HGI-RD045v2

WI-FI REQUIREMENTS FOR HOME GATEWAYS:
AUTOMATIC CHANNEL SELECTION, CHANNEL MEASUREMENTS AND REPEATERS

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3 ACRONYMS

3.1 ACRONYMS

ACS Automatic Channel Selection
AP (Wi-Fi) Access Point
ASCII American Standard Code for Information Interchange
CCA Clear Channel Assessment
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
RMS Remote Management System
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

3.2 TERMS

<table>
<thead>
<tr>
<th>Interference</th>
<th>Interference detected from a Wi-Fi AP on a channel. It can be of two types:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Wi-Fi interference, that includes all the 802.11a/b/g/n 1[2]/ac1[3] Wi-Fi APs signals.</td>
</tr>
<tr>
<td></td>
<td>- 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</td>
</tr>
</tbody>
</table>

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 [2]/ac [3] 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 adjacent overlapping channels, in the range of +/- 3 channels. Adjacent channels are overlapping the channel under examination due to the 5 MHz spacing for 20 MHz bandwidth 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.

### 3.3 Definitions of Requirements Terms

The definitions of MUST 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 HG.

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

**SHOULD**
Functionality which goes beyond the base requirements for a given class of HG, 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.
4 PURPOSE AND SCOPE OF THIS DOCUMENT

HGI considers Wi-Fi technologies as one of the most suitable technologies for offering connectivity and services in the home network, and many Wi-Fi requirements are included in HGI documents, including the Residential Profile 1[1] and in test specifications.

In recent years, new Wi-Fi standards have been developed by the industry, and new use cases have arisen; there are now many more Wi-Fi attached devices, tablets, smartphones etc. The success of Wi-Fi and its mass deployment in home networks has resulted in interference problems being reported.

The present document, HGI-RD045 covers several areas of technical requirements for Wi-Fi that have arisen in mass deployment of Access Points (AP) integrated into Home Gateways (HGs), and not fully addressed in other standards or Wi-Fi Alliance interoperability testing programs. The document provides a set of requirements both for

- embedded AP in HG
- standalone AP

These requirements are intended to improve the wireless coverage and operation of in-home wireless networks.

4.1 WI-FI IN THE HGI

The residential profile defined by HGI ([1]) provides mandatory requirements for an AP integrated in the HG. In recent years, new use cases and standards for Wi-Fi have arisen, leading to the need of upgrading also HGI requirements. 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 Telecom Operators, and progressively integrating the work with other Wi-Fi relevant topics.

This document is the first on Wi-Fi requirements, covering Automatic Channel Selection (ACS), Channel measurements (based on IEEE 802.11 1[2]) and repeaters. More documents are going to follow on other subjects like NFC simple pairing, guest access and hotspot.

4.2 STRUCTURE OF THE DOCUMENT

The document is divided into these main sections:

Chapter 5 – Wi-Fi Automatic Channel Selection
Chapter 6 – Wi-Fi Channel Measurements
Chapter 7 – Wi-Fi Repeaters Interoperability
5  **Wi-Fi Automatic Channel Selection**

5.1  **Issue Description**

Most APs can be configured to automatically choose the operating channel. The ACS (Auto Channel Selection) mechanism works well in many cases, and does not require the user to be involved in Wi-Fi channel selection. However, the ACS implementation is vendor-specific, and is not tested by the WFA. The performance of the ACS function varies among implementations and some ACS implementations have been found to fail certain cases.

Lab and in-home testing has shown issues with both Wi-Fi only interference and non-Wi-Fi interference. For example, test scenarios showed that:

- 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 1 and 11.
- In the presence of non-Wi-Fi interference, some APs chose a channel that was subject to strong interference that prevented the WLAN from working on that channel. This type of interference can be caused by continuous transmitters like analogue video senders or wireless audio devices.

The ACS requirements defined below aim to provide a more consistent and effective framework for ACS implementations.

5.2  **Requirements**


Implementations are expected to take into account both Wi-Fi and non-Wi-Fi interference.

In the 2.4 GHz range unpredictable Wi-Fi interference can become present when an inactive SSID becomes active in the current or adjacent channel. Because of the 5 MHz channel spacing for 20 MHz channel bandwidths, up to +/- 3 adjacent channels need to be taken into account (i.e., +/- 5, +/- 10 and +/- 15 MHz away from the centre frequency of the current channel). Monitoring for the presence of SSIDs must therefore be carried out in this range.

In the 5 GHz range the spacing of channels is sufficient to avoid adjacent channel interference for 20 MHz channel bandwidths, so no Wi-Fi noise from adjacent channels is found in the 5GHz band with channel bandwidths up to 20 MHz. For higher channel bandwidths the manner in which the Wi-Fi interference is handled is implementation specific, and no requirement is placed on the number of channels to be taken into account.

