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HomePlug GREEN PHY Specification

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**Change History**

|  |  |  |
| --- | --- | --- |
| **GP1.1** | **Corrected CRC-24 remainder equation per contribution:“STM\_SE110429-00\_r0\_CRC-24 Correction.docx”** | **Jim Allen (ST)** |
|  | **Updated GP1.1 labels and Copyright dates** |  |
|  | **Added missing text for DC operation per contribution:”** **ATHR\_AV110207-01\_r1\_DC Support.docx” in 5.1.1.1 and new 5.1.1.2** |  |
|  | **Added new Power Management features** |  |
|  | **Added informative information on how to calculate the PHY rate to clause 3.4.4** |  |
|  | **Added clarification about informative text to clause 1.4.1** |  |
|  | **Added Association text clarifications, r9** |  |
|  | **Updated references, ToC and index, fix clause indents** |  |

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#  Introduction

## References

Documents referenced in this specification are listed below.

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12. IEEE Std 802.3-2005: IEEE Standard for Information technology-Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications
13. RFC 768: User Datagram Protocol
14. RFC 791: Internet Protocol
15. RFC 793: Transmission Control Protocol
16. RFC 2205: Resource ReSerVation Protocol (RSVP) - Version 1 Functional Specification
17. RFC 2460: Internet Protocol, Version 6 (IPv6) Specification
18. HomePlug Powerline Alliance, HomePlug AV 1.1 Specification (May 21, 2007)
19. IEEE P1901 Draft Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications (Apr 2010)
20. HomePlug Powerline Alliance, Policy 3: HomePlug AV AVLNs operating in Coordinated or Uncoordinate Mode in the presence of other HomePlug AV AVLNs operating in CSMA-Only mode
21. HomePlug Powerline Alliance, Policy 1.1: HomePlug AV v1.1 in the presence of HomePlug BPL devices based on HomePlug 1.0.1
22. RFC 5652: Cryptographic Message Syntax (CMS)
23. RFC 5258: Internet Message Access Protocol version 4 - LIST Command Extensions
24. RFC 3565: Use of the Advanced Encryption Standard (AES) Encryption Algorithm in Cryptographic Message Syntax (CMS)
25. RFC 5280: Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile
26. RFC 5480: Elliptic Curve Cryptography Subject Public Key Information
27. RFC 5758: Internet X.509 Public Key Infrastructure: Additional Algorithms and Identifiers for DSA and ECDSA

## File Integrity Verification

All files distributed with the GREEN PHY specification are listed with a 64-digit hexadecimal hash calculated on the contents of the original file. The hash is calculated using the SHA-256 Message-Digest Algorithm as specified in reference [8]. All files distributed with the GREEN PHY specification can be verified against their originals by recalculating the SHA-256 hash and comparing it against the hash listed in this document.

## Acronyms and Abbreviations

Table 1‑1: defines the acronyms and abbreviations in this specification. For more information about an acronym or abbreviation, refer to the section shown in the **Section Ref.** column.

