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(71) Applicant *(for all designated States except US)*: **MARVELL WORLD TRADE LTD.** [BB/BB]; L'Horizon Gunsite Road, Brittons Hill, St. Michael, 14027 (BB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **WAGHOLIKAR, Sarang Shrikrishna** [US/US]; 405 Crescent Avenue, Sunnyvale, CA 94087 (US). **RAMAMURTHY, Harish** [IN/US]; 22897 Cricket Hill Road, Cupertino, CA 95014 (US). **BHAGWAT, Rajesh Shreeram** [US/US]; 1703 Bearden Drive, Los Gatos, CA 95032 (US). **SEMERSKY, Matthew L.** [US/US]; 2316 Running Water Court, Santa Clara, CA 95054 (US).

(74) Agents: **WIGGINS, Michael D.** et al.; Harness, Dickey & Pierce, P.L.C., P.O. Box 828, Bloomfield Hills, MI 48303 (US).

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(54) **Title**: MULTI-TECHNOLOGY COEXISTENCE FOR IBSS NETWORKS

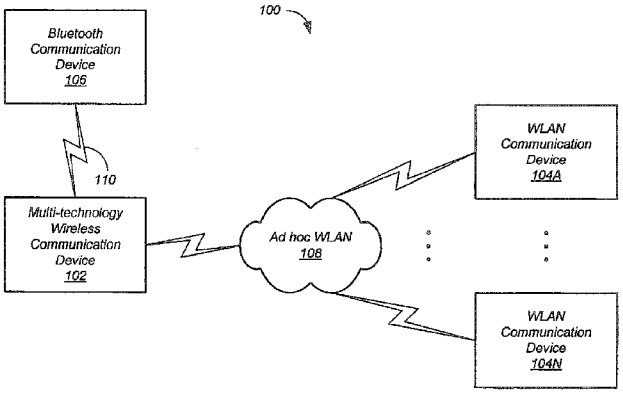

FIG. 1

(57) **Abstract**: Apparatus configured to be implemented in a first wireless communication device, having corresponding non-transitory computer-readable media, comprise a memory configured to store a coexistence schedule, wherein the coexistence schedule defines WLAN intervals and non-WLAN intervals; a WLAN transceiver configured to transmit WLAN signals in an IBSS network; a non-WLAN transceiver configured to transmit wireless non-WLAN signals; and a coexistence circuit configured to allow the WLAN transceiver to transmit the WLAN signals in the IBSS network only during the WLAN intervals, wherein the coexistence circuit is further configured to allow the non-WLAN transceiver to transmit the wireless non-WLAN signals only during the non-WLAN intervals; and wherein the coexistence circuit is further configured to cause the WLAN transceiver to transmit one or more coexistence request messages, each indicating a duration of at least one of a respective one of the WLAN intervals, and a respective one of the non-WLAN intervals.

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MULTI-TECHNOLOGY COEXISTENCE FOR IBSS NETWORKS

Inventors: **Sarang S Wagholikar**
Harish Ramamurthy
Rajesh Shreeram Bhagwat
Matthew L. Semersky

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This disclosure claims priority to U.S. Utility Patent Application Serial No. 13/458,227, filed on April 27, 2012, entitled "Multi-Technology Coexistence for IBSS Networks" and U.S. Provisional Patent Application Serial No. 61/481,079, filed on April 29, 2011, entitled "WLAN/BT Coexistence Schemes for IBSS". The disclosures thereof are incorporated by reference herein in their entirety.

FIELD

[0002] The present disclosure relates generally to wireless communications. More particularly, the present disclosure relates to coexistence between wireless local-area networking (WLAN) signals and wireless non-WLAN signals.

BACKGROUND

[0003] The popularity of various wireless networking technologies for handheld platforms has created a need to integrate multiple networking technologies on a single wireless communication device. Of these networking technologies, the two most widely used are wireless local-area networking (WLAN) and Bluetooth. Both of these technologies use the same un-licensed 2.4 GHz Industrial, Scientific and Medical (ISM) band. This situation poses a difficult problem for designing integrated circuits, external logic components, and wireless communication devices that allow these technologies to coexist. Because Bluetooth operates according to a known schedule, a multi-technology wireless communication device can schedule WLAN transmissions around the Bluetooth transmissions. However, because the Bluetooth schedule is not known to WLAN link partners, there are frequent collisions on the receive side. These collisions can reduce WLAN performance to one-half of baseline.

SUMMARY

[0004] In general, in one aspect, an embodiment features an apparatus configured to be implemented in a first wireless communication device, wherein the apparatus

comprises: a memory configured to store a coexistence schedule, wherein the coexistence schedule defines wireless local-area network (WLAN) intervals and non-WLAN intervals; a WLAN transceiver configured to transmit WLAN signals in an independent basic service set (IBSS) network; a non-WLAN transceiver configured to transmit wireless non-WLAN signals; and a coexistence circuit configured to allow the WLAN transceiver to transmit the WLAN signals in the IBSS network only during the WLAN intervals, wherein the coexistence circuit is further configured to allow the non-WLAN transceiver to transmit the wireless non-WLAN signals only during the non-WLAN intervals; and wherein the coexistence circuit is further configured to cause the WLAN transceiver to transmit one or more coexistence request messages, wherein each of the coexistence request messages indicates a duration of at least one of a respective one of the WLAN intervals, and a respective one of the non-WLAN intervals.

[0005] Embodiments of the apparatus can include one or more of the following features. In some embodiments, the IBSS network comprises one or more second wireless communication devices; and responsive to the one or more coexistence request messages, the one or more second wireless communication devices transmit no WLAN signals during the respective non-WLAN intervals. In some embodiments, the non-WLAN signals comprise at least one of: Bluetooth signals; near field communication (NFC) signals; FM signals; and GPS signals. In some embodiments, at least one of the coexistence request messages comprises: a clear-to-send-to-self frame, wherein the clear-to-send-to-self frame includes a duration parameter, wherein the duration parameter indicates the duration of the respective one of the non-WLAN intervals. In some embodiments, at least one of the coexistence request messages comprises: a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates the duration of the respective one of the non-WLAN intervals. In some embodiments, at least one of the coexistence request messages comprises: a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates the duration of a period between a respective one of the non-WLAN intervals and another one of the non-WLAN intervals. Some embodiments comprise a wireless communication device comprising the apparatus. In some embodiments, the wireless communication device is implemented as one of: a mobile telephone; a personal digital assistant (PDA); a tablet computer; and a personal computer. In some embodiments, the wireless communication device is compliant with all or part of IEEE standard 802.11, including draft and approved amendments such as 802.11a, 802.11b, 802.11e, 802.11g, 802.11i, 802.11k, 802.11n,

802.11v, 802.11w, 802.11aa, 802.11ac, 802.11ad, 802.11ae, 802.11af, 802.11ah, and 802.11ai.

[0006] In general, in one aspect, an embodiment features non-transitory computer-readable media embodying instructions executable by a computer to perform functions comprising: storing a coexistence schedule, wherein the coexistence schedule defines wireless local-area network (WLAN) intervals and non-WLAN intervals; allowing a WLAN transceiver to transmit WLAN signals in an independent basic service set (IBSS) network only during the WLAN intervals; allowing a non-WLAN transceiver to transmit wireless non-WLAN signals only during the non-WLAN intervals; and causing the WLAN transceiver to transmit one or more coexistence request messages, wherein each of the coexistence request messages indicates a duration of at least one of a respective one of the WLAN intervals, and a respective one of the non-WLAN intervals.

[0007] Embodiments of the non-transitory computer-readable media can include one or more of the following features. In some embodiments, the IBSS network comprises one or more second wireless communication devices; and responsive to the one or more coexistence request messages, the one or more second wireless communication devices transmit no WLAN signals during the respective non-WLAN intervals. In some embodiments, the non-WLAN signals comprise at least one of: Bluetooth signals; near field communication (NFC) signals; FM signals; and GPS signals.

[0008] In general, in one aspect, an embodiment features an apparatus configured to be implemented in a first wireless communication device, wherein the apparatus comprises: a wireless local-area network (WLAN) transceiver configured to transmit WLAN signals in an independent basic service set (IBSS) network, wherein the IBSS network comprises one or more second wireless communication devices; and a coexistence circuit configured to allow the WLAN transceiver to transmit no WLAN signals during non-WLAN intervals responsive to the WLAN transceiver receiving coexistence request messages, wherein each coexistence request message indicates a duration of at least one of a respective one of the non-WLAN intervals, and a period between a respective one of the non-WLAN intervals and another one of the non-WLAN intervals.

