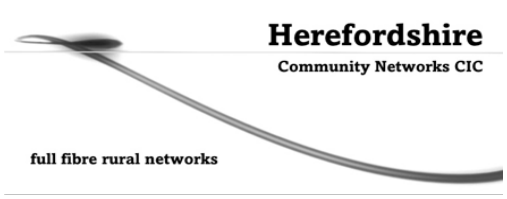

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General Wi-Fi Best Practices

Technical Guide

General Wi-Fi Best Practices

Keep the following in mind when planning or implementing your Wi-Fi network:

- When two Wi-Fi capable devices connect to one another and have different characteristics (for example, a MIMO 4x4 device talking to a MIMO 2x2 device), the lowest capable devices performance is obtained.
- For all Wi-Fi radios within range on the 2.4 GHz band, the 40 MHz wide band is only used if no other competing 2.4 GHz band devices are present. Similarly, for the 5.0 GHz band, the 80 MHz channel is only used if no other competing 5.0 GHz band devices are present.
- A Wi-Fi connection is only as "fast" as the slowest connected device (everyone must wait their turn). In other words, while the Fibre Router may support 4 spatial streams, a 1x1 STA can only support one stream so the additional streams available from the Fibre Router are 'wasted'.
- **EXCEPTION:** Multi-user MIMO devices running at 5 GHz can communicate at the same time (example: mobile phones communicating on the 5 GHz HSI SSID). In this case, four 1x1 clients would each receive one stream from the Fibre Router and thereby maximally use the air time and capabilities of the Fibre Router.
- For networks running 802.11g and below, you should expect a 40-70% drop in throughput.
- HCN strongly recommends using the auto-channel selection feature on the Fibre Router. Set both radios to "On" for auto-channel selection.
- On the 2.4 GHz band, if auto-channel selection is not used, pre-set the channels to **1, 6, or 11 only** to reduce co-channel interference with other networks in your area (such as neighbouring houses).
- For homes using wireless set-top boxes, make sure these devices are set to the default highest priority 5.0 GHz IPTV SSID.

Note: As a best practice, HCN recommends that DVRs be hard-wired via CAT5 or better Ethernet cables to the residential gateway.

- Where available, enable *DFS*.
- Generally speaking, wireless cameras always utilise the 2.4 GHz band (not configurable). Make sure the SSID assigned to this service has a high priority using WMM for 2.4 GHz and SSID prioritisation for the 5 GHz band.

Fibre Router Placement

The Fibre Router is designed to be placed within an interior, temperature-controlled environment. Use the available installation guides for instructions on proper mounting of the HCN Fibre Router. Also, review the guidelines for orientation of the unit as found in the following section.

Certain building materials are particularly effective at blocking Wi-Fi signals (see table overleaf) and should be considered when locating a Wi-Fi access point. Line of sight is not necessary since MIMO technology takes advantage of reflections in the over-the-air path to carry additional data. However, HCN recommends that when possible, the HCN Fibre Router should be placed in a centralised location within the home to yield the best possible results for Wi-Fi coverage.

Building Materials and Their Effect on Wi-Fi Signals	
Material	**Wi-Fi Attenuation**
Wood, Drywall, Particle Board, Tile	Low
Glass	Low
Water	Medium
Bricks, Cinder Block	Medium
Plaster, Stucco	High
Concrete	High
Elevator Shafts	High
Tinted or Low-E Glass (metalized)	Very High
Metal	Very High
Note: Low attenuation is considered to be best performance.	

About 2.4 GHz and 5.0 GHz Interference

2.4 GHz Interference Sources

Most interference in wireless networks occurs in the 2.4 GHz band. The table below is a partial list of "interferers" and their relative effect on Wi-Fi signals. As you gain experience with your particular environments, this list can be expanded as necessary.