| Table 1‑1: Acronyms and Abbreviations |
| --- |
| Acronym | Meaning | Section Ref. |
| ACK  | ACKnowledge  | 4.4.1.34.4.1.44.4.1.5.3.7 |
| ACLSS | AC Line Cycle Synchronized Status | 4.4.3.10 |
| ACS | Auto-Connect Service | 6.6 |
| AES | Advanced Encryption Standard | 5.4.5.1 |
| AFE | Analog Front End | 3.1 |
| AGC | Automatic Gain Control/Automatic Gain Controller | 3.1,3.6.1 |
| AIFS | Allocation Interframe Spacing | 5.6 |
| API | Application Program Interface | 12.1.4 |
| ARP | Address Resolution Protocol | 5.2.3.8.2 |
| ARQ | Automatic Repeat Request | 2.1.1 |
| ATS | Arrival Time Stamp | 6.7.3 |
| AVF | Allocation Variant Field | 9.8.3.3 |
| AVLN | HomePlug AV In-Home Logical Network | 2.2.3 |
| BBT | BeaconBackoffTime | 7.1 |
| BCAST | Broadcast | 5.2.3.8.2 |
| BDA | Bridged Destination Address | 11.5.15.3 |
| BENTRY | Beacon Entry | 4.4.3.15.4 |
| BIFS | Burst Interframe Spacing | 4.4.1.5.2.13.1 |
| BLE | Bit Loading Estimate | 4.4.1.5.2.10 |
| BPCS | Beacon Payload Check Sequence | 4.4.3.17 |
| BPL | Broadband Access over Power Lines | Chapter 10 |
| BPLN | Access/BPL Logical Network | Chapter 8 |
| BPSK | Binary Phase Shift Keying | 3.1, 3.5.5 |
| BPST | Beacon Period Start Time | 5.5.5 |
| B2BIFS | Beacon-to-Beacon Interframe Spacing | 5.6 |
| BTO | Beacon Transmission Offset | 4.4.1.5.1.2 |
| BTS | Beacon Time Stamp | 5.5 |
| BTT | Beacon Transmit Time | 5.5 |
| BurstCnt | Burst Count | 4.4.1.5.2.16 |
| CBC | Cipher Block Chaining | 5.4.5.1 |
| CA | Contention Access | 12.3.1.1.1 |
| CC | Contention Control | 9.4 |
| CCo | Central Coordinator | Chapter 7 |
| CEI | Channel Estimation Indication | 5.2.6.1 |
| CFP | Contention Free Period | 5.1.1.2.1 |
| CFPI | Contention-Free Period Initiation | 9.6.1 |
| CFS | Contention-Free Session | 4.4.1.5.2.44.4.1.5.3.24.4.1.5.2.4 |
| CI | Channel Interleaver | 3.4.3 |
| CID | Connection Identifier | 5.2.1.4.2 |
| CIFS | Contention Interframe Spacing | 9.2.2 |
| CIFS\_AV | Contention Interframe Spacing | 5.6.1 |
| CINFO | Connection Information | 7.8.1 |
| CISPR | International Special Committee on Radio Interference | 3.7.1 |
| CL | Convergence Layer | Chapter 612.1 |
| CLS | Connectionless Service | 5.2.2.1 |
| CLST | Convergence Layer SAP Type | 4.4.1.5.2.23 |
| CM | Connection Manager | 2.1.27.8.1 |
| CMS | Cryptographic Message Syntax | 13.8.2.1 |
| COS | Connection-Oriented Service | 12.3.1.1.1 |
| CP | Contention Period | 5.1.1.2.1 |
| CRC | Cyclic Redundancy Check | 4.2  |
| CSCD | Current Schedule Countdown | 4.4.3.15.4.2.2 |
| CSMA | Carrier Sense Multiple Access / Collision Detection | 4.4.1.5.2.13.1 4.4.3.15.4.3.2 |
| CSPEC | Connection Specification | 5.2.17.8.1 |
| CTS | Clear To Send | 4.4.1.5.4 |
| CW | Contention Window | 9.2.2 |
| DA | Destination Address | 5.4.1 |
| DAK | Device Access Key | 7.10.2.1 |
| DBC | Distributed Bandwidth Control | 5.8 |
| DCPPCF | Different CP PHY Clock Flag | 4.4.1.5.2.19 |
| DHCP | Dynamic Host Configuration Protocol | 5.2.3.8.2 |
| DPLL | Digital Phase Locked Loop | 5.1.1.1 |
| DPW | Device Password | 7.10.2.2 |
| DT | HomePlug 1.0.1 Delimiter Type | 4.4.1.1 |
| DT\_AV | HomePlug AV Delimiter Type | 4.4.1.2 |
| DTEI | Destination Terminal Equipment Identifier | 4.4.1.5.2.2 |
| EIFS | Extended InterFrame Space  | 2.5 |
| EKS | Encryption Key Select | 4.4.1.5.2.8 |
| EOF | End of Frame | 9.3.1 |
| ET | End Time | 4.4.3.15.4.2.4.4 |
| EVSE | Electric Vehicle Supply Equipment | 13.8 |
| FC | Frame Control | 2.2.1 |
| FC1.0.1 | HomePlug 1.0.1 Frame Control | 3.7.3.3.1 |
| FCAV | Frame Control AV | 3.7.3.3.2 |
| FCCS | HomePlug 1.0.1 Frame Control Check Sequence | 4.4.1.1 |
| FCCS\_AV | HomePlug AV Frame Control Check Sequence | 4.4.1.5.6 |
| FDCM | Frequency Division Coexistence Message | 10.5.2 |
| FEC | Forward Error Correction | 11.5.10.53.3.13.4 |
| FFDAC | Flexible frequency division access coexistence | 10.5 |
| FFT | Fast Fourier Transform  | 3.1 |
| FL\_AV | Frame Length | 4.4.1.5.2.13.1 |
| GLID | Global Link ID | 5.2.1.4.1 |
| GLID-F | GLID for the Forward Link | 5.2.1.4.2 |
