ANT Channel Search and Background Scanning Channel

ABSTRACT

ANT channel search allows a device configured as a slave to find, and synchronize with, a specific master. This application note provides an overview of ANT channel establishment, search modes, and its impact on the performance of existing channels, latency and power consumption. The background channel type, based on the ANT search mechanism, is also introduced and described in detail from concept to implementation.

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1 Introduction

The ANT channel search feature allows slave devices to search, find and synchronize with appropriate transmitting master devices according to a set search criteria.

This application note describes the ANT channel search and acquisition process. It explains the available search modes, and how to combine them for optimizing different search scenarios. Power and latency considerations relating to channel search are also discussed.

The background scanning channel type, which relies on the ANT search mechanism, is also introduced and described.

2 Relevant Documents

It is strongly recommended that the following documents be read and understood prior to using this application note.

- ANT Message Protocol and Usage
- AN02 Device Pairing

The following supplementary document may also prove helpful if intended applications will involve pairing in crowded environments:

- AN12 Proximity Search
- AN14 Continuous Scanning Mode for Asynchronous Topologies

3 ANT Channel Search

ANT channel search allows an ANT slave device to search for, and acquire, an intended unique master. Each ANT channel has an associated channel ID which is defined by the master device, and consists of the following parameters: Device Number, Device Type and Transmission Type. Refer to the ANT Message Protocol and Usage document for more details. Once a master device's channel is opened, it will immediately begin transmitting its channel ID along with the data.

The slave device's channel ID represents the master device it wishes to establish communication with. It can be configured to search for a specific master, or to search for a subset of masters by using wildcards (0) in any of the channel ID parameters. When the slave's channel is opened, it will begin searching for the master according to the channel ID criteria.

The slave will search for a matching master signal until:

- Search is successful and master acquired
- Search duration reaches user-defined time out period

The slave device will synchronize with the first matching transmission it finds. Once the slave has found a matching master, it will receive at the configured channel period (i.e. message rate). For the channel to maintain synchronization, the master and slave channel periods must either match, or be multiples of each other. If the slave's channel period is not equal to the master's channel period, then missed messages will occur.

The slave will send an EVENT_RX_FAIL (0x02) to its host MCU to indicate that a message was not received when expected.

After multiple, consecutive missed messages the slave device will drop back into search mode. If the message rate is slower than 2 Hz, the slave will go to search mode after four missed messages; for message rates faster than 2Hz, the slave will drop back into search after two seconds worth of missed messages.

The slave sends an EVENT_RX_SEARCH_TIMEOUT (0x01) to the host MCU to indicate a search has timed out on a receive channel. The channel is automatically closed.

4 Channel Search Example

Figure 1 shows a master device transmitting at a channel period of T_{ch}. When the slave opens its channel, it will immediately enter search mode. Note, the radio is only intermittently active rather than consistently active, helping to conserve power. This also means that the slave may not detect the first master transmissions that occur immediately after the slave has opened its channel and started searching.

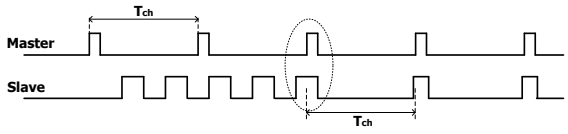

Figure 1. Example Search

Once the master transmission has been received (shown as circled in Figure 1), the slave will exit search mode and enter tracking mode. In tracking mode, the slave will receive at its designated channel period, which in this case is also T_{ch}. The slave will receive a message from the master on

each designated timeslot, which ANT passes to the host and also uses for channel synchronization. For a bidirectional channel, the slave can optionally transmit data back to the master device in the reverse direction on each channel timeslot.

5 Relationship between Master and Slave Channel Periods

Once a channel has been acquired, the channel period can affect the latency and power performances of the devices. Best practice is to set the slave's channel period equal to, or a multiple of, the master's channel period. Figure 2 shows examples where the slave's channel period is: (a) multiple; (b) factor; and (c) unrelated to the master's channel period.

