



Bluetooth Core Specification

v 5.0



Revision History

The Revision History is shown in the [Vol 0] Part C, Appendix.

Contributors

The persons who contributed to this specification are listed in the [Vol 0] Part C, Appendix.

Web Site

This specification can also be found on the official Bluetooth web site:
<https://www.bluetooth.org/en-us/specification/adopted-specifications>

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7 COEXISTENCE AND COLLOCATION

Bluetooth devices operate in the unlicensed 2.4 GHz Industrial, Scientific and Medical (ISM) band. Many other technologies utilize the ISM band, including wireless LAN, cordless phones, and microwave ovens. The ISM band is also close enough to other frequency bands that Bluetooth devices may be an interferer of or a victim of other technologies.

Radios may be *collocated* or *non-collocated*. The term "collocated" is a loose one - in the Core Specification, collocated radios are assumed to be in the same product (a *Multi-Radio Terminal* or *MRT*) and may or may not have mechanisms to coordinate their activity in order to mitigate interference.

Determining the amount of expected isolation between radios is important for choosing an appropriate coexistence mechanism. With sufficient isolation, frequency division duplexing (FDD) techniques are the most efficient. With insufficient isolation or a shared antenna, time division duplexing (TDD) techniques need to be used. In many cases, a combination of FDD and TDD techniques are required to achieve acceptable levels of performance.

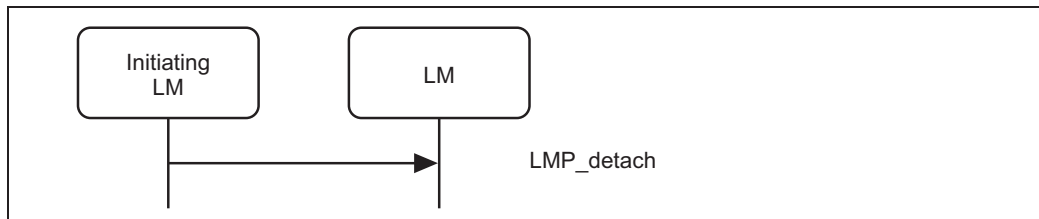
The Bluetooth Core Specification supports a variety of features that help mitigate interference to other devices and to minimize interference from other devices. Broadly, the types of solutions fall into the following categories:

Type	Description
Frequency division	Simultaneous use of multiple radios enabled by filters and/or isolation
Time division	One radio may transmit or receive at a time through scheduling or prioritization
Time alignment	Activities of the collocated radios are aligned in the time domain to optimize performances by avoiding conflicting activities. E.g. Transmissions of multiple radios may occur simultaneously, multiple receptions may occur simultaneously, but it is not possible to transmit and receive simultaneously
Hybrid frequency and time division	Use of frequency division, time alignment, and time division techniques depending on the relative frequencies in use by the radios, filters and isolation

Table 7.1: Interference mitigation types



initiating the procedure defined above. If the procedure to exit sniff mode does not complete within the LMP response timeout (30 seconds) the procedure defined above shall be initiated anyway.



Sequence 1: Connection closed by sending LMP_detach

4.1.3 Power Control

If the received signal characteristics differ too much from the preferred value of a Bluetooth device, it may request an increase or a decrease of the other device's transmit power level. A device's transmit power level is a property of the physical link, and affects all logical transports carried over the physical link. Power control requests carried over the default ACL-C logical link shall only affect the physical link associated with the requesting device's default ACL-C logical link; they shall not affect the power level used on the physical links to other slaves.

Two power control mechanisms are specified: legacy power control (see [Table 4.3](#)) and enhanced power control (see [Table 4.4](#) and [Section 4.1.3.1](#)). A device that supports enhanced power control shall also support legacy power control.

M/O	PDU	Contents
O(9)	LMP_incr_power_req	for future use (1 Byte)
O(9)	LMP_decr_power_req	for future use (1 Byte)
O(18)	LMP_max_power	-
O(18)	LMP_min_power	-

Table 4.3: Legacy Power control PDU

M/O	PDU	Contents
O(58)	LMP_power_control_req	power_adjustment_request
O(58)	LMP_power_control_res	power_adjustment_response

Table 4.4: Enhanced Power control PDU

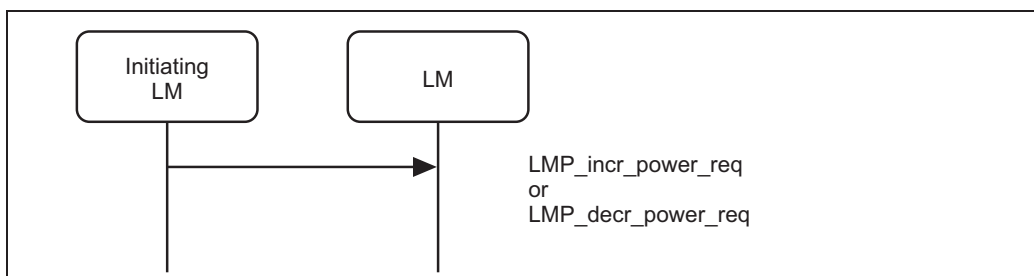
The power adjustment requests may be made at any time using the legacy power control mechanism following a successful baseband paging procedure and before the Link Manager supported features responses have been processed. After the Link Manager supported features responses have been



processed, if both devices support enhanced power control (see [Section 4.1.3.1](#)) then only enhanced power control shall be used. Otherwise, if either device supports only the legacy power control mechanism then only legacy power control shall be used.

