



Multi-Channel Design Considerations

ABSTRACT

This application note addresses some important considerations that ANT developers should take into account when designing multi-channel solutions. Potential problem areas that can arise in multi-channel systems are discussed, along with some best practices when using more than a single channel.

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1 Introduction

As the ANT protocol and hardware matures, the solutions being implemented are becoming increasingly complex, particularly as use cases for wearables and the “internet of things” become more pervasive. Many ANT devices must now take full advantage of one of the fundamental features of ANT, that being support for multiple concurrent channels on a single device.

This application note is intended to address some of the important considerations that ANT developers should take into account when designing more complex multi-channel solutions. Some of the potential problem areas that can arise in a multi-channel system are discussed, along with some best practices when using more than one channel concurrently. Typical applications of multi-channel usage are also discussed.

Basic knowledge of single channel ANT development is implied in this document.

2 Relevant Documents

It is strongly recommended that the following documents be reviewed prior to using this application note. To ensure you are using the current versions, check the ANT+ website at www.thisisant.com or contact your ANT+ representative

- ANT Message Protocol and Usage
- ANT Chip / Module Datasheet
- AN11 – ANT Channel Search
- AN04 – Burst Transfers

3 ANT Channel Overview

To understand multi-channel ANT, it is important to have an understanding of the

concept of an ANT channel.

The ANT channel is the basic building block of ANT. It is the mechanism by which two devices communicate with each other.

At the physical layer, ANT only has a single radio. ANT channels are a higher layer construction where the total available payload bandwidth of the radio is shared through a TDMA scheme. Newer ANT devices may currently have up to fifteen independent channels/connections to other devices, and this continues to increase as hardware continues to mature.

It is important to recognize that the bandwidth of the radio is shared. The maximum data rate of an ANT device is approximately 60 kbps (advanced burst) or 300 Hz (broadcast) and these maximum rates remain constant regardless of whether there is one active channel or fifteen active channels.

3.1 Why Use Multiple Channels?

Some applications are certainly better suited to use a single ANT channel, but there are also instances where taking advantage of the multi-channel capabilities of ANT can lead to improved performance. In some cases, adding more channels may allow for the reduction of physical devices in a design.

Another advantage of using multiple channels is that a device may move from being either a master or a slave to being both a master and a slave, transmitting and receiving multiple data types simultaneously. This enables complex topologies such as stars, trees, “meshes” and other high node count topologies.

Adding more channels may also allow a

developer to take advantage of more advanced ANT features such as having a “dedicated” search channel for new devices, or building mesh like topologies such as the ANT “scan and forward” reference design. This topology uses background scanning to receive messages from any ANT device and to re-transmit the message, dynamically forming a network based upon nodes broadcasting information to one another.

3.1.1 Example Multi-Channel Applications

A few of the typical ways that multiple channels have been used in actual ANT designs are given below:

Display/Collector Devices: These are devices that are intended to receive and display data from a number of sources. For example, an ANT+ enabled watch is capable of receiving several simultaneous signals, such as heart rate from a heart rate strap and speed and cadence from a foot pod. Different channels are used to listen for different devices.

Multi-Function Sensors: Some sensors, such as bike power sensors, need to listen to data from other sensors before sending the combined data on to a master device.

Relay Devices: Some ANT devices are intended to relay information from one location to another. They may listen on many channels for information that is then passed along on a separate transmit channel.

Advanced Network Topologies: The ANT protocol allows for several different types of network to be established. Using multiple channels enables more complex network designs such as star networks, personal area networks (PANs), or other high node

count topologies.

4 Design Considerations

There are several factors that play into multi-channel design that need to be considered by developers. Using more than one channel usually requires more thought than simple, single channel designs.

4.1 Dedicated Background Scanning Channel

One of the simplest ways to use multiple channels is to incorporate a dedicated background scanning channel into a design.

A background scanning channel will continuously search for devices in the area without acquiring any particular device or interfering with any other open channels. Any data messages received while searching are relayed to the host application along with the channel ID of the transmitter. The host may then decide whether it wants to connect to a particular device using another channel.

One typical use case is an application that can track devices entering or leaving its range on an ongoing basis. Another is an application that allows for finding all the devices in the vicinity before making a pairing decision, allowing flexibility in how pairing is handled.

