Wi-Fi requirements for Home Gateways - Automatic Channel Selection and Repeaters

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2 Acronyms and terminology

2.1 Acronyms

ACS  Automatic Channel Selection  
Note: in this document ACS does not mean Auto Configuration Server

AP  (Wi-Fi) Access Point

ASCII  American Standard Code for Information Interchange

CSA  Channel Switch Announcement

CAC  Channel Availability Check Time

DFS  Dynamic Frequency Selection

GUI  Graphical User Interface

HG  Home Gateway

NFC  Near Field Communication

PSK  Pre-Shared Key

SDO  Standards development organization

SSID  Service Set Identifier

Wi-Fi  Wireless Fidelity (IEEE 802.11)

WFA  Wi-Fi Alliance

WLAN  Wireless LAN

WPA  Wi-Fi Protected Access

WPS  Wi-Fi Protected Setup

2.2 Terminology

Interference  Interference detected from a Wi-Fi AP on a channel. It can be of two types:
• Wi-Fi interference, that includes all the 802.11a/b/g/n/ac Wi-Fi APs signals.

• Non-Wi-Fi interference: that includes all the remaining non-Wi-Fi signals. 
  Example of sources particularly disturbing for the Wi-Fi bands are: baby monitors, video senders, microwave ovens, wireless video cameras, cordless phones, bluetooth devices, fluorescent lights, etc.

Wi-Fi Interference  Interference detected from a Wi-Fi AP on a channel coming from 802.11a/b/g/n/ac Wi-Fi sources. The level of interference is to be determined as a function $f(N,P,T)$ taking into account the following parameters:
• Number $N$ of detected Wi-Fi networks on the channel (for 2.4 GHz operation, also on the neighbour overlapping channels, in the range of +/- 3 channels).

• Power $P$ of detected Wi-Fi networks on the channel.

• Percentage $T$ of time the channel is sensed as idle during a test period of $T_{scan}$ seconds.

Background Noise  Noise detected on the channel coming from non-Wi-Fi sources.
2.3 **Definitions of requirements terms**

The definitions of MUST, MUST NOT and SHOULD in this document are as follows:

**MUST**
A functional requirement which is based on a clear consensus among HGI Service Provider members, and is the base level of required functionality for a given class of device (AP and repeater).

**MUST NOT**
This function is prohibited by the specification.

**SHOULD**
Functionality which goes beyond the base requirements for a given class of device (AP and repeater), and can be used to provide vendor product differentiation (within that class).

Note: these definitions are specific to the HGI and should not be confused with the same or similar terms used by other bodies.
3 Scope and purpose of this document

HGI has always considered Wi-Fi technologies as one of the most suitable solutions for offering connectivity and services in the home network, and many Wi-Fi requirements are included in HGI documents ([1]) and test specifications.

In recent years, new Wi-Fi standards have been developed by the industry, and many new use cases have arisen; there are now many more Wi-Fi attached devices, tablets, smartphones etc. The success of Wi-Fi has resulted in mass-deployment of in-home WLAN networks which has led to interference problems for both end users and Service Providers.

The purpose of this document is twofold; firstly to cover the Wi-Fi HG use cases not yet contained in HGI specifications. Secondly various technical issues and functional gaps regarding the Access Points (AP) integrated into HGs have arisen during lab testing and in field deployment. These are not currently addressed by the standards, or the Wi-Fi Alliance interoperability testing programs.

This document identifies a set of requirements, intended not only for embedded APs, but also for standalone applications, for example, for extending the wireless coverage by additional APs. Detailed test cases to check compliance with these requirements are described in a separate HGI document ([5]).

At a later stage, the results of this work will be shared with the relevant SDOs with a view to upgrading future versions of the certification program for Wi-Fi APs.

3.1 Wi-Fi in the HGI

The residential profile defined by HGI ([1]) provides some mandatory requirement for an AP integrated in the HG. In recent years, new Wi-Fi standards and use cases have arisen, hence the need of upgrading also HGI specifications. The work in this direction can be huge and last a very long time, so HGI has decided to split it in different publications, addressing firstly the topics that are more significant for HGI Service Providers, and progressively integrate the work with other Wi-Fi relevant new topics.

Hence HGI first release on new Wi-Fi matters, that is the work addressed by the present document, will cover two topics: Automatic Channel Selection (ACS) mechanism and repeaters interoperability, defining a new set of requirements.

In future HGI should issue new releases covering additional Wi-Fi topics and use-cases. New issues can be, for example: requirements for fair coexistence of different Wi-Fi technologies; univocal definition of Wi-Fi channel measurements; additional requirements for WPS and NFC simple pairing. Other new use cases that can be addressed are: Wi-Fi guest access, Wi-Fi hot spot, delivery of multicast content on a Wi-Fi network,…

3.2 Structure of the document

The document is divided into two main sections:

- Chapter 4 – Automatic Channel Selection
- Chapter 5 - Wi-Fi Repeaters Interoperability
4 Automatic Channel Selection

4.1 Issue description

Most APs can be configured to automatically choose the operating channel. This feature is very useful because the ACS mechanism doesn't require the user to understand Wi-Fi channels and it can avoid interference in many cases, but today, the ACS implementation is vendor-specific, and is not tested by the WFA. This means that the performance of the ACS function can vary a lot between different implementations and some ACS implementation have been found to fail even in trivial cases.

