates connections between Nabto clients and devices.

The Nabto client initiates a direct, encrypted connection to the Nabto enabled device – the Nabto basestation mediates this direct connection: The device's unique name, e.g. <serial>.vendor.net, is mapped to the IP address of the Nabto basestation – this is where devices register when online and where clients look for available devices. After connection establishment, the client and device communicates directly with each other, the basestation is out of the loop – no data is stored on the basestation, it only knows about currently available Nabto enabled devices.

The client can also discover the device if located on the same LAN and communicate directly without the basestation – useful for bootstrap scenarios or for offline use.

Integrating Nabto on the customer's device is the topic of [TEN023].

Nabto client applications are developed using the Nabto Client SDK described in [TEN025]. The Nabto Client SDK is the lowest level way of developing a Nabto application - several wrappers exist on top of this lowest level SDK to provide a more abstract experience, for instance for developing Cordova/Ionic or Xamarin hybrid apps or just simplify native Android and iOS app development.

4.1 Nabto Communication Patterns

The Nabto platform supports 3 communication patterns that will be referenced throughout this document:

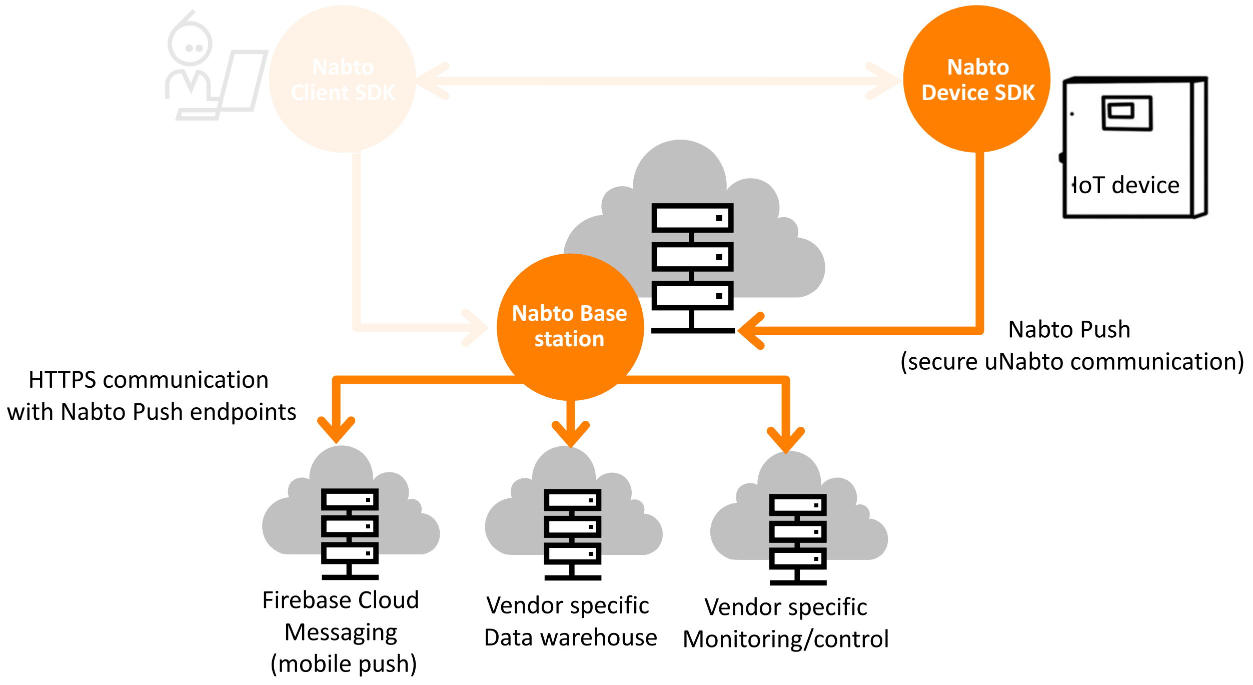
RPC: The Nabto RPC communication mechanism allows a client to securely invoke a remote function on a Nabto device. The device implements an interface definition shared between client and device, the client works with normal JSON documents, exchanged in a compact representation with the device.

Streaming: Nabto Streaming can be used for retrieving larger amounts of data from a device or sending e.g. a firmware update. With sufficient resources available on the device, Nabto Streaming can be used for high performance streaming suitable for video scenarios.