[0009] Embodiments of the apparatus can include one or more of the following features. In some embodiments, the non-WLAN signals comprise at least one of: Bluetooth signals; near field communication (NFC) signals; FM signals; and GPS signals. In some embodiments, at least one of the coexistence request messages comprises: a clear-to-send-to-self frame, wherein the clear-to-send-to-self frame includes a duration parameter, wherein the duration parameter indicates the duration of the

respective one of the non-WLAN intervals. In some embodiments, at least one of the coexistence request messages comprises: a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates a duration of the respective one of the non-WLAN intervals. In some embodiments, at least one of the coexistence request messages comprises: a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates a duration of a period between a respective one of the non-WLAN intervals and another one of the non-WLAN intervals. Some embodiments comprise a wireless communication device comprising the apparatus. In some embodiments, the wireless communication device is implemented as one of: a mobile telephone; a personal digital assistant (PDA); a tablet computer; and a personal computer. In some embodiments, the wireless communication device is compliant with all or part of IEEE standard 802.11, including draft and approved amendments such as 802.11a, 802.11b, 802.11e, 802.11g, 802.11i, 802.11k, 802.11n, 802.11v, 802.11w, 802.11aa, 802.11ac, 802.11ad, 802.11ae, 802.11af, 802.11ah, and 802.11ai.

[0010] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0011] FIG. 1 shows elements of a multi-technology wireless communication system according to one embodiment.

[0012] FIG. 2 shows detail of the multi-technology wireless communication device of FIG. 1 according to one embodiment.

[0013] FIG. 3 shows detail of a WLAN communication device of FIG. 1 according to one embodiment.

[0014] FIG. 4 illustrates a coexistence schedule according to one embodiment.

[0015] FIG. 5 shows the format of the CTS-to-self frame according to the IEEE 802.11g standard.

[0016] FIG. 6 shows the timing of the transmission of the CTS-to-self frames with reference to the coexistence schedule of FIG. 4 according to one embodiment.

[0017] FIG. 7 shows a process for the multi-technology wireless communication system of FIG. 1 according to the embodiment of FIG. 6.

[0018] FIG. 8 shows the format of the vendor-specific action frame according to the IEEE 802.11 standard.

[0019] FIG. 9 shows the format of the vendor-specific information element according to the IEEE 802.11 standard.

[0020] FIG. 10 shows the timing of the transmission of the vendor-specific action frames with reference to the coexistence schedule of FIG. 4 according to an embodiment where the duration parameter indicates the duration of the following Bluetooth interval.

[0021] FIG. 11 shows a process for the multi-technology wireless communication system of FIG. 1 according to the embodiment of FIG. 10.

[0022] FIG. 12 shows the timing of the transmission of the vendor-specific action frames with reference to the coexistence schedule of FIG. 4 according to an embodiment where the duration parameter indicates the duration of the current WLAN interval.

[0023] FIG. 13 shows the format of the Unscheduled Automatic Power Save Delivery (UAPSD) information element according to the IEEE 802.11 standard.

[0024] FIG. 14 shows a process for the multi-technology wireless communication system of FIG. 1 according to the embodiment of FIG. 13.

[0025] The leading digit(s) of each reference numeral used in this specification indicates the number of the drawing in which the reference numeral first appears.

DETAILED DESCRIPTION

[0026] Embodiments of the present disclosure provide coexistence for multi-technology wireless communication devices in an IEEE 802.11 independent basic service set (IBSS) networks. In particular, in one aspect, the disclosed embodiments describe coexistence for wireless local-area networking (WLAN) and Bluetooth technologies. However, while the disclosed embodiments are described in terms of WLAN and Bluetooth technologies, the disclosed techniques are applicable to other wireless technologies as well. The wireless technologies can include wireless non-WLAN signals other than Bluetooth. For example, the wireless non-WLAN signals can include near field communication (NFC) signals, FM signals, GPS signals, other ISM band signals, and the like.

[0027] According to the described embodiments, a multi-technology wireless communication device operates in an IBSS. The wireless technologies include wireless local-area network (WLAN) and wireless non-WLAN technologies. For example, the WLAN technology can be based on the IEEE 802.11 standard, and the

non-WLAN technology can include Bluetooth signals, near field communication (NFC) signals, FM signals, GPS signals, other ISM band signals, and the like. The multi-technology wireless communication device includes a WLAN transceiver configured to transmit WLAN signals during WLAN intervals, and a non-WLAN transceiver configured to transmit wireless non-WLAN signals during non-WLAN intervals.

[0028] In accordance with one embodiment, a WLAN transceiver transmits a coexistence request message for each of the non-WLAN intervals. As used herein, the term the term "message" generally refers to a wireless electronic signal representing a digital message. Each coexistence request message indicates a duration of a respective one of the WLAN intervals, or a duration of a respective one of the non-WLAN intervals. In response to each coexistence request message, the other WLAN devices in the IBSS transmit no WLAN signals during the respective non-WLAN interval. The result is reduction or elimination of interference between the WLAN signals and the wireless non-WLAN signals.

[0029] FIG. 1 shows elements of a multi-technology wireless communication system 100 according to one embodiment. Although in the described embodiments the elements of multi-technology wireless communication system 100 are presented in one arrangement, other embodiments may feature other arrangements. For example, elements of multi-technology wireless communication system 100 can be implemented in hardware, software, or combinations thereof.

[0030] Referring to FIG. 1, multi-technology wireless communication system 100 includes a multi-technology wireless communication device 102, one or more WLAN communication devices 104A-N, and a Bluetooth communication device 106. Multi-technology wireless communication device 102 can be implemented as any wireless communication device capable of performing the functions described herein. For example, multi-technology wireless communication device 102 can be implemented as a mobile telephone such as a smartphone or feature phone, a personal digital assistant (PDA), a tablet computer, a personal computer, or the like.

[0031] WLAN communication devices 104 can be implemented as any wireless communication devices capable of performing the functions described herein. For example, each WLAN communication device 104 can be implemented as a mobile telephone such as a smartphone or feature phone, a personal digital assistant (PDA), a tablet computer, a personal computer, or the like. In addition, each WLAN communication device 104 can be implemented as a multi-technology wireless communication device 102, but this is not required.

[0032] Multi-technology wireless communication device 102 and WLAN communication devices 104 form an independent basic service set (IBSS). That is, multi-technology wireless communication device 102 and WLAN communication devices 104 communicate over an ad hoc WLAN 108. In some embodiments, ad hoc WLAN 108 is compliant with all or part of IEEE standard 802.11, including draft and approved amendments such as 802.11a, 802.11b, 802.11e, 802.11g, 802.11i, 802.11k, 802.11n, 802.11v, 802.11w, 802.11aa, 802.11ac, 802.11ad, 802.11ae, 802.11af, 802.11ah, and 802.11ai. Multi-technology wireless communication device 102 communicates with Bluetooth communication device 106 over a wireless Bluetooth link 110.

[0033] FIG. 2 shows detail of multi-technology wireless communication device 102 of FIG. 1 according to one embodiment. Although in the described embodiments the elements of multi-technology wireless communication device 102 are presented in one arrangement, other embodiments may feature other arrangements. For example, elements of multi-technology wireless communication device 102 can be implemented in hardware, software, or combinations thereof.

[0034] Referring to FIG. 2, multi-technology wireless communication device 102 includes a WLAN transceiver 202, a Bluetooth transceiver 204, a coexistence circuit 206, a memory 212, and a timer 216. Coexistence circuit 206 can be implemented as a processor. WLAN transceiver 202, Bluetooth transceiver 204, coexistence circuit 206, memory 212, and timer 216 can be fabricated as one or more integrated circuits.

[0035] WLAN transceiver 202 transmits and receives (or transceives) WLAN signals 208 over ad hoc WLAN 108. Bluetooth transceiver 204 transceives Bluetooth signals 210 over Bluetooth link 110. Coexistence circuit 206 schedules WLAN transceiver 202 and Bluetooth transceiver 204 to prevent interference between WLAN signals 208 and Bluetooth signals 210 transmitted by multi-technology wireless communication device 102. Coexistence circuit 206 also causes WLAN transceiver 202 to transmit coexistence request messages over ad hoc WLAN 108 to prevent interference between Bluetooth signals 210 and WLAN signals 208 transmitted by WLAN communication devices 104. Memory 212 stores a coexistence schedule 214.

[0036] FIG. 3 shows detail of a WLAN communication device 104 of FIG. 1 according to one embodiment. Although in the described embodiments the elements of WLAN communication device 104 are presented in one arrangement, other embodiments may feature other arrangements. For example, elements of WLAN communication device 104 can be implemented in hardware, software, or combinations thereof.