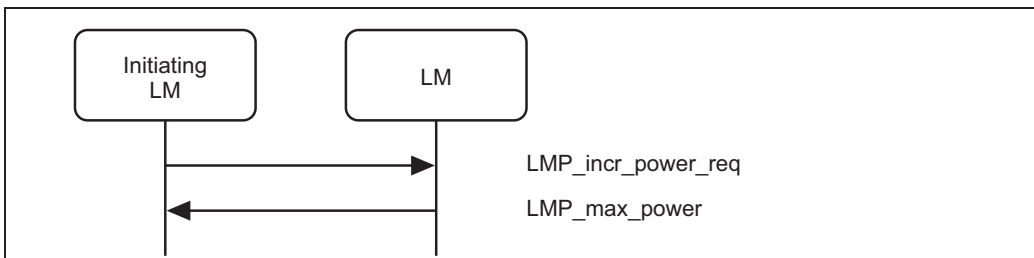
If a device does not support power control requests this is indicated in the supported features list and thus no power control requests shall be sent after the supported features response has been processed. Prior to this time, a power control adjustment might be sent and if the recipient does not support power control it is allowed to send LMP_max_power in response to LMP_incr_power_req and LMP_min_power in response to LMP_decr_power_req. Another possibility is to send LMP_not_accepted with the error code *Unsupported LMP Feature (0x1A)*.

Upon receipt of an LMP_incr_power_req PDU or LMP_decr_power_req PDU the output power shall be increased or decreased one step. See [\[Vol 2\] Part A, Section 3](#) for the definition of the step size.

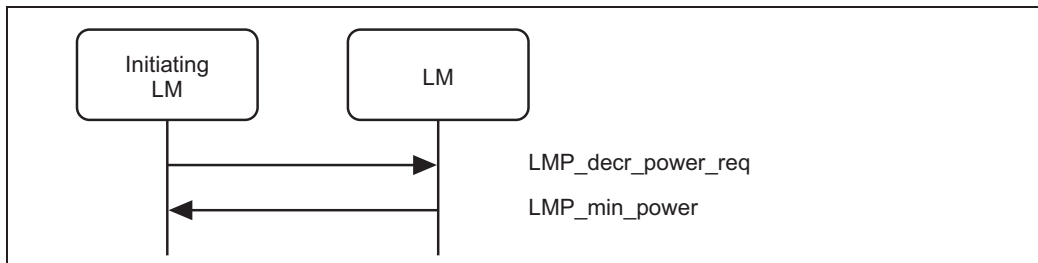


Sequence 2: A device requests a change of the other device's TX power

If the receiver of LMP_incr_power_req is at maximum power LMP_max_power shall be returned. The device shall only request an increase again after having requested a decrease at least once. If the receiver of LMP_decr_power_req is at minimum power then LMP_min_power shall be returned and the device shall only request a decrease after having requested an increase at least once.



Sequence 3: The TX power cannot be increased



Sequence 4: The TX power cannot be decreased

One byte in LMP_incr/decr_power_req is reserved for future use.

4.1.3.1 Enhanced Power Control

Enhanced power control shall only be used when both devices support the enhanced power control LMP feature. Legacy power control shall not be used when both devices support the enhanced power control LMP feature.

4.1.3.1.1 Sending Enhanced Power Control Requests

To adjust the remote device's output power, a device shall send the LMP_power_control_req PDU with the power_adjustment_request parameter.

The power_adjustment_request parameter may be set to: one step up, one step down, or all the way to the max power level. The remote device shall respond with an LMP_power_control_res PDU. The responder shall transmit the LMP_power_control_res PDU at the new power level. Upon reception of the LMP_power_control_res PDU, the initiating device should restart any processes used to determine whether additional power level changes are required.

If the receiver of the LMP_power_control_req PDU has indicated that the output power levels for all of the supported modulation modes are at maximum the requesting device shall only request an increase again after having requested a decrease at least once. If the receiver of the LMP_power_control_req PDU has indicated that the output power levels for all of the supported modulation modes are at minimum the requesting device shall only request a decrease after having requested an increase at least once.

A new LMP_power_control_req PDU shall not be sent until an LMP_power_control_res PDU has been received.