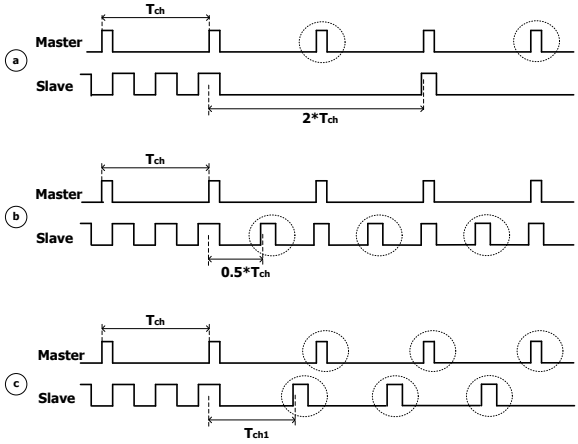

Figure 2. Relationship between Master and Slave Channel Periods.

Part (a) illustrates the case where the slave's channel period is a multiple of the master's. The slave can maintain synchronization with the master as it will receive a message for each timeslot. Slowing the slave's message rate like this can be used to conserve power on the slave device; however, it is important to note that this will also result in missed transmitted data messages (circled) and should only be used if the intended application is tolerant to missed data packets and increased latency.

When the slave's channel period is a factor of the master's, as shown in (b), then EVENT_RX_FAILs will occur as no data was transmitted by the master when the slave was expecting to receive data (circled). The slave could possibly maintain synchronization in this case, and should receive the transmitted messages; however, this situation wastes power on the slave device and should be avoided.

Another case that should be avoided is that described in part (c), where the slave and master channel periods do not match and are not multiples of each other. The slave will try to synchronize at its designated message rate T_{ch1}, resulting in multiple EVENT_RX_FAILs and missed messages (circled). There is a high potential that the number of missed messages results in the slave dropping back into search, and continually finding then dropping the master resulting in excessive power consumption and little or no data throughput.

6 Search Modes

Most ANT devices support two search modes, low priority and high priority, which differ in how existing channels are affected during channel acquisition. Low priority search provides the capability of searching for a master without interrupting other open channels on the device. A high priority search, as the name suggests, will take priority over any other open channels on the that device, interrupting their operation. The nRF24AP1 supports high priority mode only.

Figure 3 illustrates the difference between the two search modes, showing a device with two open ANT channels: channel 0 is open and synchronized to another device (not shown) and channel 1 is in search mode.

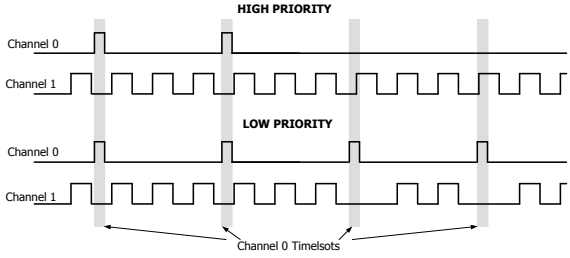

Figure 3. Low and High priority search modes.

If channel 1 is in high priority (HP) search mode then any time there is an overlap of channel 0's timeslot and channel 1's active search time, then the search is prioritized and channel 0's Tx (or Rx) operation will not occur. On the other hand, if channel 1 is in low priority (LP) search mode, then the radio will Tx (or Rx) data on channel 0 rather than perform channel 1's search during the overlapping timeslot.

6.1 Search Operation

When an ANT channel is opened on a slave device, the search is automatically and immediately initiated. ANT will first search in low

priority mode (if available*), and then will only switch to high priority mode after a defined time out. If the high priority search also times out, then ANT will issue an EVENT_RX_SEARCH_TIMEOUT and close the channel (Figure 4).

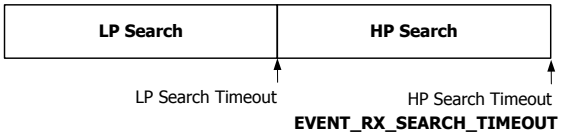

Figure 4: Low and High Priority Search

Search time outs for both low priority and high priority modes are independent, and can be adjusted to balance the latency of acquiring a new device with the performance effects on existing channels. These trade-offs are described below:

LP Search:

- Does not interfere with the operation of existing channels while searching for a master
- *Typically* results in similar latency and power consumption as HP search
- Does not ensure low latency acquisitions, and in some very rare cases may not result in an acquisition at all

HP Search:

- Existing channels will be interrupted if their timeslots overlap with the search
- Up to 50% of data messages on existing channels can be lost during search
- Will ensure a master is found with low latency (i.e. short acquisition times)

When configuring the low and high priority mode time outs, it is important to take these trade-offs into consideration. For example, the low priority search time out should be long enough to allow for most acquisitions to occur through a low priority mode search (i.e. without affecting existing channels); but, it should also be short enough that the search will search to HP mode in order to ensure low latency acquisitions.