[0037] Referring to FIG. 3, WLAN communication device 104 includes a wireless local-area network (WLAN) transceiver 302, a coexistence circuit 306, and a timer 316.

Coexistence circuit 306 can be implemented as a processor. WLAN transceiver 302, coexistence circuit 306, and timer 316 can be fabricated as one or more integrated circuits.

[0038] WLAN transceiver 302 transceives WLAN signals 208 over ad hoc WLAN 108. Coexistence circuit 306 schedules its WLAN transceiver 302 in accordance with the coexistence request messages transmitted by multi-technology wireless communication device 102 to prevent interference between WLAN signals 208 transmitted by WLAN communication devices 104 and Bluetooth signals 210.

[0039] Multi-technology wireless communication device 102 communicates with Bluetooth communication device 106 over wireless Bluetooth link 110 according to coexistence schedule 214 and timer 216. FIG. 4 illustrates a coexistence schedule 214 according to one embodiment. Coexistence schedule 214 consists of Bluetooth intervals 402 and WLAN intervals 404. In general, the schedule is periodic, so that all Bluetooth intervals 402 have the same duration Tbt, and so that all WLAN intervals 404 have the same duration Twlan. However, this periodicity is not required. In general, the duration Twlan of WLAN intervals 404 is greater than the duration Tbt of Bluetooth intervals 402, but this is not required.

[0040] Coexistence schedule 214 is known to multi-technology wireless communication device 102. Therefore coexistence circuit 206 can control the transmissions of WLAN transceiver 202 and Bluetooth transceiver 204 deterministically according to coexistence schedule 214 and timer 216 so as to avoid interference between the transmissions. In particular, coexistence circuit 206 allows WLAN transceiver 202 to transmit WLAN signals 208 only during WLAN intervals 404, and allows Bluetooth transceiver 204 to transmit Bluetooth signals 210 only during Bluetooth intervals 402.

[0041] However, coexistence schedule 214 is not known to WLAN communication devices 104. To prevent interference between the transmissions of WLAN communication devices 104 and Bluetooth signals 210, coexistence circuit 206 of multi-technology wireless communication device 102 causes WLAN transceiver 202 to transmit coexistence request messages. Each coexistence request message indicates a duration of one of the WLAN intervals 404, or a duration of one of the Bluetooth intervals 402. At each WLAN communication device 104, responsive to the WLAN transceiver 302 receiving a coexistence request message, coexistence circuit 306 allows the WLAN transceiver 302 to transmit no WLAN signals 208 during one of the Bluetooth intervals 402. Bluetooth communication device 106 has knowledge of coexistence schedule 214, and so transmits Bluetooth signals 210 only during Bluetooth intervals 402.

[0042] In some embodiments, the coexistence request message is implemented as a clear-to-send-to-self (CTS-to-self) frame. FIG. 5 shows the format of the CTS-to-self frame according to the IEEE 802.11g standard. The CTS-to-self frame includes a two-octet Frame Control field, a two-octet Duration field, a six-octet Receiver Address (RA) field, and a four-octet Frame Check Sequence (FCS) field. The RA field contains the MAC address of multi-technology wireless communication device 102. The duration field contains a duration parameter that indicates the duration of the next Bluetooth interval 402.

[0043] FIG. 6 shows the timing of the transmission of the CTS-to-self frames with reference to coexistence schedule 214 of FIG. 4 according to one embodiment. Referring to FIG. 6, coexistence circuit 206 of multi-technology wireless communication device 102 causes WLAN transceiver 202 to transmit a CTS-to-self frame 602 just prior to the start of each Bluetooth interval 402. The duration parameter of each CTS-to-self frame 602 indicates the duration of the subsequent Bluetooth interval 402. WLAN transceivers 302 of WLAN communication devices 104 receive CTS-to-self frames 602.

[0044] At each WLAN communication device 104, responsive to the WLAN transceiver 302 receiving a CTS-to-self frame 602, coexistence circuit 306 allows the WLAN transceiver 302 to transmit no WLAN signals 208 for the interval specified by the duration parameter in that CTS-to-self frame 602. That is, coexistence circuit 306 allows the WLAN transceiver 302 to transmit no WLAN signals 208 during the subsequent Bluetooth interval 402.

[0045] FIG. 7 shows a process 700 for multi-technology wireless communication system 100 of FIG. 1 according to the embodiment of FIG. 6. Although in the described embodiments the elements of process 700 are presented in one arrangement, other embodiments may feature other arrangements. For example, in various embodiments, some or all of the elements of process 700 can be executed in a different order, concurrently, and the like. Also some elements of process 700 may not be performed, and may not be executed immediately after each other. FIG. 7 is arranged in two columns, with processes of multi-technology wireless communication device 102 shown in the left-hand column, and with processes of a WLAN communication device 104 shown in the right-hand column.

[0046] Referring to FIG. 7, at 702 and 704, a WLAN interval 404 begins. During WLAN interval 404, WLAN transmission is allowed for both multi-technology wireless communication device 102 and WLAN communication device 104. At 706, multi-technology wireless communication device 102 determines when the WLAN interval 404 is ending. In particular, coexistence circuit 206 of multi-technology wireless

communication device 102 consults the coexistence schedule 214 stored in memory 212 and timer 216. At 708, just prior to the end of the WLAN interval 404, multi-technology wireless communication device 102 transmits a CTS-to-self frame 602 that includes the duration of the following Bluetooth interval 402. Then the Bluetooth interval 402 begins. Coexistence circuit 206 does not allow WLAN transmission by multi-technology wireless communication device 102 during Bluetooth interval 402.

[0047] At 710, WLAN communication device 104 receives the CTS-to-self frame 602, and gets the duration of the Bluetooth interval 402 from that frame 602. Bluetooth interval 402 begins. Coexistence circuit 306 does not allow WLAN transmission by WLAN communication device 104 during Bluetooth interval 402.

[0048] At 712, multi-technology wireless communication device 102 determines when the Bluetooth interval 402 has ended. In particular, coexistence circuit 206 of multi-technology wireless communication device 102 consults timer 216 and the coexistence schedule 214 stored in memory 212. When the Bluetooth interval 402 ends, the next WLAN interval begins at 702. Coexistence circuit 206 allows WLAN transmission by multi-technology wireless communication device 102 during WLAN interval 404.

[0049] At 714, WLAN communication device 104 determines when the peer's Bluetooth interval 402 has ended (that is, when the Bluetooth interval 402 for multi-technology wireless communication device 102 has ended). In particular, coexistence circuit 306 of WLAN communication device 104 uses timer 316 and the duration from the CTS-to-self frame 602 to determine when the peer's Bluetooth interval 402 has ended. When the peer's Bluetooth interval 402 ends, the next WLAN interval begins at 704. Coexistence circuit 306 allows WLAN transmission by WLAN communication device 104 during WLAN interval 404.

[0050] In some embodiments, the coexistence request message is implemented as a vendor-specific action frame, where the vendor-specific action frame includes a duration parameter. The coexistence request message can also be sent using beacons and probe request/response messages when possible. In some embodiments, the duration parameter indicates the duration of the following Bluetooth interval 402. In other embodiments, the duration parameter indicates the duration of the current WLAN interval 404.

[0051] FIG. 8 shows the format of the vendor-specific action frame according to the IEEE 802.11 standard. Referring to FIG. 8, the vendor-specific action frame includes a one-octet Category field, a three-octet OUI field, and a variable-length Vendor-Specific Content field. The Category field is set to the value indicating the vendor-

specific category. The OUI field contains a public OUI, assigned by the IEEE, of the entity that has defined the content of the particular vendor-specific action. The Vendor-Specific Content field contains one or more vendor-specific fields. In the described embodiment, the Vendor-Specific Content field contains the vendor-specific information element.

[0052] In some embodiments, the vendor-specific action frame includes a vendor-specific information element that includes the duration parameter. FIG. 9 shows the format of the vendor-specific information element according to the IEEE 802.11 standard. Referring to FIG. 9, the vendor-specific information element includes a one-octet Element ID field, a one-octet Length field, a three-octet OUI field, and a variable-length Vendor-Specific Content field. The Element ID field indicates the information element is a vendor-specific information element. The OUI field contains a public OUI assigned by the IEEE. The Vendor-Specific Content field contains one or more vendor-specific fields. In the described embodiment, the Vendor-Specific Content field contains the duration parameter. In other embodiments, the vendor-specific action frame includes a WiFi Direct Notice of Absence element that includes the duration parameter.