The ACS requirements listed here below are split into:
- General requirements (§5.2.1), that apply to all technologies/bands;
- 2.4GHz band requirements (§5.2.2), that apply to 2.4GHz technologies only;
- 5 GHz band requirements (§5.2.3)

5.2.1 General requirements

<table>
<thead>
<tr>
<th>№</th>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>R1</td>
<td>The AP MUST implement an Automatic radio Channel Selection (ACS) mechanism for each supported frequency band.</td>
</tr>
<tr>
<td>R2</td>
<td>It MUST be possible to enable and disable the ACS mechanism through a local manual request (e.g. from a GUI) and by a Remote Management System.</td>
</tr>
<tr>
<td>R3</td>
<td>It MUST be possible for the Remote Management System to select a specific channel. Before selecting a specific channel, the ACS SHOULD be disabled by the RMS.</td>
</tr>
<tr>
<td>R4</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 another band.</td>
</tr>
<tr>
<td>R5</td>
<td>The AP MUST run the ACS mechanism at boot time.</td>
</tr>
<tr>
<td>R6</td>
<td>After boot, the AP MUST run again the ACS mechanism:</td>
</tr>
<tr>
<td></td>
<td>- when the background noise level on the operating channel exceeds a defined threshold for a certain period of time (e.g. 30 seconds). This operation is called “Dynamic ACS”;</td>
</tr>
<tr>
<td></td>
<td>- and periodically, after a configurable timer $T_{ACS}$ (e.g. 24 hours) expires.</td>
</tr>
<tr>
<td>R7</td>
<td>If there is traffic on the AP channel of the Wi-Fi interface in use at the time the ACS is scheduled to happen then 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.</td>
</tr>
<tr>
<td>R8</td>
<td>Dynamic ACS MUST NOT be performed more than once in a configurable period of time (e.g. no more than once in 10 minutes).</td>
</tr>
<tr>
<td>R9</td>
<td>The duration of the ACS procedure SHOULD be less than 30 secs.</td>
</tr>
<tr>
<td>R10</td>
<td>The AP MUST be able to run the ACS mechanism following a local manual request (e.g. from a GUI).</td>
</tr>
</tbody>
</table>
### Requirement

R11. The ACS mechanism MUST evaluate the background noise level on each Wi-Fi channel and select a channel as defined in R14 for the 2.4 GHz and R16 for the 5 GHz interfaces respectively.

R12. In the case where more than 1 channel is below the background noise threshold (as defined in R14 for 2.4 GHz and R16 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 each Wi-Fi channel;
- and the amount of traffic on each network;
- and the power of the signal of each network.

R13. The background noise monitoring activity MUST NOT reduce the Wi-Fi interface throughput by more than 10%.

### 5.2.2 2.4GHz Band Requirements

<table>
<thead>
<tr>
<th>№</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R14.</td>
<td>In the 2.4 GHz band the ACS mechanism MUST determine from the channel set {1, 6, 11} the sub-set of channels having a background noise level below a configurable threshold. If the sub-set contains one channel than that channel is selected; if the sub-set contains more than one channel, then the ACS algorithm as per R12 MUST be applied. If the sub-set contains no channels, the channel in the set {1, 6, 11} with the minimum level of background noise MUST be chosen.</td>
</tr>
<tr>
<td>R15.</td>
<td>In the 2.4 GHz band the ACS mechanism MUST take into account +/- 3 adjacent channels when evaluating the channel least affected by other Wi-Fi networks</td>
</tr>
</tbody>
</table>
5.2.3 5 GHz Band Requirements

<table>
<thead>
<tr>
<th>N°</th>
<th>Requirement</th>
</tr>
</thead>
</table>
| R16. | In the 5 GHz frequency band, the ACS mechanism **MUST** 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 **MUST** be chosen.  
In Europe the 1st sub band **SHOULD** be reserved for manual channel selection. In Europe, channels falling into the 5600 MHz - 5650 MHz band (channel 120, 124 and 128) **SHOULD** be excluded from automatic channel selection due to the 10 minutes wait time required for CAC (as defined in the DFS technical requirement specification 1[2]) to perform radar detection. |
| R17. | In the 5 GHz band if a 802.11n 1[2]/ac 1[3] AP is configured for extended channel binding, the AP **MUST NOT** 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. |
| R18. | In the 5 GHz band if a 802.11ac 1[3] AP is configured for extended channel binding, the AP **MUST NOT** 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. |

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>N°</th>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>R19.</td>
<td>In the 5 GHz band the AP <strong>MUST</strong> support Channel Switch Announcement (CSA), as defined in 802.11 1[2], to announce that it is switching to a new channel before it begins transmitting on that channel.</td>
</tr>
<tr>
<td>R20.</td>
<td>In the 5 GHz band the Wi-Fi clients <strong>MUST</strong> support CSA to transition to the new channel with minimal downtime.</td>
</tr>
</tbody>
</table>
6  **WI-FI CHANNEL MEASUREMENTS**

6.1 **ISSUE DESCRIPTION**

Many Telecom Operator premium services are delivered over home Wi-Fi networks. Therefore Telecom Operators may wish to monitor and measure the customer Wi-Fi environment for service assurance and troubleshooting. The IEEE 802.11 standard 1[2] specifies a wide range of parameters and measurement techniques for this goal. The High level requirements defined in this section specify the subset of the IEEE 802.11 1[2] parameters and measurement techniques of interest to HGI Telecom Operators.