Push: Nabto Push is used for communication initiated by the device, for instance to implement mobile push notifications or to support big data scenarios where data is collected centrally for further analysis. Nabto Push can also trigger an M2M scenario using RPC or Streaming - e.g. when a certain condition is triggered, the device sends a Nabto Push message and a server function invokes an RPC function or streams data.

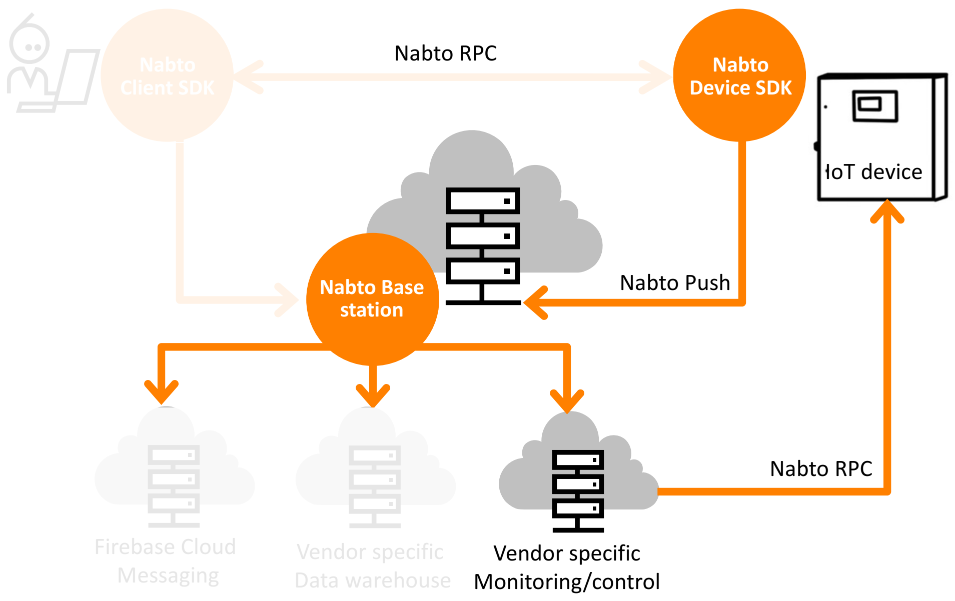
5 Using Nabto Push Services

The Nabto Push communication pattern allows Nabto enabled devices to send information on their own initiative to services configured by the vendor (denoted *endpoints*). Currently two different types of endpoints exist: Firebase Cloud Messaging (for mobile push to iOS, Android and web apps) and Generic HTTP (denoted webhook - for vendor specific services):


Nabto Client SDK
Nabto Device SDK
IoT device
Nabto Base station
Nabto Push
(secure uNabto communication)
HTTPS communication
with Nabto Push endpoints
Firebase Cloud Messaging (mobile push)
Vendor specific Data warehouse
Vendor specific Monitoring/control

Native support for additional push service providers (such as Urban Airship) will be added in the future.

The webhook endpoints can be used for sending data to a data warehouse / big data analysis solution. Or it can be used for triggering control functionality: The IoT device may trigger a notification as a threshold condition is met, the configured webhook then uses Nabto RPC to invoke the IoT device based on a central decision, e.g. involving other services or a rule engine:



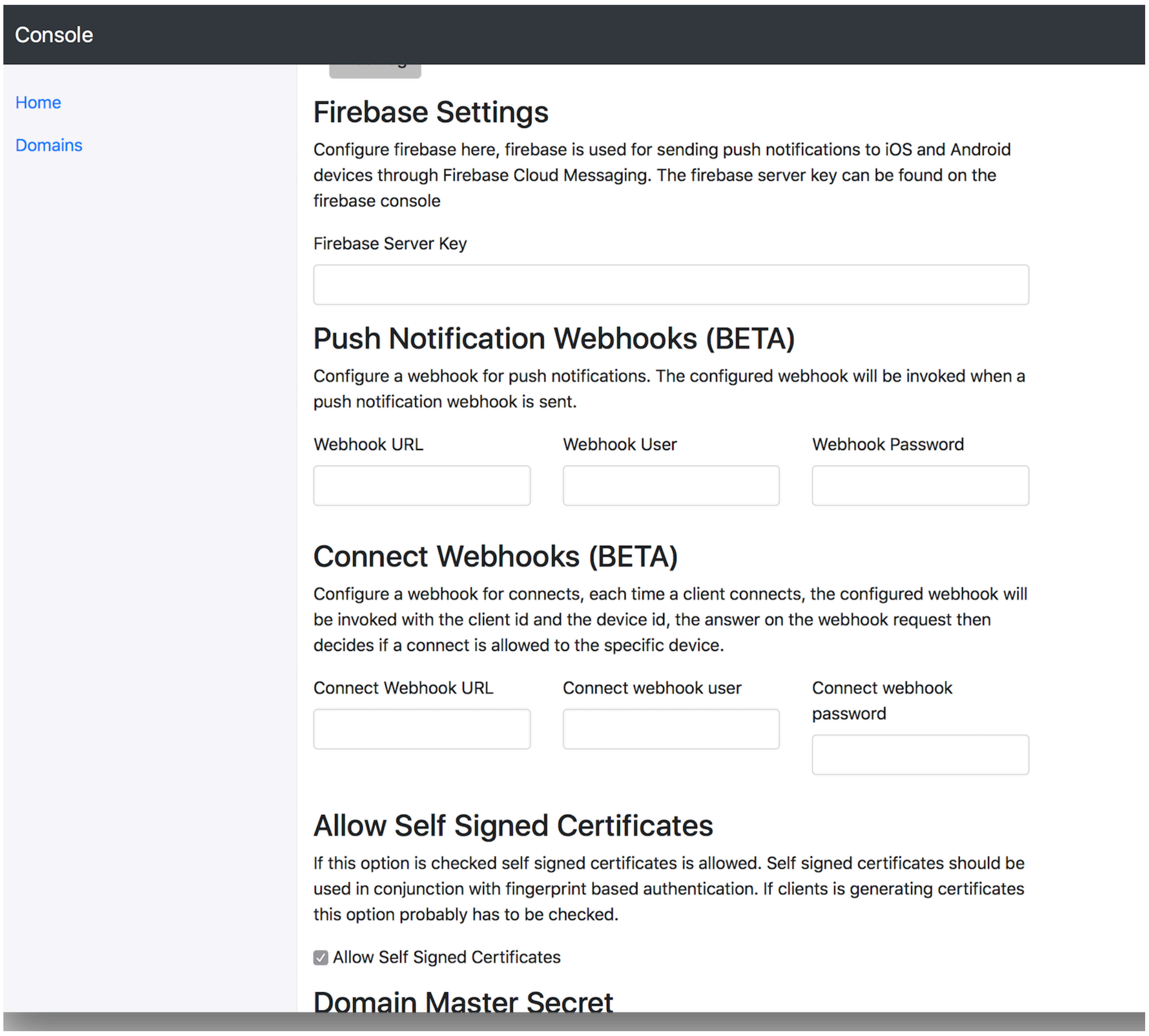
The IoT device likely already exposes a Nabto RPC interface used with regular client interaction. Also, Nabto Streaming can be used from the webhook to send or receive larger amounts of data in response to a push notification.

The webhook endpoints can also be used for adding currently unsupported mobile Push service providers through a simple adapter.

The push messages from device to basestation are sent on the secure channel established when the device registers with the basestation as outlined in [TEN036]. The shared secret based approach makes secure push notifications feasible on even very resource constrained devices.

5.1 Service Configuration

The actual endpoints are configured in the Nabto Enterprise management console (AppMyProduct OwnIt customers can contact Nabto support to setup hooks, as of writing this is not possible through the AppMyProduct console):



Firebase Settings

Configure firebase here, firebase is used for sending push notifications to iOS and Android devices through Firebase Cloud Messaging. The firebase server key can be found on the firebase console

Firebase Server Key

Push Notification Webhooks (BETA)

Configure a webhook for push notifications. The configured webhook will be invoked when a push notification webhook is sent.

Webhook URL
Webhook User
Webhook Password

Connect Webhooks (BETA)

Configure a webhook for connects, each time a client connects, the configured webhook will be invoked with the client id and the device id, the answer on the webhook request then decides if a connect is allowed to the specific device.

Connect Webhook URL
Connect webhook user
Connect webhook password

Allow Self Signed Certificates

If this option is checked self signed certificates is allowed. Self signed certificates should be used in conjunction with fingerprint based authentication. If clients is generating certificates this option probably has to be checked.