| GLID-R | GLID for the Reverse Link | 5.2.1.4.211.2.1711.2.40 |
| GreenPPEA | Green PHY-PEV-EVSE Association | 13.8 |
| HDTV | High Definition Television | 5.4.6 |
| HFID | Human Friendly Identifier | 7.3.1.2 |
| HLE | Higher Layer Entity | 11.112.1.1 |
| HM | Hybrid Mode | 4.4.3.2 |
| HOIP | Handover-in-Progress | 4.4.3.11 |
| HP10DF | HomePlug 1.0.1 Detect Flag | 4.4.1.5.2.64.4.1.5.4.6 |
| HP11DF | HomePlug 1.1 Detect Flag | 4.4.1.5.2.74.4.1.5.4.7 |
| HS-ROBO\_AV | High-Speed ROBO Mode | 3.4.4 |
| HSTA | Hidden Station | 7.7 |
| HTTP | HyperText Transfer Protocol | 10.1.3 |
| ICV | Integrity Check Value | 4.3.6 |
| IEEE | Institute of Electrical and Electronics Engineers | 4.1.2 |
| IFFT | Inverse Fast Fourier Transform  | 3.1 |
| IGF | Immediate Grant Flag | 4.4.1.5.4.9 |
| INL | Interfering Network List | 8.1 |
| IP | Internet Protocol | 12.2.2.1 |
| ISI | Inter-Symbol-interference | 3.6.1 |
| IV  | Initialization Vector | 5.4.5.311.5.2 |
| KBC | Key Being Changed | 4.4.3.15.4.8.2 |
| KCCD | Key Change Countdown | 4.4.3.15.4.8.1 |
| LBDAT | Local Bridge Destination Address Table | 5.3.1 |
| LCT | Line Cycle Time | 5.1.1.1 |
| LID | Link Identifier | 4.4.1.5.2.35.2.1.4.1 |
| LLID | Local Link ID | 5.2.1.4.15.4.1.212.3.1.1.1 |
| LSB | Least-significant bit | 4.1.1.1 |
| MAC | Media Access Control | 4.34.4Chapter 57.8.1.112.3.1 |
| MaxRxSSN | Maximum Receive Segment Sequence Number | 5.4.1.6.2 |
| MaxTxSSN | Maximum Transmit Segment Sequence Number | 5.4.1.6.1 |
| MCAST | Multicast | 5.2.3.8.2 |
| MCF | Multicast Flag | 4.4.1.5.2.204.4.1.5.4.11 |
| MFL | MAC Frame Length | 4.3.1.2 |
| MFSRspMgmt | Management MAC Frame Stream Response | 4.4.1.5.3.7 |
| MFSCmdData | Data MAC Frame Stream Command | 4.4.1.5.2.25 |
| MFSCmdMgmt | Management MAC Frame Stream Command | 4.4.1.5.2.19 |
| MFSRspData | Data MAC Frame Stream Response  | 4.4.1.5.3.6 |
| MFT | MAC Frame Type | 4.3.1.1 |
| MINI-ROBO\_AV | Mini-ROBO Mode | 3.4.3.1 |
| MinRxSSN | Minimum Receive Segment Sequence Number | 5.4.1.6.2 |
| MinTxSSN | Minimum Transmit Segment Sequence Number | 5.4.1.6.1 |
| MITM | Man-in-the-Middle | 7.10.10.1 |
| MM | Management Message | 11.1 |
| MME | Management Message Entry | 11.1.8 |
| MMQF | Management Message Queue Flag | 4.4.2.1.1.4 |
| MMTYPE | Management Message Type | 11.1.6 |
| MNBC | Multi-Network Broadcast | 5.4.3.1 |
| MNBF | Multi-Network Broadcast Flag | 4.4.1.5.2.21 |
| MPDU | MAC Protocol Data Unit | 4.4 |
| MPDUCnt | MPDU Count | 4.4.1.5.2.15 |
| MSB | Most-significant bit | 4.1.1.1 |
| MSC | Message Sequence Chart | 7.3.1.3 |
| MSDU | MAC Service Data Unit | 4.3 |
| NACK  | Negative ACKnowledge  | 4.4.15.4.1.6.1 |
| NBDA | Number of Bridged Destination Addresses | 11.5.15.2 |
| NBP | Number of Beacon Periods | 11.2.39.1 |
| NCNR | Non-Coordinating Networks Reported | 4.4.3.5 |
| NCo | Neighbor Coordinators | 8.3.5.1 |
| NEK | Network Encryption Key | 7.10.2.5 |
| NewEKS | New Key’s EKS | 4.4.3.15.4.8.3 |
| NID | Network Identifier | 0 |
| NMB | Number of Missed Beacons | 11.2.39.2 |
| NMK | Network Membership Key | 7.10.2.3 |
| NMK-HS | NMK – Secure Security Level | 7.10.3.17.10.3.1.1 |
| NMK-SC | NMK – Simple Connect Security Level | 7.3.47.10.3.1.27.10.3.5 |
| NMK-SL | NMK – Security Level | 7.3.1 |
| NPSM | Network Power Saving Mode | 4.4.3.6 |
| NPW | Network Password | 7.10.2.4 |
| NTB | Network Time Base | 5.5 |
| NTB\_STA | Network Time Base Estimate at Each Station | 5.5 |
| NumSlots | Number of Beacon Slots | 4.4.3.7 |
| ODA | Original Destination Address | 11.1.1 |
| OFDM | Orthogonal Frequency Division Multiplexing | 3.1 |
| OPAD | Octet Pad | 4.4.3.15.4.14.1 |
| OPSF | Oldest Pending Segment Flag | 4.4.2.1.1.6 |
| OSA | Original Source Address | 11.1.2 |
| OUI | Organizationally Unique Identifier | 4.4.3.15.4.16, 7.8.1.2, 11.7 |
| PAL | Protocol Adaptation Layer | 12.1.2 |
| PAPR | Peak-to-Average Power Ratio | 3.5.3 |
| PB | PHY Block | 4.4.2.1 |
| PBB | PHY Block Body | 4.4.2.1.2 |
| PBC | PHY Block Count | 5.4.5.3.2 |
| PBCS | PHY Block Check Sequence | 4.4.2.1.3 |