6.2 **REQUIREMENTS**

6.2.1 **TECHNICAL REQUIREMENTS FOR WI-FI MEASUREMENTS**

<table>
<thead>
<tr>
<th>N°</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R21.</td>
<td>The HG MUST be able to apply the IEEE 802.11 1[2] “CCA – Clear Channel Assessment” procedure for each supported channel in each available radio. Clear Channel Assessment indicates the percentage of time, linearly scaled with 255 representing 100%, that the 802.11 1[2] station sensed that the medium was busy during the measurement interval.</td>
</tr>
<tr>
<td>R22.</td>
<td>The HG MUST be able to apply the IEEE 802.11 1[2] “ANPI – Average Noise Power Indicator” (NoiseLevel in what follows) procedure, as described in “Noise Histogram Report”, for each supported channel in each available radio. NoiseLevel is the average noise plus interference power (in dBm) on the measured channel at the antenna connector during the measurement interval. If multiple antennas are present in the Home Gateway then the ANPI is measured every time for each of them.</td>
</tr>
<tr>
<td>Nº</td>
<td>Requirement</td>
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<tr>
<td>----</td>
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</tr>
<tr>
<td>R23.</td>
<td>When Clear Channel Assessment and/or ANPI procedures have been enabled and started, the HG MUST continually monitor the status of each active channel (there may be more active channels if more radios are available, i.e. 2.4 and 5 GHz.) by performing the CCA and/or ANPI procedures and keeping the measured values of last ReportingPeriod, with a default sampling period of MeasSamplingPeriod seconds. Each measurement takes place in no more than MeasDuration milliseconds.</td>
</tr>
</tbody>
</table>

The report MUST include the following information:

- **Radio[i]**: the radio carrier being measured [2.4 or 5 GHz]
- **Channel[i]**: the active channel for the selected Radio on which measurements are carried out
- **MeasDuration**: the duration in milliseconds of the interval over which the measurements are carried out
- **MeasSamplingPeriod**: the duration in seconds of the interval between two consecutive samples (should be 60 as a default value)
- **ReportingPeriod**: the duration in minutes of the Reporting Period, i.e. the interval over which samples are stored and reported to the ACS or the qualified technician (should be 1440, corresponding to 24 hours, as a default value).
- **TimeStamp[i]**: the UTC time and date, syntax as per RFC1123 1[4], when the i-th measurement in the Reporting Period was carried out (one sample every MeasSamplingPeriod seconds, \(i = 1\) to \(\text{ReportingPeriod} / (\text{MeasSamplingPeriod} / 60)\))
- **CCA[i][j]**: the i-th value in the Reporting Period of Clear Channel Assessment for the j-th active channel (one sample every MeasSamplingPeriod seconds, \(i = 1\) to \(\text{ReportingPeriod} / (\text{MeasSamplingPeriod} / 60)\))
- **NoiseLevel[i][j]**: the i-th value in the Reporting Period of NoiseLevel for the j-th active channel (one sample every MeasSamplingPeriod seconds, \(i = 1\) to \((\text{ReportingPeriod}*60)/\text{MeasSamplingPeriod})\))
### Requirements for Remote Management of Wi-Fi Measurements

<table>
<thead>
<tr>
<th>N°</th>
<th>Requirement</th>
</tr>
</thead>
</table>
| R24. | Upon explicit Remote Management request the HG MUST carry out a global channel status report on every channel of every supported, enabled, and powered up radio, by performing and buffering a limited number of measurements on each supported channel in each such radio and reporting the following information:  
  - **Radio [i]**: the radio carrier being measured [2.4 or 5 GHz]
  - **Channel[i]**: the active channel for the selected Radio on which measurements are carried out
  - **MeasDuration**: the duration in milliseconds of the interval over which measurements are carried out
  - **MeasSamplingPeriod**: the duration in milliseconds of the interval between two consecutive samples (should be 1 as a default value)
  - **NSamples**: the number of measurement samples that are stored and reported to the ACS or the qualified technician (SHOULD be 1 as a default).
  - **TimeStamp[i]**: the UTC time and date, syntax as per RFC1123, when the i-th measurement in the Reporting Period was carried out (one sample every MeasSamplingPeriod seconds, i = 1 to NSamples)
  - **CCA[i][j]**: the i-th value in the Reporting Period of Clear Channel Assessment for the j-th active channel (one sample every MeasSamplingPeriod seconds, i = 1 to NSamples)
  - **NoisePower[i][j]**: the i-th value in the Reporting Period of NoiseLevel for the j-th active channel (one sample every MeasSamplingPeriod milliseconds, i = 1 to NSamples) |
| R25. | The HG SHOULD carry out the global channel status report as per R23 when the following events take place: HG power up, HG reboot, Wi-Fi power up. |
| R26. | The HG SHOULD carry out the global channel status report as per R23 at start of the Channel Load Report or ANPI procedures, whichever comes first. |