4.2 ANT Networks

There are three main types of networks available to ANT devices: public, managed (such as the ANT+ network), and private networks. Channels cannot communicate between networks, but a single device may access multiple networks by assigning different channels to different networks.

Up to a maximum of 15 network keys (with the latest available hardware at the time

this article was updated) can be assigned to different channels on a device, as partially illustrated in Figure 1.

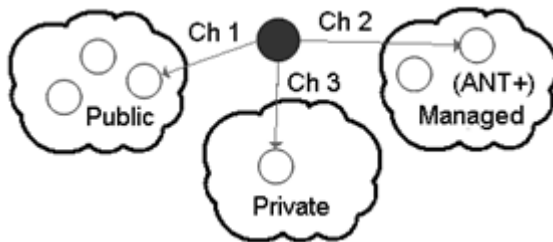


Figure 1. Multi-Channel Networks

As shown in the figure, the only way to communicate between networks is via an intermediary device that has access to both. For this reason, multi-network, multi-channel applications need to pay be aware of things such as search priority and/or search sharing, discussed in sections 4.5.5 and 4.5.6 respectively.

4.3 Power Considerations

Typically, adding channels comes at some cost to power consumption. The more channels that are added, the more the radio will be “on” and consuming power.

However, channels can still be added to a device without breaking a device’s power budget. This can be achieved by managing channel periods to keep the overall radio usage the same or lower. For example, a device may listen for ANT+ heart rate on a second channel at 1 Hz instead of the standard 4 Hz if this rate is acceptable.

4.4 Channel Collision

As discussed in section 3, ANT channels on a single device share a single radio. In most cases, this sharing works seamlessly, but there are circumstances where more than one channel tries to access the radio simultaneously and not all of the channels can be serviced. This event is known as a

“channel collision” and it occurs at the chip or device level (not in the RF space).

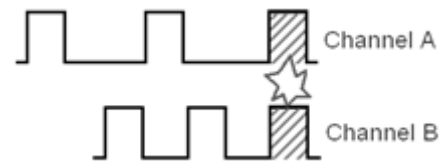


Figure 2. Graphic Example of Channel Collision

In this case, only one of the competing channels will “win” access to the radio. For slave channels, the data in the channel that is denied access is lost. For master channels in a collision, the data will remain in the buffer and be retried on the next channel period, assuming the application does not overwrite this buffer in the meantime. This behavior may be controlled by listening for the `EVENT_CHANNEL_COLLISION` message, described below.

It is important to recognize that a channel collision is not an error. Under certain multi-channel configurations channel collision is a known and expected event. Channel collision only becomes a problem when it occurs at such a frequency that one or more other channels in a system are starved for data. Steps can be taken in a multi-channel application to both minimize the chances of collision and properly deal with potential consequences of channel collision outcomes (such as a channel dropping into search due to extended receive failures). These configurations are discussed in the following sections.

4.4.1 *EVENT_CHANNEL_COLLISION*

On some ANT devices an explicit channel event is raised when ANT detects that a channel collision has occurred. This is raised through the Channel Response / Event (0x40) message. The AP1 device does not generate this event.

Applications may listen for this event and choose to take action, if necessary. It should be noted that most ANT applications are designed to accommodate minor loss of data without any explicit actions being taken.

For specific event codes refer to the “Ant Message Protocol and Usage” document.

4.4.2 Causes of Channel Collision

Common circumstances that can cause a channel collision may include some or all of the following. Developers should be aware of these factors and create designs that minimize these factors.

4.4.2.1 High Channel Periods

Channel periods in the area of 8 Hz and higher are particularly susceptible to collisions in multi-channel applications. Developers should make efforts to reduce the channel periods in their design.

4.4.2.2 Channel Periods that Drift / Overlap

Frequencies such as 4.06 Hz (ANT+ Heart Rate) and 4.005 Hz (ANT+ Bike Power) will periodically “drift” into each other, or into other channel periods that may be present in the vicinity. During this overlap, channel collisions may occur as the radio can only service channel at a time.

Sometimes this drifting behavior can be intentionally used to resolve collision problems. When two channels on fixed channel periods are colliding for long periods of time, intentionally selecting a drifting period can help alleviate this under certain circumstances.