4.1.3.1.2 Responding to Enhanced Power Control Requests

When a device receives an LMP_power_control_req PDU with the power_control_adjust parameter set to "increment one step," all supported modulations that are not at the maximum level shall be increased one step.



When a device receives an LMP_power_control_req PDU with the power_control_adjust parameter set to "decrement one step", all supported modulations that are not at the minimum level shall be decreased one step.

Implementations shall not violate the relative power level between modulations (see [Vol 2] Part A, Section 3).

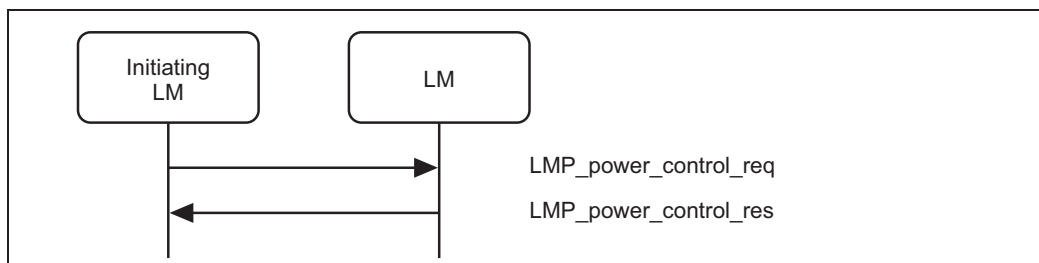
When a device receives an LMP_power_control_req PDU with the power_control_adjust parameter set to "increment power to maximum value", each supported modulation mode shall be set to its maximum power level.

Note: See [Vol 2] Part A, Section 3 for requirements on the relative power levels of different modulation modes.

The responding LM shall send the LMP_power_control_res PDU to indicate the status for every modulation. The power_adjustment_response parameter has three 2-bit fields indicating the status for each modulation mode: GFSK, DQPSK and 8DPSK. Each 2-bit field shall be set to one of the following values: *not supported*, *changed one step*, *max power*, or *min power*. The changed one step value shall only be used when the power level for that modulation mode has not reached the minimum or maximum level.

The *not supported* value shall be used for each unsupported modulation type.

The responder shall transmit the LMP_power_control_res PDU at the new transmit power level and shall not change its power level until requested by the remote device by a subsequent LMP_power_control_req PDU.



Sequence 5: A device responds to a power control request

4.1.4 Adaptive Frequency Hopping

AFH is used to improve the performance of physical links in the presence of interference as well as reducing the interference caused by physical links on other devices in the ISM band. AFH shall only be used during the connection state.

The LMP_set_AFH PDU contains three parameters: AFH_Instant, AFH_Mode, and AFH_Channel_Map. The parameter, AFH_Instant, specifies the instant at which the hopset switch shall become effective. This is specified as a Bluetooth Clock value of the master's clock, that is available to both devices. The AFH



M/O	PDU	Contents
O(35) Rx O(43) Tx	LMP_set_AFH	AFH_Instant, AFH_Mode, AFH_Channel_Map

Table 4.5: AFH PDU

instant is chosen by the master and shall be an even value at least $6 \cdot T_{poll}$ or 96 slots (whichever is greater) in the future. The AFH_instant shall be within 12 hours of the current clock value. The parameter AFH_Mode, specifies whether AFH shall be enabled or disabled. The parameter AFH_Channel_Map, specifies the set of channels that shall be used if AFH is enabled.

When the LMP_set_AFH PDU is received the AFH instant shall be compared with the current Bluetooth clock value. If it is in the past then the AFH_instant has passed and the slave shall immediately configure the hop selection kernel (see [Vol 2] Part B, Section 2.6.3) with the new AFH_mode and AFH_channel_map specified in the LMP_set_AFH PDU. If it is in the future then a timer shall be started to expire at the AFH instant. When this timer expires it shall configure the hop selection kernel with the new AFH_mode and AFH_channel_map.

The master shall not send a new LMP_set_AFH PDU to a slave until it has received the baseband acknowledgment for any previous LMP_set_AFH addressed to that slave and the instant has passed.

Role switch while AFH is enabled shall follow the procedures define by [Vol 2] Part B, Section 8.6.5.

4.1.4.1 Master Enables AFH

Prior to enabling AFH the master LM shall pause traffic on the ACL-U logical link (see [Vol 2] Part B, Section 5.3.1). The master shall then enable AFH on a physical link by sending the LMP_set_AFH PDU with AFH_mode set to AFH_enabled, the AFH_channel_map parameter containing the set of used and unused channels, and an AFH_instant. The LM shall not calculate the AFH instant until after traffic on the ACL-U logical link has been stopped. The master considers the physical link to be AFH_enabled once the baseband acknowledgment has been received and the AFH_instant has passed. Once the baseband acknowledgment has been received the master shall restart transmission on the ACL-U logical link.