6.2.2 Requirements for Remote Management of Wi-Fi Measurements
<table>
<thead>
<tr>
<th>N°</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R27.</td>
<td>The Telecom Operator MUST be able to remotely manage (configure, enable/disable, start/stop) the IEEE 802.11 1[2] Clear Channel Assessment procedure through the RMS. Qualified technicians MUST be able to locally manage the Clear Channel Assessment procedure.</td>
</tr>
<tr>
<td>R28.</td>
<td>The Telecom Operator MUST be able to view IEEE 802.11 1[2] Clear Channel Assessment procedure results on a per user or aggregate basis through his RMS. Qualified technicians MUST be able to locally view the local Clear Channel Assessment procedure results.</td>
</tr>
<tr>
<td>R29.</td>
<td>The Telecom Operator MUST be able to remotely manage (configure, enable/disable, start/stop) the IEEE 802.11 1[2] “ANPI – Average Noise Power Indicator” procedure through his RMS. Qualified technicians MUST be able to locally manage the ANPI procedure.</td>
</tr>
<tr>
<td>R30.</td>
<td>The telecom Operator MUST be able to view IEEE 802.11 1[2] “ANPI – Average Noise Power Indicator” procedure results on a per-user or aggregate basis through the RMS. Qualified technicians MUST be able to locally view the local “ANPI – Average Noise Power Indicator” procedure results.</td>
</tr>
<tr>
<td>R31.</td>
<td>Content of each measurement buffer MUST be emptied when general events like HG reboot or procedure disable / enable take place (Note: commands for procedure start/stop are not requested to reset buffers), or specific events relevant to that buffer take place, like (if applicable) channel change or reconfiguration of MeasDuration / MeasSamplingPeriod. As a general rule, as many measurement samples as possible SHOULD be conserved. Note: behaviour when ReportingPeriod and/or NSamples changes is unspecified.</td>
</tr>
</tbody>
</table>

7  **Wi-Fi Repeaters Interoperability**

7.1  **Issue Description**

Wi-Fi repeaters (also known as range extenders) are popular devices that 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 time they 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 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 among devices. The following issues related to repeaters have arisen:

- the SSID of the repeater could be different to the SSID of the HG. This can in fact 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 handover to the HG, and can lead to interoperability issues when WPS is used to configure the repeater.
- 5 GHz repeaters sometimes support only the 1st sub-band and so do not work with HGs operating in the 2nd or 3rd sub-band.
- The MAC address seen by HGs for devices associated with repeaters is not the real MAC address of the device.
- Performance decreases more than expected when more than 1 client is associated with the repeater.

High level requirements are defined (from which test cases can be derived) to describe the desired behaviour of repeaters.

### 7.2 Requirements

The following requirements cover 802.11b/g/n 1[2] technologies for 2.4GHz frequency band and 802.11n 1[2]/ac 1[3] for 5GHz.

<table>
<thead>
<tr>
<th>N°</th>
<th>Requirement</th>
</tr>
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<tbody>
<tr>
<td>R32.</td>
<td>A repeater MUST support the WPS push button for association with the primary AP.</td>
</tr>
<tr>
<td>R33.</td>
<td>When using the WPS procedure the repeater MUST be able to extend all the SSIDs advertised by the primary AP on its supported bands.</td>
</tr>
<tr>
<td>R34.</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>R35.</td>
<td>The repeater MUST support simultaneous traffic association and 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>R36.</td>
<td>If the repeater supports the 5 GHz band, it MUST support all channels from all sub-bands 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 R33 (e.g. a repeater is extending the WLAN using a different SSID name)

Note that Credentials can be given in 2 ways at the end of the WPS procedure: binary PSK format or passphrase.

If the SSID used by the repeater is different from the SSID of the AP then the PSK also changes, as it is derived from the passphrase and the SSID according to the following formula 1[5]:

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

<table>
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<tr>
<th>Nº</th>
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<tr>
<td>R37.</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 MUST provide credentials in passphrase format at the end of the WPS procedure (i.e. not in binary PSK format).</td>
</tr>
</tbody>
</table>
8 REFERENCES

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