4.4.2.3 Using Too Many Simultaneous Channels

Some ANT devices can currently have up to 15 simultaneous channels. Unused channels do not add any overhead to a design, but

each time an additional channel is opened on a device, the amount of free radio bandwidth is decreased, which in turn increases the odds of channel collision occurring. The severity of this is application specific, but it becomes more of a concern when using slave channels mixed with master channels.

4.4.2.4 Searching

A slave channel dropping into search can cause a high level of channel collisions on a device, particularly if the channel performs a high priority search (not to be confused with the channel search priority command, which manages priority between multiple channels searching concurrently).

Channel collision can also cause a receiver to drop into search because it was starved for data. This can have further unintended consequences, particular if an application does not anticipate this happening. Searching

4.5 Search

Searching is the method by which an ANT slave device finds and establishes communication with a master. In a multi-channel application, searching has the potential to impact other channels.

There are two main types of search available to ANT devices: low priority and high priority search. As shown in Figure 3, the difference between low and high priority search is in the behavior that occurs in the event that a search waveform overlaps with a channel. For a high priority search, the search will take precedence and the channel will be blocked, while for a low priority search the channel will take precedence and the search will be blocked.

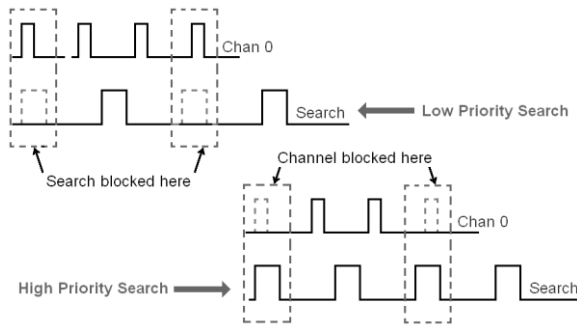


Figure 3. Graphic Example of Channel Collision

In a multi-channel application, it is important to select the type of priority search that is most appropriate for the application.

4.5.1 Search Timeouts

Search timeouts are another aspect of searching that should be carefully considered in a multi-channel system. Long timeouts increase the likelihood of finding other devices, but at the cost of increasing the chance of channel collisions. This may have further consequences for other channels in the system (i.e. other channels dropping to search).

It is important to note that search can impact both master and slave channels. Channels using acknowledged messages are particularly susceptible, as acknowledged messages effectively use double the radio bandwidth of regular broadcast messages.

In general, shorter search timeouts are safer in a multi-channel use case, but the consequences of a search ending without acquisition (and channels closing) must also be considered.

4.5.2 Searching on More than One Channel

Search timeouts are another aspect of searching that should be carefully considered in a multi-channel system. Long

timeouts increase the likelihood of finding other devices, but at the cost of increasing the chance of channel collisions. This may have further consequences for other channels in the system (i.e. other channels dropping to search).

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4.5.3 Search Waveform

The search waveform command controls the amount of time the radio hardware is active during a slave channel search, and consequently affects the balance between channel acquisition time and average power consumption.

This command must be used with extreme care. Setting the search waveform to a value other than the ones recommended here may have unintended consequences. One severe consequence may be the inability to discover master channels transmitting at certain channel periods, as some 'timeslots' may be left undetected by that search waveform.

The fastest acquisition times can still only be achieved by devices in scanning mode or with high duty search enabled.

The search waveform should not be set when high duty search or scanning mode is in use. Please note, changing the search

waveform **after** high duty search has been configured may have a detrimental effect on search acquisition time and **should be avoided**.

Table 1. Search Waveform Options

| Search Waveform Type | Value |
|---|-------|
| Standard | |
| Ideal trade-off between average power consumption and acquisition time during a channel search. | 316 |
| Fast | |
| A very large increase in average power consumption over a standard waveform with a corresponding reduction in acquisition time during a channel search. | 97 |

4.5.4 High Duty Search

High duty search uses the entire available resources of the radio to search for a master device. The effect is that latency to acquire the master device is drastically reduced to an average of 1/2 period assuming ideal RF conditions. Once the device is acquired the channel becomes synchronized to the master. This mode of operation consumes high power while in search and should only be used in applications that have considerable power resources available such as PC and mobile applications.