[0053] FIG. 10 shows the timing of the transmission of the vendor-specific action frames with reference to coexistence schedule 214 of FIG. 4 according to an embodiment where the duration parameter indicates the duration of the following Bluetooth interval 402. Referring to FIG. 10, coexistence circuit 206 of multi-technology wireless communication device 102 causes WLAN transceiver 202 to transmit a vendor-specific action frame 1002 just prior to the start of each Bluetooth interval 402. The duration parameter of each vendor-specific action frame 1002 indicates the duration of the subsequent Bluetooth interval 402. WLAN transceivers 302 of WLAN communication devices 104 receive the vendor-specific action frames 1002.

[0054] At each WLAN communication device 104, responsive to the WLAN transceiver 302 receiving a vendor-specific action frame 1002, coexistence circuit 306 allows the WLAN transceiver 302 to transmit no WLAN signals 208 for the interval specified by the duration parameter in that vendor-specific action frame 1002. That is, coexistence circuit 306 allows the WLAN transceiver 302 to transmit no WLAN signals 208 during the subsequent Bluetooth interval 402.

[0055] FIG. 11 shows a process 1100 for multi-technology wireless communication system 100 of FIG. 1 according to the embodiment of FIG. 10. Although in the described embodiments the elements of process 1100 are presented in one arrangement, other embodiments may feature other arrangements. For example, in various embodiments, some or all of the elements of process 1100 can be executed in a different order,

concurrently, and the like. Also some elements of process 1100 may not be performed, and may not be executed immediately after each other. FIG. 11 is arranged in two columns, with processes of multi-technology wireless communication device 102 shown in the left-hand column, and with processes of a WLAN communication device 104 shown in the right-hand column.

[0056] Referring to FIG. 11, at 1102 and 1104, a WLAN interval 404 begins. During WLAN interval 404, WLAN transmission is allowed for both multi-technology wireless communication device 102 and WLAN communication device 104. At 1106, multi-technology wireless communication device 102 determines when the WLAN interval 404 is ending. In particular, coexistence circuit 206 of multi-technology wireless communication device 102 consults the coexistence schedule 214 stored in memory 212 and timer 216. At 1108, prior to the end of the WLAN interval 404, multi-technology wireless communication device 102 transmits a vendor-specific action frame 1002 that includes the duration of the following Bluetooth interval 402. Then the Bluetooth interval 402 begins. Coexistence circuit 206 does not allow WLAN transmission by multi-technology wireless communication device 102 during Bluetooth interval 402.

[0057] At 1110, WLAN communication device 104 receives the vendor-specific action frame 1002, and gets the duration of the Bluetooth interval 402 from that frame 1002. Bluetooth interval 402 begins. Coexistence circuit 306 does not allow WLAN transmission by WLAN communication device 104 during Bluetooth interval 402.

[0058] At 1112, multi-technology wireless communication device 102 determines when the Bluetooth interval 402 has ended. In particular, coexistence circuit 206 of multi-technology wireless communication device 102 consults timer 216 and the coexistence schedule 214 stored in memory 212. When the Bluetooth interval 402 ends, the next WLAN interval begins at 1102. Coexistence circuit 206 allows WLAN transmission by multi-technology wireless communication device 102 during WLAN intervals 404.

[0059] At 1114, WLAN communication device 104 determines when the peer's Bluetooth interval 402 has ended (that is, when the Bluetooth interval 402 for multi-technology wireless communication device 102 has ended). In particular, coexistence circuit 306 of WLAN communication device 104 uses timer 316 and the duration from the vendor-specific action frame 1002 to determine when the peer's Bluetooth interval 402 has ended. When the peer's Bluetooth interval 402 ends, the next WLAN interval 404 begins at 1104. Coexistence circuit 306 allows WLAN transmission by WLAN communication device 104 during WLAN intervals 404.

[0060] FIG. 12 shows the timing of the transmission of the vendor-specific action frames with reference to coexistence schedule 214 of FIG. 4 according to an embodiment where the duration parameter indicates the duration of the current WLAN interval 404. Referring to FIG. 12, coexistence circuit 206 of multi-technology wireless communication device 102 causes WLAN transceiver 202 to transmit a vendor-specific action frame 1202 at the start of each WLAN interval 404. The duration parameter of each vendor-specific action frame 1202 indicates the duration of that WLAN interval 404. WLAN transceivers 302 of WLAN communication devices 104 receive vendor-specific action frames 1202.

[0061] At each WLAN communication device 104, responsive to the WLAN transceiver 302 receiving a vendor-specific action frame 1202, coexistence circuit 306 allows the WLAN transceiver 302 to transmit WLAN signals 208 only during the interval specified by the duration parameter in that vendor-specific action frame 1202. That is, coexistence circuit 306 allows the WLAN transceiver 302 to transmit WLAN signals 208 only during that WLAN interval 404.

[0062] In some embodiments, the vendor-specific action frame includes an Unscheduled Automatic Power Save Delivery (UAPSD) information element that includes the duration parameter. FIG. 13 shows the format of the UAPSD information element according to the IEEE 802.11 standard. Referring to FIG. 13, the UAPSD information element includes a one-octet Element ID field, a one-octet Length field, an eight-octet TSF 0 Offset field, a four-octet Interval/Duration field, and a variable-length Optional Subelements field.

[0063] The Element ID field contains a predetermined value that identifies the information element as being the UAPSD information element. The value of the Length field is 12 plus the length of any additional subelements present. The TSF 0 Offset field is not required in this embodiment. The Interval/Duration field contains the duration parameter. The Optional Subelements field format contains zero or more subelements.

[0064] FIG. 14 shows a process 1400 for multi-technology wireless communication system 100 of FIG. 1 according to the embodiment of FIG. 13. Although in the described embodiments the elements of process 1400 are presented in one arrangement, other embodiments may feature other arrangements. For example, in various embodiments, some or all of the elements of process 1400 can be executed in a different order, concurrently, and the like. Also some elements of process 1400 may not be performed, and may not be executed immediately after each other. FIG. 14 is arranged in two columns, with processes of multi-technology wireless

communication device 102 shown in the left-hand column, and with processes of a WLAN communication device 104 shown in the right-hand column.

[0065] Referring to FIG. 14, at 1402 and 1404, a Bluetooth interval 402 begins for multi-technology wireless communication device 102. During Bluetooth interval 402, WLAN transmission is not allowed for either multi-technology wireless communication device 102 or WLAN communication device 104. At 1406, multi-technology wireless communication device 102 determines when the Bluetooth interval 402 has ended. In particular, coexistence circuit 206 of multi-technology wireless communication device 102 consults the coexistence schedule 214 stored in memory 212 and timer 216. At 1408, after the end of the Bluetooth interval 402, multi-technology wireless communication device 102 transmits a vendor-specific action frame 1302 that includes the duration of the current WLAN interval 404. Coexistence circuit 206 allows WLAN transmission by multi-technology wireless communication device 102 only during WLAN intervals 404.

[0066] At 1410, WLAN communication device 104 receives the vendor-specific action frame 1302, and gets the duration of the WLAN interval 404 from that frame 1302. WLAN interval 404 has begun. Coexistence circuit 306 allows WLAN transmission by WLAN communication device 104 only during WLAN intervals 404.

[0067] At 1412, multi-technology wireless communication device 102 determines when the WLAN interval 404 has ended. In particular, coexistence circuit 206 of multi-technology wireless communication device 102 consults timer 216 and the coexistence schedule 214 stored in memory 212. When the WLAN interval 404 ends, the next Bluetooth interval begins at 1402. Coexistence circuit 206 does not allow WLAN transmission by multi-technology wireless communication device 102 during Bluetooth intervals 402.

[0068] At 1414, WLAN communication device 104 determines when the WLAN interval 404 has ended. In particular, coexistence circuit 306 of WLAN communication device 104 uses timer 316 and the duration from the vendor-specific action frame 1302 to determine when the WLAN interval 404 has ended. When the WLAN interval 404 ends, the next Bluetooth interval 402 begins at 1404. Coexistence circuit 306 doe not allow WLAN transmission by WLAN communication device 104 during Bluetooth intervals 402.

[0069] Multiple embodiments have been described using CTS-to-self frames and vendor-specific action frames. In some devices, only one of these embodiments are implemented. In other devices, two or more of these embodiments are implemented, and are selected dynamically according to factors such as network conditions. For

example, embodiments that employ CTS-to-self frames can be selected when the IBSS includes only one multi-technology wireless communication device 102 and one WLAN communication device 104 and no other IBSS is nearby. As another example, embodiments that employ vendor-specific action frames can be selected when the IBSS includes multiple WLAN communication devices 104.