| PBH | PHY Block Header | 4.4.2.1 |
| PBSz | PHY Block Size | 4.4.1.5.2.114.4.1.5.5.4 |
| PCo | Proxy Coordinator | 7.7 |
| PCS | Physical Carrier Sense | 3.8.4 |
| PEKS | Payload Encryption Key Select | 11.5.2.1 |
| PEV | Plug-in Electric Vehicle | 13.8 |
| PHY | Physical Layer | Chapter 3 |
| PhyClk | PHY (layer) Clock | 3.7.3.1 |
| PhyNet | Physical Network | 2.2 |
| PID | Protocol ID | 11.5.2.3 |
| PLID | Priority Link ID | 5.2.1.35.2.1.4.1 |
| PMN | Protocol Message Number | 11.5.2.5 |
| PN | Pseudo Noise | 03.5.1 |
| PPB | Pending PHY Block | 4.4.1.5.2.8.1 |
| PPDU | PHY Protocol Data Unit | 3.2.13.2.1.1 |
| PRN | Protocol Run Number | 11.5.2.5 11.5.2.4 |
| PRP | Priority Resolution Period | 9.2.1 |
| PRS | Priority Resolution Slots | 3.6.5 |
| PSCD | Preview Schedule Countdown | 4.4.3.15.4.2.1 |
| PSD | Power Spectral Density | 3.6.6 |
| PSTA | Proxy Station | 7.7 |
| PxN  | Proxy Network | 7.7 |
| QAM | Quadrature Amplitude Modulation | 3.13.53.6.1 |
| QMP | QoS and MAC parameters | 7.8.1 |
| QPSK | Quadrature Phase Shift Keying | 3.5.43.5.5 |
| QoS | Quality of Service | 5.3.36.57.8.1 |
| RBAT | Remote Bridged Address Table | 5.3.2 |
| RCG | RTS-to-CTS Gap | 5.6.1 |
| REQ\_TM | Max. Tone Maps Requested | 4.4.1.5.5.8 |
| RET | Region End Time | 4.4.3.15.4.3 |
| RFC | Request for Comments | 1.1 |
| RIFS\_AV | Response Interframe Spacing | 4.4.1.5.2.12 |
| ROBO  | ROBust OFDM | 3.4.3.1 |
| RRTF | Request Reverse Transmission Flag | 4.4.1.5.3.5 |
| RSC | Recursive Systematic Convolutional | 0 |
| RSOF | Reverse SOF | 4.4.1.5.6  |
| RSR | Request SACK Retransmission | 4.4.1.5.2.22 |
| RSVD | Reserved | 4.4.1 |
| RSVP | Resource Reservation Protocol | Chapter 13 |
| RTS | Request To Send | 4.4.1.5.4 |
| RTSBF | RTS Broadcast Flag | 4.4.3.12 |
| RTSF | RTS Flag | 4.4.1.5.4.8 |
| RxWSz | Receive Window Size | 4.4.1.5.3.10 |
| SA | Source Address | 5.4.1 |
| SACK | Selective Acknowledgement | 4.4.1.5.35.4.8.1 |
| SACKD | SACK Data | 4.4.1.5.3.8 |
| SACKT | SACK Type | 5.4.8.1 |
| SAF | Sound ACK Flag | 4.4.1.5.5.6 |
| SAI | Session Allocation Information | 4.4.3.15.4.1.2 |
| SAP | Service Access Point | 12.2 |
| SBM | Subnet Bandwidth Manager | Chapter 13 |
| SC-Add | Simple Connect Add State | 7.3.5.3 |
| SCF | Sound Complete Flag | 4.4.1.5.5.7 |
| SC-Join | Simple Connect Join State | 7.3.5.3 |
| SDTV | Standard Definition Television | 5.4.6 |
| SJR | Signal-to-Jammer Power Ratio | 3.8.4.13.8.4.2 |
| SL | Security Level | 7.3.17.10.3.1 |
| SLAC | Signal Level Attenuation Characterization | 5.2.9 |
| SlotID | Beacon Slot ID | 4.4.3.9 |
| SlotUsage | Beacon Slot Usage | 4.4.3.8 |
| SNID | Short Network Identifier | 4.4.1.411.2.29.3 |
| SNR | Signal-to-Noise Power Ratio | 3.6.23.8.4.13.8.4.25.5.4 |
| SOF | Start of Frame | 4.4.1.5.2 |
| SPCS | Sound Payload Check Sequence | 4.4.4.1.2 |
| SSN | Segment Sequence Number | 4.4.2.1.1.15.4.1.3 |
| STA | Station | 2.3 |
| STA\_Clk | Station (free-running) Clock | 3.7.3.1 |
| STD-ROBO\_AV | Standard ROBO Mode | 3.4.3.1 |
| STEI | Source Terminal Equipment Identifier | 4.4.1.5.2.1 |
| SYNCP, SYNCM | SYNChronization symbols | 3.6.1 |
| TCC | Turbo Convolutional Code | 0 |
| TCP | Transmission Control Protocol | 6.2.2 |
| TDMA | Time Division Multiple Access | 5.1.3.1.3 |
| TEI | Terminal Equipment Identifier | 7.3.2.111.2.29.4 |
| TEK | Temporary Encryption Key | 7.10.2.6 |
| TM | Tone Map | 3.2.1 |
| TMD | Tone Map Data | 4.4.1.5.5.135.2.6.211.5.10 |
| TMI\_AV | Tone Map Index | 4.4.1.5.2.13 |
| TPD\_RMS | Transmit Preamble Distortion | 3.7.3.3.3 |
| TPRSD\_RMS | Transmit PRS Waveform Distortion | 3.7.3.3.4 |
| TXOP | Transmission Opportunity | 7.8.1 |
| UDP | User Datagram Protocol | 6.3 |
| UE | User Experience | 13.2 |
| UI | User Interface | 7.3.1.27.4 |
| UIS | User Interface Station | 7.10.9 |
| UKE | Unicast Key Exchange | 7.10.3.5 |
| USTT | Unassociated Station Transmissin Time | 7.1 |
| VCS | Virtual Carrier Sense | 5.1.3.1.2 |
| VF\_AV | Variant Fields | 4.4.1.5 |
| VPBF | Valid PHY Block Flag | 4.4.2.1.1.3 |
| ZPAD | Zero Pad | 4.4.4.1.1 |