A channel in high duty search can co-exist with other channels. However the effect of the high duty search on the other channels must be taken into account as a high priority searching scheme can interfere with the performance of other channels causing unacceptable outages due to constant channel collisions. To mitigate this problem the suppression cycle may be used to alternate windows of high and low priority search modes. A search window is defined to be 250ms within a period of 1.25s. The

application has the option of setting X windows of low priority search within the period. For example, a suppression cycle of 1 opens up one 250ms low priority window within a 1.25s period. A suppression cycle of 0 uses high priority search across the entire period, whereas a suppression cycle of 5 uses low priority across the entire period. Please note that not all parts that support high duty search also support the suppression cycle. For these parts the high duty search uses high priority mode at all times. High duty search may also be affected by co-existence with other protocols on multi-mode com chips.

4.5.5 Effect of Channel Search Priority on More than One Searching Channel

The “channel search priority” command may be used to configure the search priority of the channel. If a channel has a higher search priority, it will pre-empt lower search priority searching channels that are already in progress. A pre-empted search will resume when the higher priority search has either acquired a connection, or timed out. This functionality is primarily for determining precedence with multiple search channels that cannot co-exist (Search channels with different networks or RF frequency settings). Please note that this message is only available on specific devices.

For example, if both channel 0 and channel 1 have a search priority of 0, then whichever channel goes to search first is the search channel and the other channel must wait until it is finished before searching.

If channel 1 has a search priority of 2 and channel 0 has a search priority of 0, then channel 1 will become the search channel anytime it goes to search, forcing channel 0

to wait until channel 1 has either acquired a device, or times out.

4.5.6 Search Sharing

This command may be used to configure the search sharing behaviour of the channel. To enable two (or more) channels to search concurrently on different RF channels or network keys, they can be configured to alternate which channel uses the radio for searching. The “search sharing cycles” parameter is used to specify how many cycles of the search waveform should be run before switching to other channels which also have search sharing enabled, are currently searching, and do not share the same RF channel or network key.

Search sharing will only be active for slave channels which share the same search priority level; i.e. slave channels with higher channel priority will not share usage of the radio with slave channels of lower search priority when attempting to acquire a channel. This is not to be confused with low priority search timeout, which prevents searches on a channel from interrupting other active channels.

It is recommended that the search sharing cycles parameter be set to 1 (or to 7 on devices with high duty search enabled). This will reduce any potential complications due to search sharing. High duty search cycles require additional time to start and stop compared to normal searches, thus setting the search sharing cycles parameter too low will result in increased acquisition times. Please note that some devices have high duty search enabled by default, e.g. USB-m.

Assuming power consumption constraints allow, it is recommended that the fast search waveform be set on devices which enable search sharing but do not enable

high duty search. Optimizing the search waveform may be used to decrease the search latency.

The search waveform of each channel should be set to the same value in order to improve the determinism of the acquisition time for each channel. Differing search waveforms on each channel may result in extremely variant acquisition times for each channel.

Each additional channel that shares searching with other channels will increase the average acquisition time by a proportional amount, assuming the channels share the same search waveform and search sharing cycle count. For example, if the average acquisition time for every channel is 1 second, then each additional channel that the search is shared with will increase the average acquisition time by 1 second.

Note that whenever search sharing is used it is important to test with each application’s master channel period to ensure that each application’s master channel period(s) can always be found. If incompatible parameters are chosen for search sharing it is possible that the search time for a given master may be infinite.

4.5.7 Search Timeouts

Search timeouts are another aspect of searching that should be carefully considered in a multi-channel system. Long timeouts increase the likelihood of finding other devices, but at the cost of increasing the chance of channel collisions. This may have further consequences for other channels in the system (i.e. other channels dropping to search).

It is important to note that search can

impact both master and slave channels. Channels using acknowledged messages are particularly susceptible, as acknowledged messages effectively use double the radio bandwidth of regular broadcast messages.

In general, shorter search timeouts are safer in a multi-channel use case, but the consequences of a search ending without acquisition (and channels closing) must also be considered.

4.6 Bursting

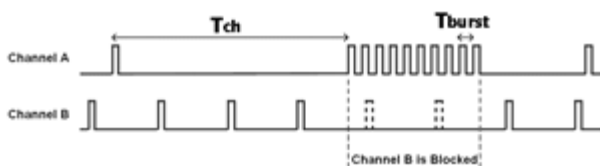


Figure 4. Bursting with Two Channels

Applications must carefully control the length of bursting to ensure that any other channels are not starved for data. Slave channels that are starved for too long may drop into search mode.