Lab and in-home testing has shown issues in both Wi-Fi only interference and non-Wi-Fi interference scenarios, for example:

- with Wi-Fi only interference in a ‘shielded tent’ environment, some APs did not consistently choose channel 6 in an environment where there were already APs operating on channels 11.
- in the presence of non-Wi-Fi interference, other APs chose a frequency channel that was subject to such strong interference that the WLAN would not actually work. Such interference can be due to continuous transmitters such analogue video senders or wireless audio devices.

Since ACS is a basic but very important functionality of Wi-Fi APs, even if implementations remain proprietary, there should be little variation between devices, and no failures in trivial cases.

4.2 Requirements

High level requirements are defined (from which test cases are derived in [5]) to try and make ACS implementations more consistent and work properly.

The implementation details are left to each vendor.

Following requirements cover 802.1b/g/n technologies for 2.4GHz frequency band and 802.1n/ac for 5GHz. They are splitted in:

- General requirements (§4.2.1), that apply to all technologies/bands;
- 2.4GHz band requirements (§4.2.2), that apply to 2.4GHz technologies only;
- 5 GHz band requirements (§4.2.3), that apply to 5GHz technologies only.

4.2.1 General requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.1</td>
<td>The AP MUST implement an Automatic radio Channel Selection (ACS) mechanism for each supported frequency band.</td>
</tr>
<tr>
<td>R.2</td>
<td>It MUST be possible to enable and disable the ACS mechanism through a local manual request (eg. from a GUI) and by a Remote Management System.</td>
</tr>
<tr>
<td>R.3</td>
<td>In the case where the AP supports multiple frequency bands, the ACS mechanism MUST operate independently for each band i.e. operation of ACS on one band, MUST NOT impact the channel section on the other band.</td>
</tr>
<tr>
<td>R.4</td>
<td>The AP MUST run the ACS mechanism at boot time.</td>
</tr>
</tbody>
</table>
### Requirement Description

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
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</table>
| R.5         | After boot, the AP **MUST** run again the ACS mechanism:  
- when the background noise level on the operating channel exceeds a defined threshold for a certain period of time (e.g. 30 seconds). This is called “Dynamic ACS”;  
- periodically, after a configurable timer $T_{ACS}$ (e.g. 24 hours). |
| R.6         | If there is traffic on the AP Wi-Fi interface at the time the ACS is scheduled to happen, the ACS **MUST** be delayed by a configurable time (e.g. 3 minutes). This procedure **MUST** be repeated until there is no traffic on the AP Wi-Fi interface. |
| R.7         | Dynamic ACS **MUST NOT** be performed more than once in a configurable period of time (e.g. no more than once in 10 minutes). The duration of the ACS procedure **MUST** be less than 30 secs. |
| R.8         | The AP **MUST** be able to run the ACS mechanism following a local manual request (e.g. from a GUI). |
| R.9         | The ACS mechanism **MUST** evaluate the background noise level on each Wi-Fi channel and select a channel as defined in R.12/R.13 and R.14 for the 2.4 GHz and 5GHz interfaces respectively. |
| R.10        | In the case where more than 1 channel is below the noise threshold (as defined in R.12 for 2.4 GHz and R.14 for 5 GHz), the ACS mechanism **MUST** select the channel least affected by other Wi-Fi networks on the basis of:  
- the number of Wi-Fi networks operating on the same Wi-Fi channel,  
- the amount of traffic on each network,  
- the power of the signal of each network. |
| R.11        | The background noise monitoring activity **MUST NOT** reduce the Wi-Fi interface throughput by more than 10%. |

#### 4.2.2 2.4GHz band requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.12</td>
<td>The ACS mechanism <strong>MUST</strong> find all the channels in the set {1, 6, 11}, having a background noise level below a configured threshold. If all the channels in the set have a background noise level higher than the threshold, the channel with the minimum level of background noise <strong>MUST</strong> be chosen.</td>
</tr>
<tr>
<td>R.13</td>
<td>When evaluating the channel least affected by other Wi-Fi networks (R.10) also the number of overlapping channels, i.e. within +/- 3 channels, <strong>MUST</strong> be taken into account.</td>
</tr>
</tbody>
</table>
4.2.3 5 GHz band requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.14</td>
<td>In the 5 GHz frequency band, the ACS mechanism <strong>MUST</strong> find all the channels having a level of background noise below a given threshold. If all the channels have a background noise level higher than the threshold, the channel with the minimum level of background noise <strong>MUST</strong> be chosen.</td>
</tr>
<tr>
<td></td>
<td>In Europe the 1(^{st}) sub band <strong>SHOULD</strong> be reserved for manual channel selection. In Europe, Channels falling into the 5600 MHz - 5650 MHz band (channel 120, 124 and 128) <strong>SHOULD</strong> be excluded for automatic channel selection due to the 10 minutes CAC(as defined in the DFS technical requirement specification [6]) wait time required for operation (radar detection).</td>
</tr>
<tr>
<td>R.15</td>
<td>If a 802.11n/ac AP is configured for extended channel binding, the AP <strong>MUST NOT</strong> extend the channel bandwidth to 40 MHz if the background noise level of non-Wi-Fi interference on the extended channel is above a defined threshold.</td>
</tr>
<tr>
<td>R.16</td>
<td>If a 802.11ac AP is configured for extended channel binding, the AP <strong>MUST NOT</strong> extend the channel bandwidth to 80 MHz if the background noise level of non-Wi-Fi interference on the extended channel is above a defined threshold.</td>
</tr>
</tbody>
</table>