Either mode can be disabled as desired. However, care should be taken to avoid disabling both time outs at once, as this would result in an EVENT_RX_SEARCH_TIMEOUT (and channel closure) immediately after the channel was opened.

* For nRF24AP1 devices, when a slave channel is opened it will go immediately into a high priority search as there is no low priority search mode.

6.2 Configuring Search Timeouts

The search mode time outs can be configured using the following commands:

LP Search:

- *Set Low Priority Search Timeout* (0x63)

HP Search:

- *Set Channel Search Timeout* (0x44)

These commands can be used to set the maximum duration (in intervals of 2.5 seconds) that ANT will search for a device in each respective mode.

For example, the default low priority search time out value is 2, which results in 5 seconds of low priority mode search before switching to high priority mode, as shown in Figure 4.

The default high priority search time out value is 10, resulting in 25 seconds of high priority search before timing out, at which point ANT will send an EVENT_RX_SEARCH_TIMEOUT to the host and close the channel.

Note, for nRF24AP1 the only search mode available is an HP search, and its default timeout value is 12 (i.e. 30 seconds).

If search time out values other than the defaults are desired, these should be set prior to opening the channel, as shown in Figure 5.

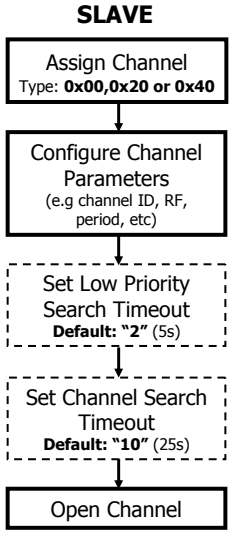

Figure 5. Configuring Search Timeouts

6.2.1 Considerations

Low and high priority search time outs can be configured independently or combined depending on the requirements of the application. Using a combination of low and high priority search modes will guarantee that a new device will be found relatively quickly, while also limiting the performance effects on existing channels. Selection of time outs for both search modes is dependent on the master's message rate, data loss tolerance of existing channels and the acceptable latency for acquisition of new channels. The default and max/min time out values are listed in Table 1.

Table 1. Default and Special Time outs

Value	HP Search Timeout (seconds)	LP Search Timeout (seconds)	nRF24AP1 Search Timeout (seconds)
Default	25 (0x0A)	5 (0x02)	30 (0x0C)
0x00	0 < 2.5	0 < 2.5	0 < 2.5
0xFF	Infinite	Infinite	10.5mins

The default values for both high and low priority search are optimized for a ~4Hz message rate. Care must be taken to ensure at least one of the time out values is non-zero.

An infinite search time out can be achieved by setting the time out value to 255, allowing a slave to search for a master indefinitely; except for nRF24AP1, which has high priority search only, and a value of 255 results in a maximum search time out of 10.5 minutes.

7 Power and Latency

A slave device consumes more current during a channel search than it does when synchronized. The average current consumption in search mode is typically around 2 to 3 mA.

Acquisition times depend on the channel period of the master that is being acquired. The worst case acquisition times for common transmission message rates are shown in Table 2.

Table 2: Worst Case Channel Acquisition

Message rate (Hz)	Worst case search time (s)
10	2
4	3
2	7
1	15
0.5	45

There is no mathematical formula for calculating these numbers. These estimates were empirically defined assuming zero packet loss and a favorable RF environment.

8 Background Scanning Channel

Background scanning channel is a special channel type that operates in search mode (as described earlier); however, instead of acquiring a master, ANT will pass the data to the host and continue searching.

The *Enable Extended Messages* (0x66) command can be used to allow the master's channel ID to be passed from the slave's ANT to host, along with the data message that was received. Should the slave device want to establish communication with that master, the host application can then use the received channel ID to open and establish another channel with that specific device.

As the name suggests, the background scanning channel will continue to search in the background, passing on any received messages from in-range master devices. The slave's host application can then chose to ignore the transmission; or to open and establish a channel with those masters. Note that the background scanning channel will not receive messages from any master that has an established channel with the device. This is further explained in the example below.