For more information on bursting, refer to the “Burst Transfers” application note.

It should be noted that ANT-FS uses bursting and the same rules apply to using ANT-FS with more than one channel.

4.7 Over-the-Air Coexistence

ANT’s adaptive isochronous coexistence scheme requires many features to be enabled to help ensure ANT master channels do not interfere with one another. Certain ANT features can interfere with ANT OTA coexistence:

4.7.1 Transmit Only Master Channels

Transmit only channels can help save the device power by not allowing ANT to open receive windows for the channel. However, this disables ANT coexistence meaning channels will always broadcast into one

another’s timeslots. This command should be used with **extreme prejudice**.

4.7.2 Fast Transmit Start for Master Channels

ANT master channels typically run a receive window first to help ensure they do not begin broadcasting into another master channel’s timeslot. Using this command can help the device reduce the latency of when a command is sent, but at the risk a master channel may broadcast during another master’s timeslot. This command should be used with **extreme prejudice**.

4.7.3 Bi-directional Continuous Scan Mode

Continuous scan mode allows an ANT device to receive all master and slave communications occurring over the same network (RF channel and network key). Opening a bi-directional continuous scan mode device allows multiple masters to send and receive broadcast, acknowledged and burst messages to and from the continuous scanning node directly. However, if nodes attempt to send burst/acknowledged messages to each other over the same network, the continuous scan node will also attempt to respond to these messages and collisions/interference will occur.

This combination should only be used when it is expected that nodes will only use broadcast messages between each other in the presence of a bi-directional continuous scan node. ANT+ Device Profiles typically recommend that broadcast messages be the predominant form of communication to reduce potential interference.

5 Common Misconceptions

A few common misconceptions regarding multiple channels are as follows:

Misconception: The high priority search is somehow faster or better than the low priority search.

Truth: In most instances, there will be no visible difference in acquisition time between a low and high priority search. The difference lies in whether the search channel or other channels take priority in the event of a collision. Whether high, low, or both types of search are used depends on the application.

Misconception: Adding channels to a device can increase the overall output of a device.

Truth: Adding channels does not add more device throughput. The max data rate of an ANT device is approximately 60 kbps (advanced burst) or 300 Hz (broadcast). This bandwidth is shared between all of the channels.

Misconception: Unused channels burden a device.

Truth: Unused channels do not impact device performance.

Misconception: All channels in a device all need to operate on the same parameters.

Truth: There are no dependencies between channel parameters – they can all be on different channel periods, frequencies, and networks (max three).

6 General Multi-Channel Best Practices

In addition to the guidelines for best practices of using multiple channels found throughout this document, a few high level multi-channel design best practices are:

1) Use ANTware II to mock up channel configurations as one of the first steps of

the design process.

Often devices reach a late stage of development before multi-channel issues such as channel collision or search problems are encountered. In many cases, these issues can easily be exposed using ANTware II without writing any code.

2) Try to minimize the following in designs:

- The number of different radio frequencies used.
- The number of networks used.
- The channel periods (message rates).
- The usage of TX-only or Fast TX-start for master channels.

Reducing these will reduced the likelihood of channel collisions and other design problems related to using multiple channels.

3) Manage Searching:

- Use low priority search whenever possible, as to not interfere with other channels.
- Be aware of the consequences on all channels on both sides of a system if one channel goes into search, even unexpectedly.
- Use search sharing to manage channels with different RF channels and/or network keys because these channels cannot share the same search time.

3) Manage Channel Periods

- Channels which share integer multiples of one another will be less likely to collide with one another

due to drifting timeslots

4) Take advantage of the additional features on the newer ANT chips. Features such as low priority search, a background scanning channel, “EVENT_CHANNEL_COLLISION” event messages, search sharing, channel search priority, search waveform, and high duty search on newer devices.

7 Closing Remarks

This application note has detailed how to develop ANT devices using multiple channels. Although multi-channel devices generally require more thought during design than single channel devices, the guidelines in this document can help to make development easier.

If any of the concepts presented in this application note are unclear or for any further inquiries, please use the developer forum at www.thisisant.com.