## Conventions

All sections in the body of this specification constitute normative text, except when explicitly identified as informative. Appendices are individually identified as being normative or informative.

### Informative Text

When appropriate, informative text is placed throughout the specification to provide additional information (for example, to clarify a complex normative statement or to articulate an alternate solution). Informative text is either specified in the clause (for example see clauses 1.5.1 to 1.5.3), or set off in one or more separate paragraph, with a border surrounding the informative text. It is preceded by a header centered on the page, indicating that the text is informative. For example:

|  |
| --- |
| Informative: Example of Informative TextThis is an example of how informative text shall be displayed herein.It may consist of more than one paragraph and it may wrap to additional pages. |

### Binary and Hexadecimal Numbers

Binary numbers are indicated by the prefix 0b followed by the binary digits. Hexadecimal numbers are indicated by the prefix 0x followed by the hexadecimal digits.

### Words and Phrases

Table 1‑2 describes the words and phrases used in this specification.

Table 1‑2: Words and Phrases

| Word or Phrase | Meaning |
| --- | --- |
| Shall | The definition is an absolute requirement of the specification. Either the term “required” or “must” may be used with this the same meaning. |
| Shall not | The definition is an absolute prohibition of the specification. The phrase “must not” may be used with this the same meaning. |
| Should | There may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course. The adjective “recommended” may be used with the same meaning. |
| Should not | There may be valid reasons in particular circumstances when the particular behavior is acceptable or even useful; however, the full implications should be understood and the case carefully weighed before implementing any behavior described with this label. The phrase ”not recommended” may be used with this the same meaning. |
| May | An item is optional. One implementer may choose to include the item because a particular marketplace requires it or because the implementer feels that it enhances the product, while another implementer may omit the same item. An implementation that does not include a particular option must be capable of interoperating with another implementation that does include the option without compromising the minimum set of functions required of all devices. This specification does clearly call out options. Similarly, an implementation that does include a particular option must be capable of interoperating with another implementation that does not include the option (except, of course, for the feature the option provides). The adjective "optional" may be used with this same meaning. |
| Reserved | The specified bits are not currently used and are only available for use via extensions to the specification. They are not available for use by a particular implementation of this specification. Reserved bits shall be set to zero by the sender. Reserved bits shall be ignored by the receiver. When the term “reserved” is used in this specification to define the meaning of a given value or set of values for a field or other element, it means the values are not currently used and are only available for use via extensions to the specification. They are not available for use by a particular implementation of this specification. Reserved values shall not be used by the sender. Reserved values shall be ignored by the receiver. |

### Abbreviations

Abbreviations are always expanded the first time they are used. The expansion is of the form “Term To Be Abbreviated (TTBA).” For example: “Central Coordinator (CCo).” The expansion is repeated where the term is actually defined, if different. Abbreviations are case sensitive.

### Message Nomenclature

Message nomenclature (REQ, CNF, IND, RSP) shall follow the conventions shown in Figure 1‑1.

* Request messages always end in .REQ. The response (if any) to a Request message is always a Confirmation message, which ends in .CNF.
* Indication messages always end in .IND. The response (if any) to an Indication message is always a Response message, which ends in .RSP.



Figure 1‑1: Message Nomenclature

### Message Nomenclature

Message Sequence Charts (MSCs) shall follow the conventions shown in Figure 1‑2. Time is shown vertically, with the earliest time at the top. Space is shown horizontally.

* Stations of direct interest in the protocol being described are indicated by vertical lines, with a label at the top displaying the name of the station.
* Bubbles are used to reveal processing that occurs at a station.
* Messages are depicted as horizontal arrows originating at the sending station. The text describes the contents of the message and other characteristics as appropriate.
* Messages sent to all stations (i.e., broadcast either within an AVLN or all stations) are shown as arrows that extend most, but not all, the way to one of the destination stations in the MSC. See the first message in Figure 1‑2.
* Messages that may be sent, depending on the circumstances, are shown with dashed lines. This convention is independent of the arrow termination conventions.
* Messages sent to a specific station shown in the MSC (i.e., with a unicast MAC address) are depicted with the arrowhead terminating on the destination station. (Note that these messages might or might not use the broadcast TEI.) See the second and third messages in Figure 1‑2.
* Unicast or broadcast messages sent to other stations not shown in the MSC are depicted as short arrows that may repeat to indicate the sender repeating similar messages to multiple recipients. See the last three arrows in Figure 1‑2.
* Alternative protocol paths are separated by heavy dashed lines, and the alternative is labeled using rotated text on the left side.