In the 5 GHz band, the use of CSA (Channel Switch Announcement) is considered useful. In order to work, it should be supported by both the AP and the Wi-Fi clients, as in the following requirements.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
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<tbody>
<tr>
<td>R.17</td>
<td>The AP <strong>MUST</strong> support Channel Switch Announcement (CSA), as defined in [4], to announce that it is switching to a new channel before it begins transmitting on that channel.</td>
</tr>
<tr>
<td>R.18</td>
<td>The Wi-Fi clients <strong>MUST</strong> support CSA to transition to the new channel with minimal downtime.</td>
</tr>
</tbody>
</table>
5 Wi-Fi Repeaters Interoperability

5.1 Issue description

Wi-Fi repeaters (also known as range extenders) are popular devices to extend the coverage of a Wi-Fi network without cabling. Typically they associate as a client to an existing AP (e.g. the HG) and at the same type act as an AP, publishing a SSID and forwarding the traffic of associated devices to the HG.

Wi-Fi certification from the WFA is not available for repeaters, so the devices on the market are either not certified, or Wi-Fi certified as APs.

Since multiple options exist for implementing a Wi-Fi repeater, interoperability with HGs may be poor, and the user experience can vary between devices. The following issues related to repeaters have arisen:

- the SSID of the repeater being different to the SSID of the HG. This can actually help the user to verify that the repeater is working and to understand if a device has associated with the HG or the repeater. However it prevents devices from performing a handover to the HG, and can lead to interoperability issues when WPS is used to configure the repeater.
- 5 GHz repeaters only supporting the 1\textsuperscript{st} sub-band and so not working with HGs operating in the 2\textsuperscript{nd} or 3\textsuperscript{rd} sub-bands.
- The MAC address seen by HGs for devices associated with repeaters is not the real device MAC address.
- Performances decreasing more than expected when more than 1 client is associated with the repeater.

5.2 Requirements

High level requirements are defined (from which test cases can be derived) to describe required behavior of repeaters.

Following requirements cover 802.1b/g/n technologies for 2.4GHz frequency band and 802.1n/ac for 5GHz.

<table>
<thead>
<tr>
<th>Requirement for repeater</th>
<th>Description</th>
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<tbody>
<tr>
<td>R.19</td>
<td>A repeater MUST support WPS push button for association with the primary AP.</td>
</tr>
<tr>
<td>R.20</td>
<td>When using the WPS procedure the repeater MUST be able to extend all the announced AP WLANs on its supported bands.</td>
</tr>
<tr>
<td>R.21</td>
<td>After WPS configuration, the repeater MUST create a WLAN with the same SSID and security settings as the AP it is extending.</td>
</tr>
<tr>
<td>R.22</td>
<td>The repeater MUST support simultaneous association and traffic forwarding to at least 5 Wi-Fi client devices without significant traffic degradation. In this case, the aggregate Wi-Fi throughput with 5 Wi-Fi clients MUST be at least 50% of the throughput with only 1 client.</td>
</tr>
<tr>
<td>R.23</td>
<td>If the repeater supports 5 GHz, it MUST support all possible channels within that band.</td>
</tr>
</tbody>
</table>
The following requirement allows an AP to interwork with a repeater that supports WPS, but is not satisfying R.21 (eg. a repeater is extending the WLAN using a different SSID name)⁠¹

<table>
<thead>
<tr>
<th>Requirement for AP</th>
<th>Description</th>
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<tbody>
<tr>
<td>R.24</td>
<td>If the AP is configured for WPA-PSK or WPA2-PSK security, and the key is configured as ASCII passphrase (8-63 characters), the AP <strong>MUST</strong> provide credentials in passphrase format at the end of WPS procedure (i.e. not in binary PSK format).</td>
</tr>
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¹ Credentials can be given in 2 ways at the end of the WPS procedure: binary PSK format or passphrase. The PSK key is not consistent if the SSID name is different, as it is derived from the passphrase according to the following formula ([7]):

\[
\text{Key} = \text{PBKDF2}(\text{passphrase, ssid, 4096, 256})
\]
6 References

[1] HGI-RD001-R2.01 - Home Gateway Technical Requirements: Residential Profile V1.01