☑ Allow Self Signed Certificates

Domain Master Secret

To use Firebase Cloud Messaging for sending push notifications, a Firebase Server Key must be specified, obtained through the Firebase Console: Click the settings icon for your project > Project Settings > Cloud Messaging > Server key.

For generic webhooks, a URL and an optional HTTP basic auth username and password can be specified. The push data is then send as HTTP post data payload exactly as transmitted from the uNabto device.

5.2 Performance notes

It is important to note that the performance of push notifications to phones will depend on the Firebase service, and for Apple devices also on the Apple push service. Neither Google nor Apple makes any promises on delivery times or even that notifications are ever delivered. This means that though push notifications for phones can be useful to alert users of critical system events, it should not be the only means of conveying critical information to users.

For example, the Apple developer documentation states that if multiple notifications are sent simultaneously only the latest notification is forwarded to the phone, the rest is simply discarded.

(https://developer.apple.com/library/content/technotes/tn2265/_index.html#//apple_ref/doc/uid/DTS40010376-CH1-TNTAG23)

Using webhooks, the basestation will send the notification to an endpoint configured by the customer, assuming the provided endpoint is reachable by the basestation.

It is important to note that a positive status indication on the uNabto side as elaborated below means the basestation has successfully received the notification, *not* that the notification has successfully been delivered to the endpoint. This means that if the basestation is not able to reach the endpoint, the notification delivery will currently fail silently to the uNabto device and with no ability to trace this from a central log. This will be improved in a near future release.

6 Integrating Nabto Push in the uNabto Device

Push notification support is provided at two levels in the uNabto SDK: The core uNabto SDK provides the low level capabilities to send push notifications to the basestation and the higher level push_service module provides an easy to use "fire and forget" API that maintains necessary state during communication with the basesation at the cost of a bit higher resource requirements.

Push notifications in uNabto are configured using the following definitions in unabto_config.h:

- `NABTO_ENABLE_PUSH` - enables push notifications, default is 0 (off)
- `NABTO_PUSH_QUEUE_LENGTH` - determines the amount of push notifications uNabto can store at a given time, default is 10. Each entry requires approximately 20 bytes of memory. This is also used to determine buffer length in the push_service module.
- `NABTO_PUSH_BUFFER_ELEMENT_SIZE` - Determines the maximum size of a push notification to be stored by the push_service module. If this module is used, it will use in the excess of `NABTO_PUSH_QUEUE_LENGTH * NABTO_PUSH_BUFFER_ELEMENT_SIZE` bytes of memory to store notifications.

6.1 Push using the push_service module

The easiest way to enable a uNabto device to send push notifications is to use the push_service module in uNabto. This module handles the proper construction of payloads for the push notification packet sent to the basestation, as well as storing notifications while waiting for a resolution of the notification.

Using this module, it is as simple as follows to send a push notification from a device:

```
void callback_function(void* context, const unabto_push_hint* hint) {
    printf("got notification callback with status indication %d", (int)hint);
}

push_message mp;
init_push_message(&pm, UNABTO_PUSH_PNS_ID_FIREBASE, "\"to\": \"<Firebase_Token>\"");
add_title(&pm, "High temperature");
add_body(&pm, "Temperature is 42 degrees");
send_push_message(&pm, &callback_function, null);
```

First a variable of type `push_message` is defined and initialized with the function init_push_message:

```
init_push_message(push_message* msg, uint16_t pnsid, const char* staticData)
```

The `pnsid` parameter must currently be either `UNABTO_PUSH_PNS_ID_FIREBASE` or `UNABTO_PUSH_PNS_ID_WEBHOOK`.

The `staticData` parameter must be a zero-terminated JSON formatted string which will be used directly in the JSON document forwarded by the basestation. For webhooks, this document can be anything, however, for Firebase it must follow the Firebase HTTP Server protocol (https://firebase.google.com/docs/cloud-messaging/http-server-ref).

Using the Firebase HTTP Server protocol, the `staticData` document must contain a “`to`” field defining which mobile device (or other supported app) the notification should be sent to, any other parameters of this protocol can also be included.

Since the `staticData` “`to`” field contains the Firebase token for the receiving phone, it is recommended that this string is built on the client side, and then transferred to the uNabto device, and that all event specific data is added using the helper functions described below.