[0070] Various embodiments of the present disclosure can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations thereof. Embodiments of the present disclosure can be implemented in a computer program product tangibly embodied in a computer-readable storage device for execution by a programmable processor. The described processes can be performed by a programmable processor executing a program of instructions to perform functions by operating on input data and generating output. Embodiments of the present disclosure can be implemented in one or more computer programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and at least one output device. Each computer program can be implemented in a high-level procedural or object-oriented programming language, or in assembly or machine language if desired; and in any case, the language can be a compiled or interpreted language. Suitable processors include, by way of example, both general and special purpose microprocessors. Generally, processors receive instructions and data from a read-only memory and/or a random access memory. Generally, a computer includes one or more mass storage devices for storing data files. Such devices include magnetic disks, such as internal hard disks and removable disks, magneto-optical disks; optical disks, and solid-state disks. Storage devices suitable for tangibly embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, such as EPROM, EEPROM, and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM disks. Any of the foregoing can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits).

[0071] A number of implementations have been described. Nevertheless, various modifications may be made without departing from the scope of the disclosure. Accordingly, other implementations are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An apparatus configured to be implemented in a first wireless communication device, wherein the apparatus comprises:

a memory configured to store a coexistence schedule, wherein the coexistence schedule defines wireless local-area network (WLAN) intervals and non-WLAN intervals;

a WLAN transceiver configured to transmit WLAN signals in an independent basic service set (IBSS) network;

a non-WLAN transceiver configured to transmit wireless non-WLAN signals; and

a coexistence circuit configured to allow the WLAN transceiver to transmit the WLAN signals in the IBSS network only during the WLAN intervals,

wherein the coexistence circuit is further configured to allow the non-WLAN transceiver to transmit the wireless non-WLAN signals only during the non-WLAN intervals; and

wherein the coexistence circuit is further configured to cause the WLAN transceiver to transmit one or more coexistence request messages, wherein each of the coexistence request messages indicates a duration of at least one of

a respective one of the WLAN intervals, and

a respective one of the non-WLAN intervals.

2. The apparatus of claim 1, wherein:

the IBSS network comprises one or more second wireless communication devices; and

responsive to the one or more coexistence request messages, the one or more second wireless communication devices transmit no WLAN signals during the respective non-WLAN intervals.

3. The apparatus of claim 1, wherein the non-WLAN signals comprise at least one of:

Bluetooth signals;

near field communication (NFC) signals;

FM signals; and

GPS signals.

4. The apparatus of claim 1, wherein at least one of the coexistence request messages comprises:

a clear-to-send-to-self frame, wherein the clear-to-send-to-self frame includes a duration parameter, wherein the duration parameter indicates the duration of the respective one of the non-WLAN intervals.

5. The apparatus of claim 1, wherein at least one of the coexistence request messages comprises:

a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates the duration of the respective one of the non-WLAN intervals.

6. The apparatus of claim 1, wherein at least one of the coexistence request messages comprises:

a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates the duration of a period between a respective one of the non-WLAN intervals and another one of the non-WLAN intervals.

7. A wireless communication device comprising the apparatus of claim 1.

8. The wireless communication device of claim 7, wherein the wireless communication device is implemented as one of:

a mobile telephone;

a personal digital assistant (PDA);

a tablet computer; and

a personal computer.

9. The wireless communication device of claim 7, wherein the wireless communication device is compliant with all or part of IEEE standard 802.11, including draft and approved amendments such as 802.11a, 802.11b, 802.11e, 802.11g, 802.11i, 802.11k, 802.11n, 802.11v, 802.11w, 802.11aa, 802.11ac, 802.11ad, 802.11ae, 802.11af, 802.11ah, and 802.11ai.

10. Non-transitory computer-readable media embodying instructions executable by a computer to perform functions comprising:

storing a coexistence schedule, wherein the coexistence schedule defines wireless local-area network (WLAN) intervals and non-WLAN intervals;

allowing a WLAN transceiver to transmit WLAN signals in an independent basic service set (IBSS) network only during the WLAN intervals;

allowing a non-WLAN transceiver to transmit wireless non-WLAN signals only during the non-WLAN intervals; and

causing the WLAN transceiver to transmit one or more coexistence request messages, wherein each of the coexistence request messages indicates a duration of at least one of

a respective one of the WLAN intervals, and

a respective one of the non-WLAN intervals.

11. The non-transitory computer-readable media of claim 10, wherein:

the IBSS network comprises one or more second wireless communication devices; and

responsive to the one or more coexistence request messages, the one or more second wireless communication devices transmit no WLAN signals during the respective non-WLAN intervals.

12. The non-transitory computer-readable media of claim 10, wherein the non-WLAN signals comprise at least one of:

Bluetooth signals;

near field communication (NFC) signals;

FM signals; and

GPS signals.

13. An apparatus configured to be implemented in a first wireless communication device, wherein the apparatus comprises:

a wireless local-area network (WLAN) transceiver configured to transmit WLAN signals in an independent basic service set (IBSS) network, wherein the IBSS network comprises one or more second wireless communication devices; and

a coexistence circuit configured to allow the WLAN transceiver to transmit no WLAN signals during non-WLAN intervals responsive to the WLAN transceiver receiving coexistence request messages, wherein each coexistence request message indicates a duration of at least one of

a respective one of the non-WLAN intervals, and

a period between a respective one of the non-WLAN intervals and another one of the non-WLAN intervals.

14. The apparatus of claim 13, wherein the non-WLAN signals comprise at least one of:

Bluetooth signals;

near field communication (NFC) signals;

FM signals; and

GPS signals.

15. The apparatus of claim 13, wherein at least one of the coexistence request messages comprises:

a clear-to-send-to-self frame, wherein the clear-to-send-to-self frame includes a duration parameter, wherein the duration parameter indicates the duration of the respective one of the non-WLAN intervals.

16. The apparatus of claim 13, wherein at least one of the coexistence request messages comprises:

a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates a duration of the respective one of the non-WLAN intervals.

17. The apparatus of claim 13, wherein at least one of the coexistence request messages comprises:

a vendor-specific action frame, wherein the vendor-specific action frame includes a duration parameter, wherein the duration parameter indicates a duration of a period between a respective one of the non-WLAN intervals and another one of the non-WLAN intervals.

18. A wireless communication device comprising the apparatus of claim 13.

19. The wireless communication device of claim 18, wherein the wireless communication device is implemented as one of:

a mobile telephone;

a personal digital assistant (PDA);

a tablet computer; and

a personal computer.

20. The wireless communication device of claim 18, wherein the wireless communication device is compliant with all or part of IEEE standard 802.11, including draft and approved amendments such as 802.11a, 802.11b, 802.11e, 802.11g, 802.11i, 802.11k, 802.11n, 802.11v, 802.11w, 802.11aa, 802.11ac, 802.11ad, 802.11ae, 802.11af, 802.11ah, and 802.11ai.

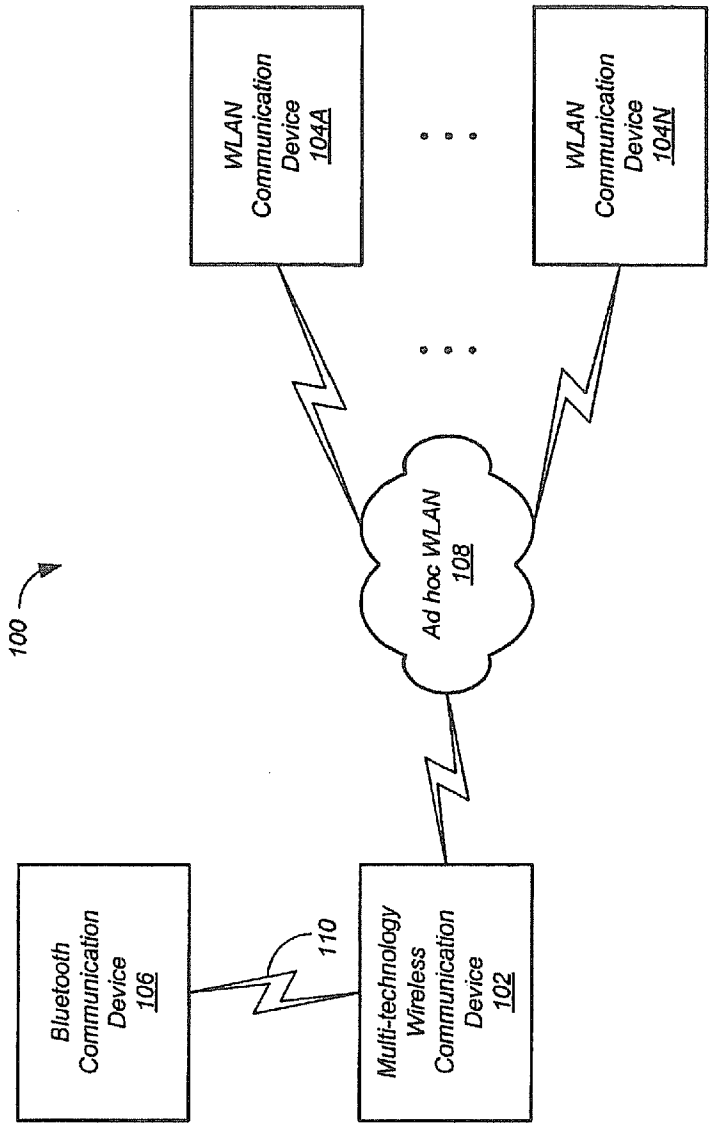
WLAN Communication Device 104A
WLAN Communication Device 104N
Ad hoc WLAN 108
100
Bluetooth Communication Device 106
110
Multi-technology Wireless Communication Device 102