2.4 GHz Device Interferers and their Effect on Wi-Fi Signals		
Very High Interferers		
Microwave Oven	2.4 GHz Cordless Phone	Neighbors Wireless Devices
Other Interferers		
Proximity Sensors	Wireless Mouse	Set-top Boxes
Wireless Audio Devices (headsets or speakers)	Bluetooth Devices	Wireless Video/Surveillance Cameras
Outdoor microwave links	Fluorescent Lights	WiMAX
Loose electrical connections	RF leakage (Satellite TV)	Baby Monitors
ZigBee devices	Certain External monitors and LCD displays (typically 2.4 GHz band near Channel 11)	Elevator Motors

5 GHz Interference Sources

5.0 GHz Device Interferers and their Effect on Wi-Fi Signals		
Very High Interferers		
5 GHz Cordless Phone	Nearby 802.11a or 802.11n WLANs	Radar (Weather or Military), DFS Channels only
Other Interferers		
Digital Satellite Transmissions	Outdoor wireless 5 GHz bridges	Perimeter sensors

Fibre Router Orientation

Fibre Router

The HCN Fibre Router uses internal antennas, making for a more attractive, maintenance free product while preserving Wi-Fi performance. The 5 GHz antennas are located along the top edge while the 2.4 GHz antennas are located along the side nearest the LEDs. HCN recommends orienting the Fibre Router antennas up or out to the right where they are most effective. In the photos below the "Wall Mount" shows the unit with antennas facing out (into the room or dwelling). The "Table Top Mount" means the 5 GHz radios are facing up while the 2.4 GHz radios are facing out to the right.

Note: Due to the location of the radios, do not mount the Fibre Router flat upon a desktop or flush against the ceiling. In additional, HCN recommends orienting the Fibre Router such that the LEDs are facing the areas of coverage. The unit can be mounted vertically or horizontally and will provide excellent Wi-Fi coverage in either orientation. However, every structure is unique in its construction and you may find that the desired coverage can be optimised by changing the orientation of the Fibre Router.

Wall Mount - Horizontal	Wall Mount - Vertical
	

Tabletop Mount


Mitigating Common Interferers

The primary method of avoiding interference is to move away from channels that have interference and migrate to channels with no or less interference.

Note: Although moving to channels with little to no interference seems intuitive, this approach is more effective in the 5 GHz band than in the 2.4 GHz band due to number of overall channels available.

Channel selection is accomplished in one of two ways:

Channel Selection at Start-up - Using this method, a channel is manually selected for a given radio. Once a client or client attaches to that channel, the channel is locked until there are no clients or clients present. Once a channel is clear, another channel can be selected. This method is commonly used on the 2.4 GHz band due to the limited number of channels available.

Dynamic Channel Selection - Using this method, the AP can change its channel whenever the opportunity presents itself to increase throughput. This occurs independently of attached clients or clients and the AP is constantly looking to occupy the "cleanest" spectrum with the least amount of interference.

Automatic channel selection or "hopping" can be configured at start-up or it can occur dynamically (during operation). Wi-Fi radio manufacturers often will incorporate dynamic

channel hopping for the 5 GHz band because it is highly effective with a wide range of channel options to "hop" to. For the 2.4 GHz band, it is likely that manufacturers only provide automatic channel selection upon startup (since there are typically only 3 channels to choose from). The reason 2.4GHz dynamic hopping is not commonly used is that it can cause more problems than it solves. The act of hopping channels is sometimes more disruptive than the interference itself and if all of the 2.4 GHz channels are crowded, hopping serves no benefit.

Note: The HCN Fibre Router follows the approach described above. That is, the 5.0 GHz band is configured for dynamic channel selection during operation, whereas the 2.4 GHz band uses manual channel selection at start-up.

It is also possible to judiciously use manual channel selection in a designed deployment strategy.

Other interference mitigation can be done by desensitising the receiver and for narrow band interference (cordless phones and baby monitors) by manipulating the Optical Frequency Division Multiplexing (OFDM) sub-carriers. The Fibre Router has automatic interference mitigation using these two techniques, where the mitigation is only done when interference is detected.

About SSID Naming

If seamless roaming between 2.4 GHz and 5 GHz radios is desired, set-up identical SSID names and passwords and assign them to both bands.

Note: In a high-density environment, this may be less desirable as clients should be utilising the 5 GHz band wherever possible. Generally, clients select the band by which SSID has the highest signal strength. By having different SSID names (i.e. Smith_2_4GHz and Smith_5GHz), clients could have control over the band the client is currently in.