Once the message is Initialized, additional fields can be added using the following helper functions:

- `add_title()` - adds a title field to the notification
- `add_body()` - adds a body field to the notification
- `add_title_loc_key()` - adds a title localization key to the notification
- `add_title_loc_string_arg()` - adds a title localization string argument to the notification
- `add_body_loc_key()` - adds a body localization key to the notification

- `add_body_loc_string_arg()` - adds a body localization string argument to the notification

`add_title()`, `add_body()`, `add_title_loc_key()` and `add_body_loc_key()` should maximally be called once. The `string_arg` functions to add string arguments to the notifications can be added multiple times.

Once the notification is constructed, it can be sent using the `send_push_message()` function, which in addition to the constructed message takes a callback function and a pointer to some user defined context to be added to the callback.

The best practice is to just reference templates that are bundled in the client app instead of hardcoding strings in the device application. Parameters are then supplied to the template - for greater flexibility, simpler maintenance and to support localization. To do that, use the “loc” functions:

```
push_message mp;
init_push_message(&pm, UNABTO_PUSH_PNS_ID_FIREBASE, "\"to\": \"<Firebase_Token>\"");
add_title_loc_key(&pm, "title_high_temperature");
add_body_loc_key(&pm, "body_temperature_message");
add_body_loc_string_arg(&pm, "42");
send_push_message(&pm, &callback_function, null);
```

In the latter example, the construction of the string shown to the user is postponed to the individual target client to allow its localization framework to look up the localized string associated with the given key and patches it with the data.

When the message is sent using `send_push_message()`, the push_service module will then interact with the uNabto core to transmit the notification to the basestation. Once the basestation has successfully received the notification, `UNABTO_PUSH_HINT_OK` is returned by the core to the push_service module, which will forward this status to the application using the previously provided callback function.

It is important to note that a return status of OK means the basestation has successfully received the notification, *not* that the notification has successfully been delivered to the endpoint. This means that if the basestation is not able to reach the endpoint, the notification delivery will currently fail silently to the uNabto device and with no ability to trace this from a central log. This will be improved in a near future release.

Any other returned status means the notification was not sent to the basestation, and the notification will not arrive at its destination. A more detailed description of return statuses is provided in the following section.

6.2 Push without the push_service module

The push_service module described above reserves enough memory to store entire push notifications. As many push notifications may reuse most of the data in a notification, this may be inefficient. Hence, for memory critical systems, it may be beneficial to handle the memory allocation in the application and not use the push_service module and instead use the uNabto core functionalities directly.

Push notifications in the uNabto core works by first calling the unabto_send_push_notification function with the PNS ID and the address of an integer where the core can assign a sequence number to the notification. This function will return immediately, and if the return status was UNABTO_PUSH_HINT_OK, the core will start preparing to send the notification asynchronously. Once the core is ready to send the notification, it will request the data to be put into the notification by calling the function:

```
uint8_t* unabto_push_notification_get_data(uint8_t* bufStart, const uint8_t* bufEnd, uint32_t
seq)
```

This function should be implemented in the application. `bufStart` is a pointer to where the data should be copied, `bufEnd` is a pointer to the last address available for the data, and `seq` is the sequence number of the notification for which the data is requested as returned by `unabto_send_push_notification()`.

The function must return a pointer to the last data element copied. The data provided with the unabto_push_notification_get_data function must be in nabto payloads of type `NP_PAYLOAD_TYPE_PUSH_DATA`. This payload is defined as:

```
+-----+------------------------------------------------------------+
|  +0 |  Payload header (NP_PAYLOAD_HDR_BYTELENGTH bytes)          |
+-----+------------------------------------------------------------+
|  +4 |  +0 | purpose                                              |
+-----+-----+------------------------------------------------------+
|  +5 |  +1 | encoding                                             |
+-----+-----+------------------------------------------------------+
|  +6 |  +2 | Data                                                 |
+-----+-----+------------------------------------------------------+
```

The purpose can be either `NP_PAYLOAD_PUSH_DATA_PURPOSE_STATIC` or `NP_PAYLOAD_PUSH_DATA_PURPOSE_DYNAMIC`. A push notification should not contain more than 1 payload of each purpose. This means the notification can contain up to 2 payloads. Each payload type can use 2 different encodings, `NP_PAYLOAD_PUSH_DATA_ENCODING_JSON` and `NP_PAYLOAD_PUSH_DATA_ENCODING_TLV`.