FIG. 1

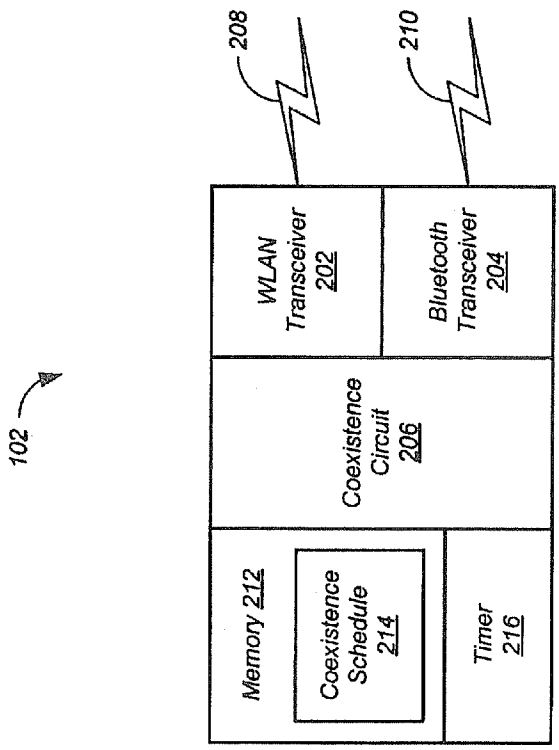
102
208
210
WLAN Transceiver 202
Bluetooth Transceiver 204
Coexistence Circuit 206
Memory 212
Coexistence Schedule 214
Timer 216

FIG. 2

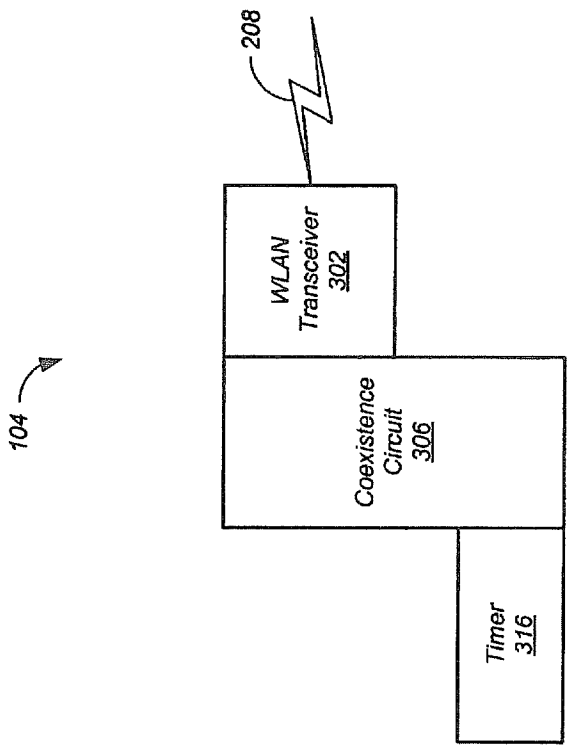
104
208
WLAN Transceiver 302
Coexistence Circuit 306
Timer 316

FIG. 3

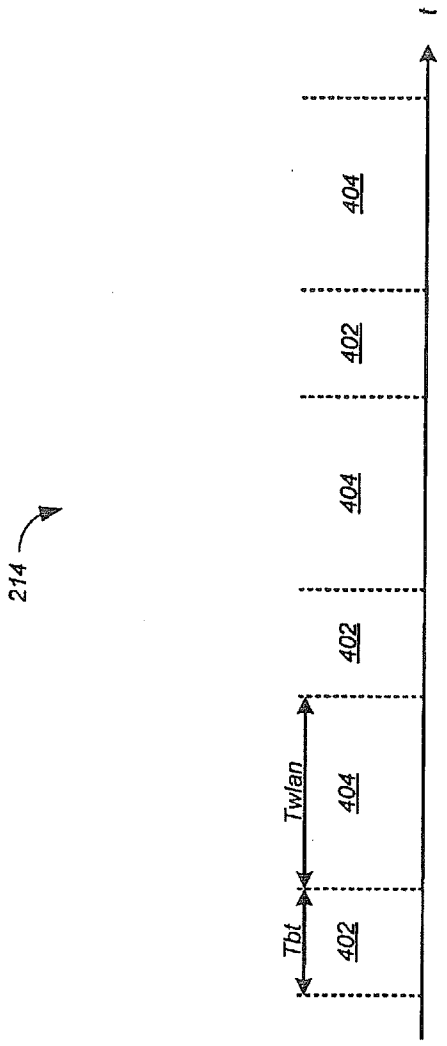

FIG. 4

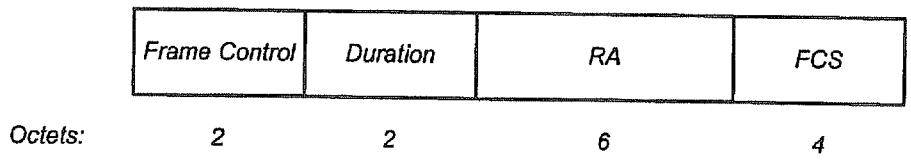
Frame Control
Duration
RA
FCS
Octets:
2
2
6
4

FIG. 5

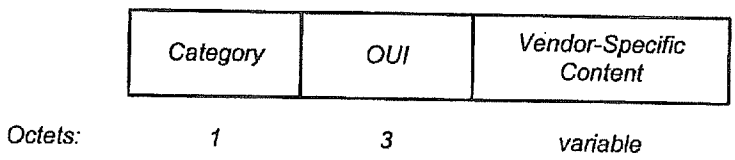
Category
OUI
Vendor-Specific Content
Octets:
1
3
variable