Figure 1‑2. Message Sequence Chart Conventions

## Overview of HomePlug Green PHY - A Low Power, Legacy Interoperable, Highly Reliable PLC from HomePlug

The following criteria are considered to be essential for any technology targeting smart energy, home control, home automation, etc., applications:

1. Maintain high reliability/robustness (which includes range/coverage) despite reduced complexity
2. Coexistence and interoperability with existing, deployed, and standardized technologies
3. Scale to support for many low rate devices on a shared medium (which translates to high, bursted, bit rates)
4. Provide greatly reduced power consumption
5. Be cost effective
6. Address time to market concerns (which includes availability from multiple suppliers)

To address all of these criteria, the Home Plug Powerline Alliance has developed a new specification, “Green PHY”, which is a greatly simplified derivative of the existing, widely deployed, HomePlug AV technology.

Basing the Green PHY upon HomePlug AV was a reasonable choice considering its field-proven characteristics, large and worldwide installed base, well established Compliance & Interoperability (C & I) program, and multi-vendor ecosystem. In effect, HomePlug AV jumpstarts the Green PHY.

HomePlug AV employs three robust modes of communication, called ROBO Modes, for several purposes, including beaconing, data broadcast/multicast communication, session setup, and exchange of Management Messages. All ROBO Modes use QPSK modulation, along with a ½ rate Turbo Convolutional Code. The Green PHY uses only these modes.

Besides the robust nature of these modes, the further advantages of using only the ROBO modes for the Green PHY are as follows:

1. minimum impact on HPAV throughput
2. interoperable with current HPAV and future IEEE P1901 solutions baselined on HPAV (the Green PHY will be certified by HomePlug as a profile of P1901)
3. able to support multiple PHY Rates (3.8 Mbps, 4.9 Mbps, 9.8 Mbps)
4. reuses the entire 2 – 30 MHz band
5. reduces complexity of PHY (e.g., FEC, AFE, DFE)
6. enables low power modes via reduced duty cycle (i.e., “awake” time)

Since a high speed bursted mode is used, an effective packet throughput (per device/application) of approximately 250 kbps can met by utilizing <7% of the beacon period. However, since the Green device is only “on” or “awake” for this short interval, the estimated average power consumption is approximately 7% that of HPAV. To extrapolate further, by exploiting the duty cycle, 10 kbps could be provided using <1% duty cycle which provides opportunity for very low power modes. Alternately, higher throughput rates can be supported using more of the beacon period (but with a consequent increase in power consumption).

The advantages of reusing the entire 2 – 30 MHz band is that optimal performance can still be maintained (i.e., maximizing the number of potentially usable carriers) and tone masking and amplitude (TX power) maps for regulatory compliance and coexistence with HAM bands are still supported.

But it is not only in the PHY where advantages are obtained. Since the MAC is also reused, not only can the Green PHY device receive HPAV beacons, it can also transmit HPAV beacons. This means that a single, standalone Green PHY device can be a member of an AV network and can be the CCo in the AV network.

However, in order to reduce MAC complexity, a Green PHY device is only required to be a CCo in support of CSMA/CA only. In HPAV terms, the Green PHY device only needs to be a Level-0 CCo. This means that connection oriented communication cannot be controlled by a Green PHY devices, although it can participate in an AV network that permits connection oriented communications between HPAV devices.

A further simplification for the MAC occurs directly from the PHY simplification. Exclusive use of the ROBO modulation modes implies that there is no need to manage/maintain tone maps.

Despite simplification of the MAC, reuse of the multiple priority level QoS mode and Priority Resolution mechanism allows for straightforward low latency support of Demand Response / Load Shedding.

### Comparisons between HomePlug GREEN PHY and HomePlug AV PHY [Informative]

The material in this section informatively compares the HomePlug AV specification to the HomePlug GREEN PHY specification. However, it is essential to note that GREEN PHY is based upon HomePlug AV and is designed to be interoperable with HomePlug AV. Any items not specifically identified as being optional for GREEN PHY must be assumed to be requirements for both GREEN PHY and HomePlug AV.

### Differences between HomePlug GREEN PHY and HomePlug AV PHY [Informative]

The material in this section points to the sections of this specification that modify (i.e., reduce or relax in functionality) HomePlug AV. Brief descriptions are included. However, this section must be considered as informational only and therefore used only as a quick reference for the reader.

Table 1‑3: Differences between HomePlug GREEN PHY and HomePlug AV PHY

|  |  |  |
| --- | --- | --- |
| Chapter3 | PHY | Description of change |
| 3.1  | Overview | GP overview; includes TX/RX block diagram |
| 3.2.1  | PPDU Formats | GP PPDU payload formats are ROBO only |
| 3.2.3  | Symbol Timing | Table 3-2 (GIs for 417, 567, 3534 are not required) |
| 3.4 | Payload FEC Processing | Only rate ½ is supported by GP, 16/21 is not supported by GP; ROBO Interleaver is required |
| 3.4.2  | Turbo Convolutional Encoder | rate 16/21 is not supportedFig 3-10b, puncturing is not supported |
| 3.4.2.2  | Constituent Encoders | puncturing is not supported |
| 3.4.2.3  | Puncturing | puncturing Is not supported (Tables 3-5, 3-6) |
| 3.4.3  | Channel Interleaver | Table 3-11 (only rate ½ applies, rate 16/21 is not supported) |
| 3.5  | Mapping | Table 3-14 (only QPSK is required, only FC and ROBO are applicable)Only ROBO tone maps are supported by GP |
| 3.5.2  | Last Symbol Padding | Table 3-15 indicates that ROBO must obey/comply to the Tone Map/Tone Mask/Amplitude MASK; other modulations are not applicable to GP |
| 3.5.5  | Mapping for BPSK, etc. | Only QPSK applies (all other modulation schemes do not apply) Only QPSK appliesTable 3-17 only row for QPSKTable 3-18 only column for QPSKTable 3-19 not applicableTable 3-20 only row for QPSK |
| 3.7.3.2  | Transmit Constellation Error | Table 3-25, RMS Transmit Constellation Error Limit is ≤ -10 for GP PPDU |
| 3.8.1.1  | Receiver Minimum Input Voltage | Redefined, does not refer to rate 16/21, 1024-QAM |
| 3.8.1.2  | Receiver Maximum Input Voltage | Redefined, does not refer to rate 16/21, 1024-QAM |