8.1 Background Scanning Channel Example

Figure 6 provides an example background scanning channel operating on a slave device's channel 0. Two master devices (MASTER_1 and MASTER_2) are also present and transmitting at their own channel periods, T_{ch1} and T_{ch2}, respectively. As described earlier, the search algorithm activates the radio intermittently in order to conserve power. As such, the slave may not catch all transmissions. The transmissions that are received by the background scanning channel are passed to the host application, along with the master's channel ID. In this case, on receiving MASTER_1's data and ID, the slave opens a second channel, ANT channel 1, with MASTER_1's channel ID. The slave device will continue to search and any new data received (such as transmissions from MASTER_2) will be passed to the host on channel 0. In this case, data from MASTER_2 is ignored; however, if communication with that master were desired, a third channel could also be opened.

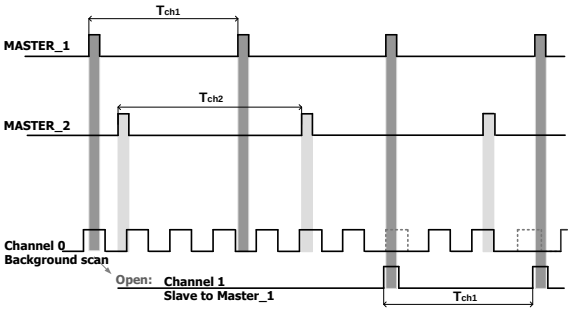

Figure 6. Background Scanning Channel

When data from MASTER_1 is received again, channel 1 will synchronize to that device. Note, the slave must have knowledge of the channel period T_{ch1}. Provided the search parameters are configured for low priority mode only, then channel 0 will only search when channel 1 is not active. In other words, priority of the overlapping timeslots will be given to channel 1. As such, channel 0 will never receive data from channel 1's master device. It is not recommended to use a background scanning channel in high priority search mode as this can interfere with any open channel on the device.

The background scanning channel will perform high and low priority searches exactly as described in the previous sections. Therefore care must be taken when defining their values. As this channel type is intended to run in the background, it is recommended that the high priority search mode is disabled (i.e. set to zero).

Low priority search mode is defined as desired. An infinite search time (0xFF) can be used if the background scanning channel is intended to be active all the time or a timed search may be more appropriate depending on the application. For a set duration search, ensure that high priority search mode is disabled.

8.2 Configuring a Background Scanning Channel

The necessary steps to configure a background scanning channel are shown in Figure 7. The background channel is enabled by setting the extended assignment byte to 0x01, and including this byte when sending the *Assign Channel* (0x42) command. As a background scanning channel cannot transmit data in the reverse direction it should be assigned the receive only channel type (0x40).

Background Scanning Channel

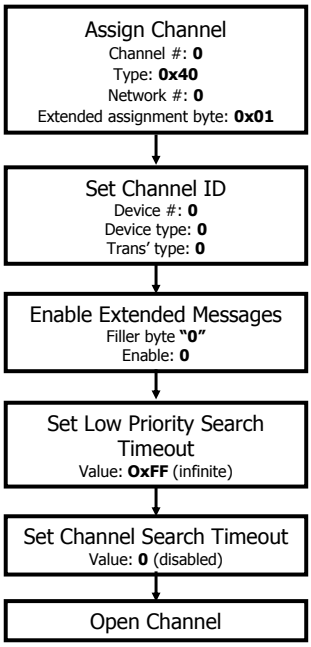

Figure 7. Configuring Background Scanning Channel

The Channel ID must also be set to define the background scanning channel's search criteria. In this case all fields are wild carded and any ANT master device transmissions will be passed to the host application. The search criteria can be limited by setting one or more of the channel ID fields to a specific value. Refer to application note AN02 – Device Pairing for more information.

Extended messages should also be enabled such that the slave host application can associate each received message with the appropriate master.

The low and high priority search time outs must also be set appropriately. It is recommended to disable the high priority search mode and set the low priority search mode to the desired duration. In this example, the high priority mode is disabled and the low priority mode is assigned an infinite time out. If using time outs of a set duration, remember that a disabled high priority mode can still potentially interrupted open channels in the 0<2.5 seconds after a low priority mode time out.

The final step is to open the channel.

9 Closing Remarks

This application note provides an overview of the ANT channel search mechanism, including the low and high priority search modes and configuration combinations of these two modes to meet application requirements. Note, all diagrams are conceptual examples only and timing details are not to scale. Power consumption and latency considerations during channel acquisition are also provided. The background scanning channel type, which relies on the search mechanism, is introduced and discussed.