FIG. 8

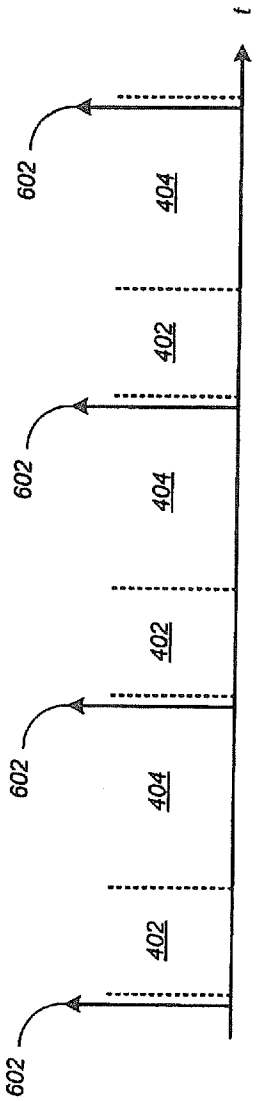

FIG. 6

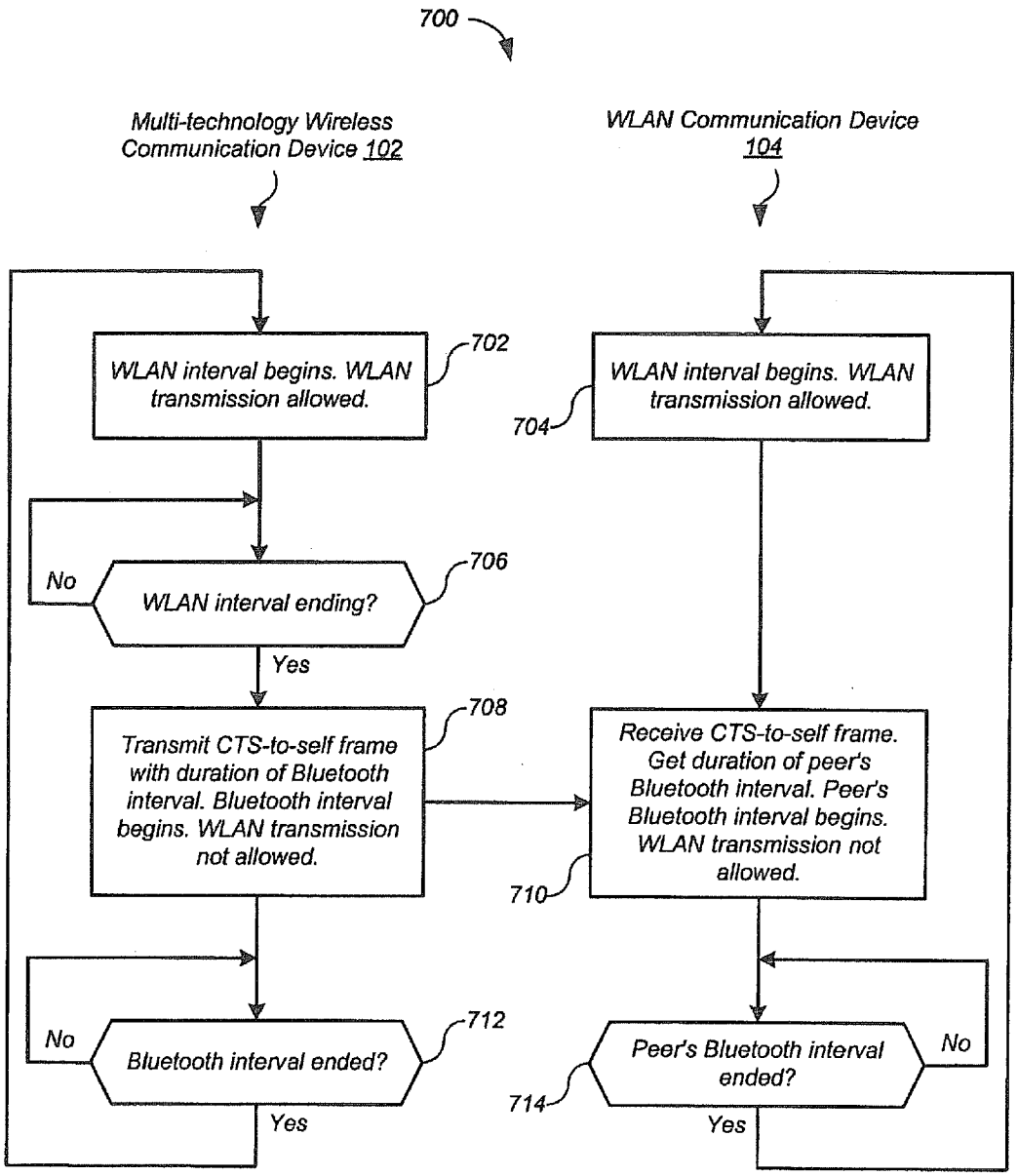
700
Multi-technology Wireless Communication Device 102
WLAN Communication Device 104
WLAN interval begins. WLAN transmission allowed.
702
WLAN interval begins. WLAN transmission allowed.
704
No
WLAN interval ending?
706
Yes
Transmit CTS-to-self frame with duration of Bluetooth interval. Bluetooth interval begins. WLAN transmission not allowed.
708
Receive CTS-to-self frame. Get duration of peer's Bluetooth interval. Peer's Bluetooth interval begins. WLAN transmission not allowed.
710
No
Bluetooth interval ended?
712
Yes
Peer's Bluetooth interval ended?
714
No
Yes

FIG. 7

	Element ID	Length	OUI	Vendor-specific content
Octets:	1	1	1	n-3

FIG. 9

	Element ID	Length	TSF 0 Offset	Interval/ Duration	Optional Subelements
Octets:	1	1	8	4	variable

FIG. 13

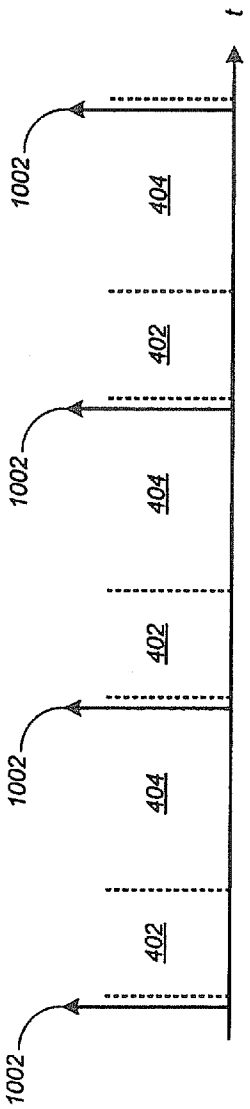

FIG. 10

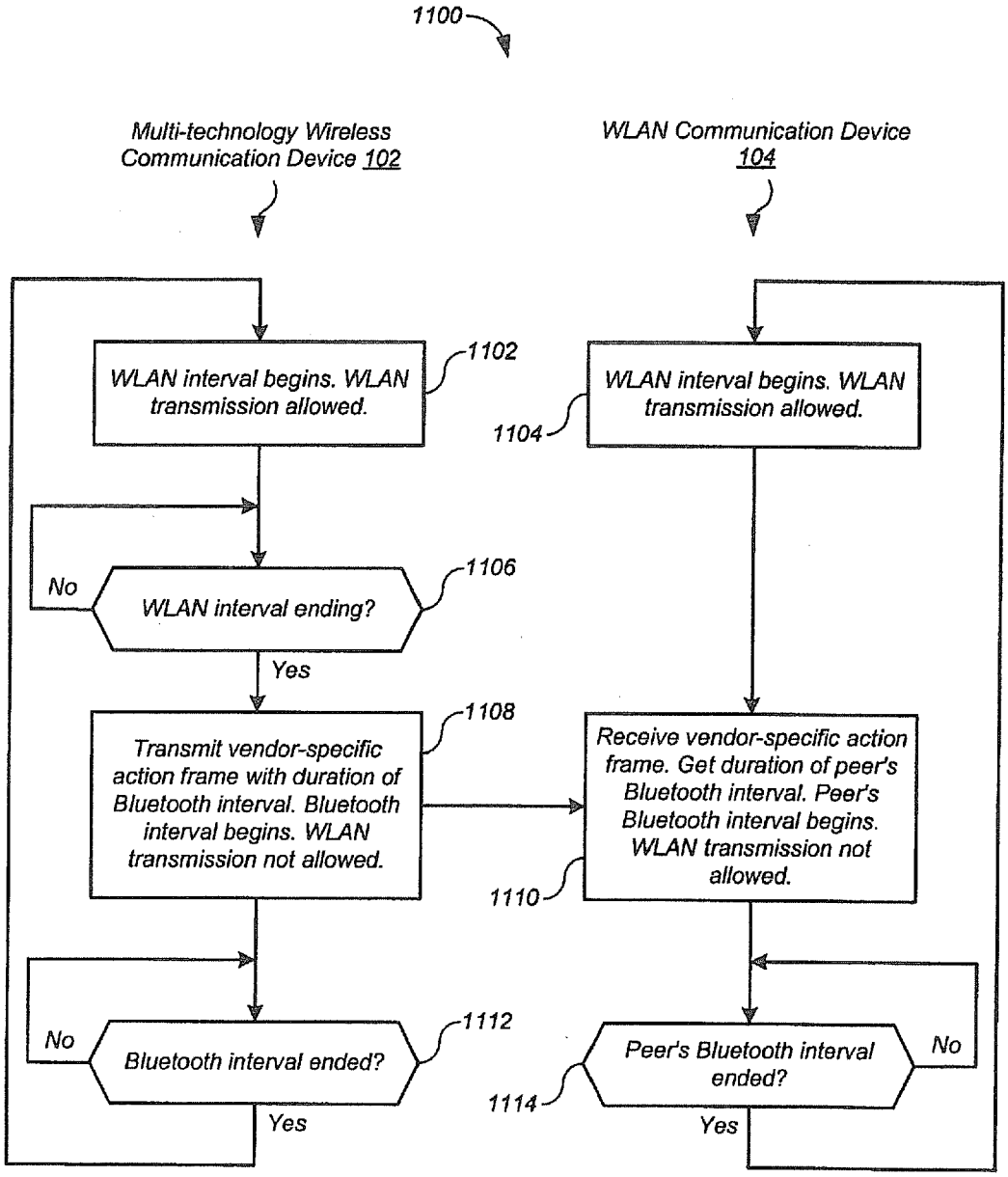
1100
Multi-technology Wireless Communication Device 102
WLAN Communication Device 104
WLAN interval begins. WLAN transmission allowed.
1102
WLAN interval begins. WLAN transmission allowed.
1104
No
WLAN interval ending?
1106
Yes
Transmit vendor-specific action frame with duration of Bluetooth interval. Bluetooth interval begins. WLAN transmission not allowed.
1108
Receive vendor-specific action frame. Get duration of peer's Bluetooth interval. Peer's Bluetooth interval begins. WLAN transmission not allowed.
1110
No
Bluetooth interval ended?
1112
Yes
Peer's Bluetooth interval ended?
1114
No
Yes