### Differences between HomePlug GREEN PHY MAC (and above) and HomePlug AV MAC (and above) [Informative]

The material in this section points to the sections in this specification that either modify (e.g., reduce or relax functionality) or extend the HomePlug AV specfication. Brief descriptions are included. However, this section must be considered as informational only and therefore used only as a quick reference for the reader.

Table 1‑4: Differences between HomePlug GREEN PHY MAC and above) and HomePlug AV (MAC and above)

|  |  |  |
| --- | --- | --- |
| Chapter 4  | Frame Formats | description of change |
| 4.3.2.1 | Arrival Time Stamp | Not required as Connection services are not required for GREEN PHY |
| 4.4.1.5.2.1.1 | Source Terminal Equipment Identifier (STEI) | Behavior for routing/repeating in GREEN PHY |
| 4.4.1.5.2.8.1 | Encryption Key Select (EKS) | Describes additional feature |
| 4.4.1.5.2.9 and4.4.1.5.2.9.1 | Pending PHY Blocks (PPB) | Behavior for routing/repeating in GREEN PHY |
| 4.4.1.5.2.10 and4.4.1.5.2.10.1 | Bit Loading Estimate | Behavior for routing/repeating in GREEN PHY |
| 4.4.1.5.2.13.1 | Tone Map Index (TMI\_AV) | Only ROBO modes are required for GREEN PHY |
| 4.4.1.5.2.19.1 | Different CP PHY Clock Flag (DCPPCF) | Optional feature for GREEN PHY |
| 4.4.3 | Format of Beacon MPDU Payload | New beacon payload fields for GREEN PHY |
| 4.4.3.12.1 | RTS Broadcast Flag (RTSBF) | Optional feature for GREEN PHY |
| 4.4.3.15.2 | Beacon Entry Header (BEHDR) | New beacon entry headers for GREEN PHY |
| 4.4.3.15.4.6 | Discovered Info BENTRY | New capability/versioning added for GREEN PHY |
| 4.4.3.15.4.6.10 | GREEN PHY Capability | New |
| 4.4.3.15.4.6.11 | HPAV Version | New  |
| 4.4.3.15.4.15(and 4.4.3.15.4.15.1-6) | Power Save BENTRY | New Beacon Entry for GREEN PHY |
| 4.4.3.18 | Proxy Level (Plevel) | New feature  |
| 4.4.3.19 | Reusable SNID Flag (RSF) | New feature |
| Chapter 5 | MAC | description of change |
| 5.1.1.1.1 | Line Cycle Synchronization | Required for ISP |
| 5.1.2.1.1 | Beacon Period Structure in CSMA-Only Mode | CSMA-CA is required for GREEN PHY.Station must be Level 0 CCo |
| 5.1.2.2.1 | Beacon Period Structure in Uncoordinated Mode | Uncoordinated mode is not required for GREEN PHY. Station is not required to be Level 1 CCo |
| 5.1.2.3.1 | Beacon Period Structure in Coordinated Mode | Coordinated mode is not required for GREEN PHY. Station is not required to be Level 2 CCo |
| 5.1.3.1.4 | Channel Access Priority | Informative text added for Preferred Allocation |
| 5.1.3.1.5 | CSMA/CA Channel Access | References to Preferred Allocation and Distributed Bandwidth Control |
| 5.2.1.3.1 | Connectionless “Links” | Required for GREEN PHY |
| 5.2.1.4.3 | Link Identifiers | New feature added to identify GREEN PHY Preferred Allocations |
| 5.2.1.4.4 | Connection Identifiers | New feature added to identify GREEN PHY Preferred Allocations |
| 5.2.3.1.1 | Connection Setup | Not required for GREEN PHY |
| 5.2.3.2.1 | Global Link Setup | Not required for GREEN PHY |
| 5.2.3.5.3 | Connection Teardown | Not required for GREEN PHY |
| 5.2.3.7.3 | Connection Reconfiguration | Not required for GREEN PHY |
| 5.2.3.8.2 | Squeeze and De-squeeze | Not required for GREEN PHY |
| 5.2.6.1.1.3 | Channel Estimation | Not required for GREEN PHY as only ROBO modes are used. |
| 5.2.6.7 | Handling of Channel Estimation Requests | Although GREEN PHY does not initiate channel estimation, it is required to respond appropriately to channel estimation. |
| 5.3.1.1.1 | Behavior for Incoming Traffic | Behavior for routing/repeating in GREEN PHY |
| 5.4.6.1 | MPDU Bursting | Green PHY stations do not transmit MPDU bursts but are capable to receive MPDU bursts |
| 5.4.7.4 | Bidirectional Bursting | Not required for GREEN PHY |