JSON encoding means the data field contains a JSON formatted string, and TLV encoding means the data follows a TLV format described in the following section. The TLV encoding can contain multiple TLV values in sequence.

Using Firebase to send push notifications requires a payload with purpose `NP_PAYLOAD_PUSH_DATA_PURPOSE_STATIC` which follows the same restrictions as described in the previous section.

Once the uNabto core has received the notification data, it will start encrypting the data, and send the notification to the basestation. If any of the notification preparation steps fails, or when the transmission to the basestation has been resolved, the uNabto core will call the function:

```
       void unabto_push_notification_callback(uint32_t seq, unabto_push_hint* hint)
```

This function must also be implemented in the application. The hint reference will reflect if notification preparation step failed or the notification transmission status using the following status codes:

`UNABTO_PUSH_HINT_OK`

`UNABTO_PUSH_HINT_QUEUE_FULL`

`UNABTO_PUSH_HINT_INVALID_DATA_PROVIDED`

`UNABTO_PUSH_HINT_NO_CRYPTO_CONTEXT`

`UNABTO_PUSH_HINT_ENCRYPTION_FAILED`

`UNABTO_PUSH_HINT_FAILED`

`UNABTO_PUSH_HINT_QUOTA_EXCEEDED`

`UNABTO_PUSH_HINT_QUOTA_EXCEEDED_REATTACH`

OK means the notification was successfully received by the basestation. As described in the previous section, this is not an acknowledgement that it was send to the final endpoint.

`QUEUE_FULL` means the unabto_send_push_notification was not able to enqueue another notification as NABTO_PUSH_QUEUE_LENGTH notifications is already in the queue.

`INVALID_DATA_PROVIDED` means that the data provided in the unabto_push_get_data call did not fit properly within the provided buffer.

`NO_CRYPTO_CONTEXT` means the core was not able to encrypt the notification as the unabto_main_context did not contain a crypto context.

`ENCRYPTION_FAILED` is reserved for encryption errors but currently not used.

`QUOTA_EXCEEDED` means the basestation returned this status, this results in the uNabto core refusing to transmit new notifications for the next `UNABTO_PUSH_QUOTA_EXCEEDED_BACKOFF` milliseconds which defaults to 1 minute.

After this backoff period, notifications will be sent normally. This is meant as a way to guard the basestation against faulty devices, but is currently not implemented in the basestation.

Similarly, `UNABTO_PUSH_HINT_QUOTA_EXCEEDED_REATTACH` means the uNabto core will refuse to send notifications until the device has reattached. This is meant as a way to guard the basestation against extremely faulty devices, but has also yet to be implemented in the basestation.

In conclusion, to use the uNabto core push functionality, the application must implement the functions:

```
uint8_t* unabto_push_notification_get_data(uint8_t* bufStart, const uint8_t* bufEnd, uint32_t
seq)

void unabto_push_notification_callback(uint32_t seq, unabto_push_hint* hint)
```

Notifications are then sent by calling `unabto_send_push_notification()`. This will call the `unabto_push_notification_get_data()` function to retrieve the notification data. And once the notification has been resolved, the core will `call unabto_push_notification_callback()` function which provides a hint to the status of the notification. For examples on how to implement this, see the uNabto push_service module.

6.2.1 The TLV format

A TLV value is defined as:

```
+-----+------------------------------------------------------------------+
|  +0 | Type                                                             |
+-----+------------------------------------------------------------------+
|  +1 | Length                                                           |
+-----+------------------------------------------------------------------+
|  +2 | Data                                                             |
+-----+------------------------------------------------------------------+
```

Where the currently supported values for the Type field is:

`NP_PAYLOAD_PUSH_DATA_VALUE_TITLE`

`NP_PAYLOAD_PUSH_DATA_VALUE_BODY`

`NP_PAYLOAD_PUSH_DATA_VALUE_BODY_LOC_KEY`

`NP_PAYLOAD_PUSH_DATA_VALUE_BODY_LOC_STRING_ARG`

`NP_PAYLOAD_PUSH_DATA_VALUE_TITLE_LOC_KEY`

`NP_PAYLOAD_PUSH_DATA_VALUE_TITLE_LOC_STRING_ARG`

The Length field is the length of the Type field, the Length field, and the Data field combined, and the Data field is a string.