FIG. 11

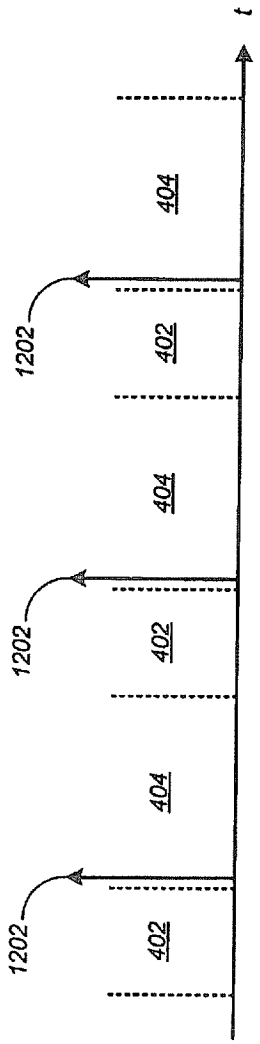

FIG. 12

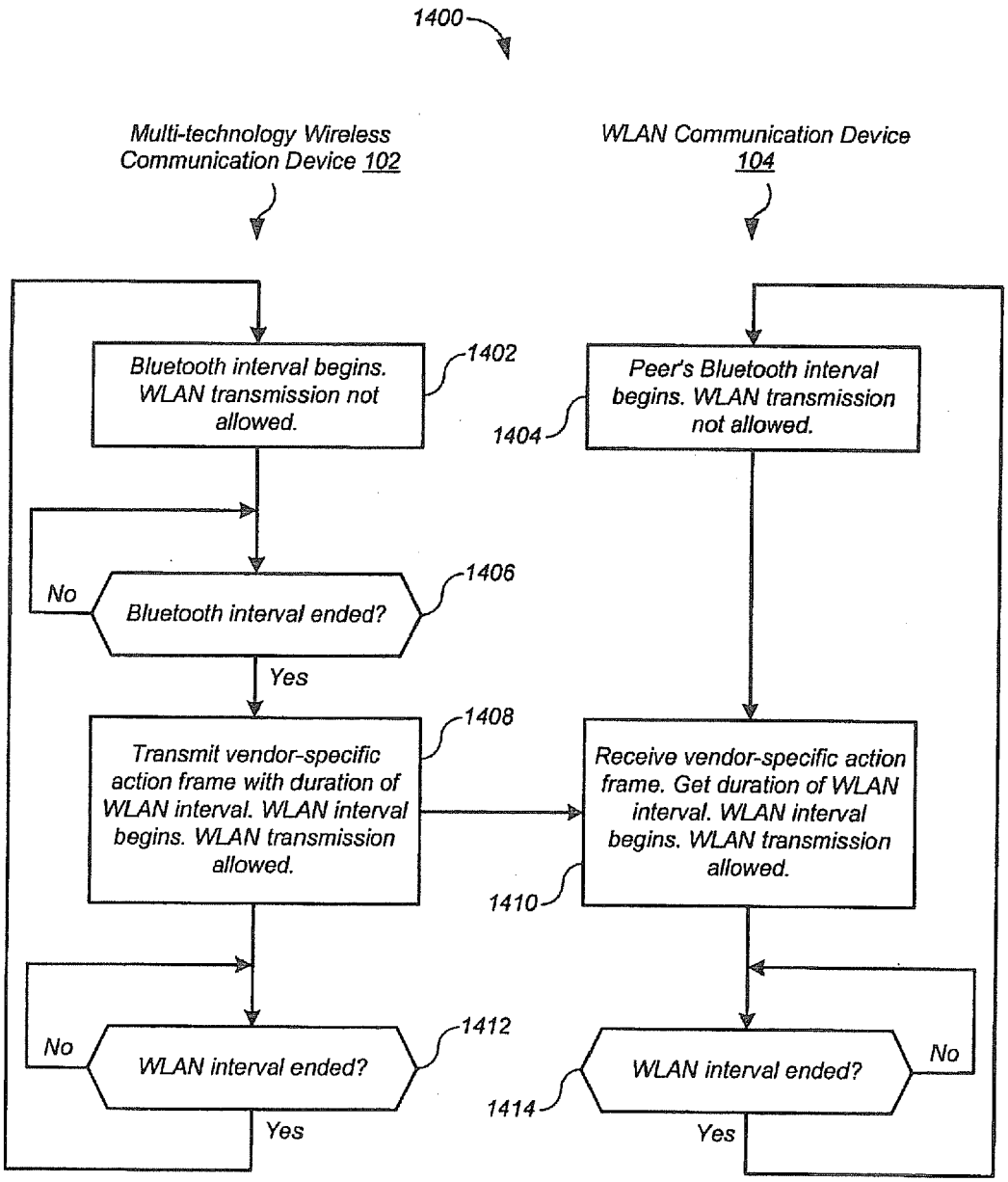
1400
Multi-technology Wireless Communication Device 102
WLAN Communication Device 104
Bluetooth interval begins. WLAN transmission not allowed.
1402
Peer's Bluetooth interval begins. WLAN transmission not allowed.
1404
No
Bluetooth interval ended?
1406
Yes
Transmit vendor-specific action frame with duration of WLAN interval. WLAN interval begins. WLAN transmission allowed.
1408
Receive vendor-specific action frame. Get duration of WLAN interval. WLAN interval begins. WLAN transmission allowed.
1410
No
WLAN interval ended?
1412
Yes
WLAN interval ended?
1414
No
Yes

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/035597

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, COMPENDEX, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/097998 A1 (KO LI-CHUN [TW] ET AL) 28 April 2011 (2011-04-28) paragraph [0007] - paragraph [0009] paragraph [0026] - paragraph [0028] paragraph [0046] - paragraph [0047]	1-20
X	WO 2008/070777 A2 (MOTOROLA INC [US]; HIDDINK GERRIT W [NL]; CHEN XIANG [US]; GEURTSEN AA) 12 June 2008 (2008-06-12) paragraph [0002] - paragraph [0013] paragraph [0028] - paragraph [0043] paragraph [0067] - paragraph [0071]	1-20
X	WO 2009/101567 A1 (NXP BV [NL]; HIRSCH OLAF [US]; GARG PARAG [US]; ESWARAMOORTHY KUMAR [U) 20 August 2009 (2009-08-20) page 2, line 30 - page 3 page 5, line 12 - page 7, line 13	1-20

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 July 2012	06/08/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Frantzeskakis, D

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/035597

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2008/279163 A1 (DESAI PRASANNA [US]) 13 November 2008 (2008-11-13) paragraph [0014] paragraph [0145] - paragraph [0164] -----	1-20
A	US 2009/245279 A1 (WAN WEI-LUN [TW] ET AL) 1 October 2009 (2009-10-01) paragraph [0005] - paragraph [0006] paragraph [0018] - paragraph [0022] -----	1-20
A	US 2005/025174 A1 (FISCHER MICHAEL ANDREW [US] ET AL) 3 February 2005 (2005-02-03) paragraph [0015] - paragraph [0020] paragraph [0049] - paragraph [0078] -----	1-20
A	WO 2006/090254 A1 (NOKIA CORP [FI]; NOKIA INC [US]; PALIN ARTO [FI]; HONKANEN MAURI [FI];) 31 August 2006 (2006-08-31) the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/035597

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		EP 2090027 A2	19-08-2009
		KR 20090089373 A	21-08-2009
		US 2008139212 A1	12-06-2008
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WO 2009101567 A1	20-08-2009	NONE	
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		TW 200941962 A	01-10-2009
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		KR 20070113246 A	28-11-2007
		WO 2006090254 A1	31-08-2006