Managing Expectations

The 5 GHz band is definitely the future of high reliability and high-performance Wi-Fi. While there are many legacy 2.4 GHz only clients, there are very few of these requiring high speeds. If customers expect to stream high definition video, they should realise that the 5 GHz band is the preferred spectrum for HD video. In short, all clients that can use 5 GHz should be moved to the 5 GHz band.

In addition, while enabling DFS channels in the Fibre Router more than doubles the available 5 GHz spectrum, it is important to note that not all clients can tune to DFS channels. Some lower cost Wi-Fi clients (such as USB dongles) do not support DFS channels. In these cases, the operator may wish to turn off DFS channels for users who have clients that don't support DFS channels, but at the same time realise that the 2.4 GHz band may not be adequate for their needs.

High Density Wi-Fi Best Practices

To recap the salient points concerning Wi-Fi Best Practices, keep the following in mind:

- **Manage Expectations -** 2.4 GHz should be considered ‘best effort’ while the 5 GHz band should be used for high speed and high reliability needs.
- **Channel Selection -** For the 5 GHz band, HCN recommends using dynamic auto-channel selection; for the 2.4 GHz band, a manual channel selection plan with 3 channel frequency re-use may be needed. Always use only Channels 1, 6 and 11 for the 2.4 GHz band.
- **Channel Width:** In any 2.4 GHz high density environment, 40 MHz channels should never be used. The ‘good neighbour’ rule prevents use of 40 MHz channels if there is an overlapping channel, which there always will be in any high-density environment. For 5 the GHz band, it may be possible to use 80MHz channels but 40MHz channels are preferable to avoid interference.
- **DFS Spectrum:** If possible, DFS channels should be enabled for 5 GHz as this spectrum will more than double the number of available channels and reduce the probability for interference. This is especially true for IPTV deployments. For subscribers that have clients that cannot access DFS channels and want to operate on the 5 GHz band with no IPTV services, DFS channels in the auto-selection mode may be disabled for that subscriber.
- **Transmit Power:** For the 2.4 GHz band, it may be beneficial to reduce the transmit power to reduce interference. However, this should be balanced against reduced range that will result with reduced transmit power. For 5 GHz, the radio has dynamic power reduction built in (based on how close a given client is to the Fibre Router).

PHY Rate vs. Data Throughput

The PHY rate is the rate often quoted by manufacturers to describe the throughput speed of any Wi-Fi access point. PHY rate is the theoretical link rate that is determined by the number of spatial streams, modulation type, channel bandwidth, and the like. In reality, usable data transmission is usually at best about one-half of the PHY rate due to overhead in the 802.11 protocol (headers, retransmissions, management frames) that are carried as Wi-Fi data in addition to the user data. Other impairments also lower the available data transmission rate as detailed in the next section of this guide. Since IEEE 802.11 is a highly adaptive protocol, it is difficult to predict actual throughput rates in any given environment. For this reason, PHY rates are typically used to describe and compare the throughput capability of a Wi-Fi access point.

Note: Poor PHY rate results are often caused by poor downstream signal strength and/or interference. Move the client closer to the Fibre Router or move the Fibre Router to a more advantageous location within the home.

Wireless Network Behaviour

The adaptive nature of the 802.11 protocol allows the radio to change its transmission characteristics to maintain data integrity. Known as "rate adaptation", various techniques are used by Wi-Fi radios to determine the optimal data transmission rate based on existing environmental conditions.

Different manufacturers employ different algorithms, however all of them monitor the same channel conditions (including detected interference, data error rates, and number of retransmissions) and will lower the data rate until error rates are below acceptable levels. When conditions improve, the algorithms also allow for an increase in the data rate (up to the maximum level), in optimum conditions. This accounts for the variations users see in the available PHY rate reported by their device.

Due to rate adaptation, the PHY rate of the radio can be used to determine the quality of the Wi-Fi link. The rate adaption algorithm reports the rate that the radio is capable of supporting given the signal quality. In the presence of data errors, the PHY rate begins dropping in incremental steps (as opposed to a continuous, steady drop) until an acceptable data error rate is reached. The radio may also decrease the rate further by changing the modulation type to a less interference prone and slower scheme. When conditions improve, rate adaptation allows the radio to raise its PHY rate, improving throughput, as long as data integrity is maintained (up to its maximum PHY rate).