| 5.4.8.1.2 | Request SACK Retransmission | Not required for GREEN PHY |
| 5.8 | Distributed Bandwidth Control | New feature |
| 5.9 | Power Save Mode | New feature |
| 5.10 | Routing and Repeating | New feature |
| 5.11 | Transmit Power Control | New feature |
| Chapter 6 | Convergence Layer | description of change |
| 6.2.4 | Packet Classification | Clarification for GREEN PHY |
| 6.6.3 | Auto Connect Service | Not required for GREEN PHY |
| 6.7.3.1 | Smoothing | Not required for GREEN PHY |
| Chapter 7 | CCo | description of change |
| 7.2.3.1 | Identifying HomePlug GREEN PHY Stations | New feature |
| 7.3.5.3.1 | SC-Join and SC-Add | Behavioral clarification  |
| 7.4.1 | CCo Selection for a New AVLN | Behavioral clarification |
| 7.7 | Proxy Networking with GREEN PHY Extensions to Support Routing and Repeating | New features |
| 7.7.1 | Identification of Hidden Stations | Includes elaboration on new features |
| 7.7.3.2 | PCo-Required Task | Includes elaboration on new features |
| 7.7.4 | Proxy Beacons | Includes elaboration on new features |
| 7.7.5 | Provisioning the NMK to Hidden Stations | Includes elaboration on new features |
| 7.7.6 | Provisioning NEK for Hidden Stations (Authenticating the HSTA) | Includes elaboration on new features |
| 7.7.7 | Exchange of MMEs Through a PCo | Includes elaboration on new features |
| 7.7.12 | Proxy Network Limitations | Includes elaboration on new features |
| 7.8.1.7 | Connection Specification (CSPEC) | not required |
| 7.8.2.1 | Scheduler and Bandwidth Allocation | not required  |
| 7.8.3.1 | Connection Admission Control | not required |
| 7.8.5 | Bandwidth Allocation | Informative text on Preferred Allocation |
| Chapter 8 | Multiple Networks | description of change |
| 8.1.1.1 | CSMA-Only Mode | Required |
| 8.1.2.1 | Uncoordinated Mode | Not required |
| 8.1.3.1 | Coordinated Mode | Not required |
| 8.2.1.1 | GREEN PHY Preferred Allocation and Minimum CSMA Region | New feature |
| Chapter 11 | MMEs | description of change |
| 11 | Management Messages | Many new MMEs for GREEN PHY, also many existing MMEs are not required |
| 11.2.10 | MME Support of HomePlug GREEN PHY | detailed description of required MMEs, optional MMEs, new MMEs |
| 11.2.54 | CC\_BLE\_UPDATE.IND | New |
| 11.2.55 | CC\_BCAST\_REPEAT.IND | New |
| 11.2.56 | CC\_BCAST\_REPEAT.RSP | New |
| 11.2.57 | CC\_POWERSAVE.REQ | New |
| 11.2.58 | CC\_POWERSAVE.CNF | New |
| 11.2.59 | CC\_POWERSAVE\_EXIT.REQ | New |
| 11.2.60 | CC\_POWERSAVE\_EXIT.CNF | New |
| 11.2.61 | CC\_POWERSAVE\_LIST.REQ | New |
| 11.2.62 | CC\_POWERSAVE\_LIST.CNF | New |
| 11.5.10 | CM\_CHAN\_EST.IND | additions to accommodate GP |
| 11.5.29 | CM\_GET\_BEACON.CNF | additions to accommodate GP |
| 11.5.37 | CM\_STA\_IDENTIFY.REQ | New |
| 11.5.38 | CM\_STA\_IDENTIFY.CNF | New |
| 11.5.39 | CM\_STA\_IDENTIFY.IND | New |
| 11.5.40 | CM\_STA\_IDENTIFY.RSP | New |
| 11.5.41 | CM\_ROUTE\_INFO.REQ | New |
| 11.5.42 | CM\_ROUTE\_INFO.CNF | New |
| 11.5.42.1 | Route Data Rate (RDR) | New |
| 11.5.43 | CM\_ROUTE\_INFO.IND | New |
| 11.5.44 | CM\_UNREACHABLE.IND | New |
| 11.5.44.1 | Unreachable Time Stamp (UnrchTS) | New |
| Chapter 12 | SAP Primitives | description of change |
| 12.2.50 | APCM\_SET\_HD\_DURATION.REQ | new |
| 12.2.51 | APCM\_SET\_HD\_DURATION.CNF | new |
| 12.2.52 | APCM\_UNASSOCIATED\_STA.IND | new |
| 12.2.53 | APCM\_SC\_JOIN.REQ | new |
| 12.2.54 | APCM\_SC\_JOIN.CNF | new |
| 12.2.55 | APCM\_SET\_PPKEYS.REQ | new |
| 12.2.56 | APCM\_SET\_PPKEYS.CNF | new |
| Chapter 14 | ISP | description of change |
| 14 | ISP | new |

### Identical Requirements for HomePlug GREEN PHY and HomePlug AV PHY

Unless specifically identified as differing in functional requirement, (e.g.,, reduction or relaxation in functionality) all requirements for HomePlug AV are applicable to the HomePlug GREEN PHY.