

**METHODS FOR MULTIPLE AP COORDINATED OVERLAPPING
TARGET WAKE TIME OPERATION****CROSS REFERENCE TO RELATED APPLICATION**

[0001] This application claims the benefit of U.S. Provisional Application No. 63/526,773 filed July 14, 2023; U.S. Provisional Application No. 63/502,516 filed May 16, 2023; U.S. Provisional Application No. 63/498,421 filed April 26, 2023; U.S. Provisional Application No. 63/491,870 filed March 23, 2023; and U.S. Provisional Application No. 63/486,828 filed February 24, 2023; the contents of all which are incorporated herein by reference.

SUMMARY

[0002] An access point (AP) is disclosed. The AP may include a processor configured to negotiate coordinated multiple AP target wake time (C-MAP TWT) parameters with another AP, wherein the C-MAP TWT parameters include one or more of a TWT Tx power, Tx slot, and/or Tx subchannel; and a transceiver configured to transmit a beacon frame including a C-MAP TWT element including an indication of whether a TWT service period (SP) overlaps with a TWT SP of the another AP, and C-MAP TWT parameters of the TWT SP. The processor and the transceiver may be configured to communicate with a station (STA) during the TWT SP using the negotiated C-MAP TWT parameters transmitted in the beacon frame. In further embodiments of the access point, the C-MAP TWT parameters of the TWT SP may include a MAP type. In further embodiments of the access point, the MAP type may include at least one of: coordinated spatial reuse (C-SR), coordinated orthogonal frequency division multiple access (C-OFDMA), coordinated time division multiple access (C-TDMA), coordinated Beamforming (C-BF), and joint multiple input multiple output transmission (J-MIMO). In further embodiments of the access point, in response to the MAP type being C-SR, the C-MAP TWT parameters may include: an AP transmit power and an allowed transmit power from non-AP stations (STAs). In further embodiments of the access point, in response to the MAP type being C-OFDMA, the C-MAP TWT parameters may include: an operation channel width for each AP within a MAP TWT service period (SP), and a punctured channel indication for each AP and its associated STAs / TWT member STAs in the MAP TWT SPs. In further embodiments of the access point, in response to the MAP type being C-TDMA, the C-MAP TWT parameters may include time slots with the MAP TWT SPs assigned for each AP and its associated STAs/TWT member STAs. In further embodiments of the access point, the MAP TWT element may include at least one of: a MAP indication field, a MAP type indication field, a MAP overlapping TWT indication field, an AP allowed transmit power field, a maximum uplink target receiver power field, an operation channel width, a punctured channel indication, a temporal primary channel and a time slot field.

[0003] A method for coordinating a target wake time (TWT) schedule, is disclosed. In embodiments, the method may include negotiating by a first access point (AP) coordinated multiple AP target wake time (C-MAP TWT) parameters with another AP, wherein the C-MAP TWT parameters include one or more of a TWT Tx

power, Tx slot, and/or Tx subchannel; transmitting by the first AP a beacon frame including a C-MAP TWT element including an indication of whether a TWT service period (SP) overlaps with a TWT SP of the another AP, and C-MAP TWT parameters of the TWT SP; and communicating by the first AP with a STA during the TWT SP using the negotiated C-MAP TWT parameters transmitted in the beacon frame. In further embodiments of the method, the C-MAP TWT parameters of the TWT SP may include a MAP type. In further embodiments of the method, the MAP type may include at least one of: coordinated spatial reuse (C-SR), coordinated orthogonal frequency division multiple access (C-OFDMA), coordinated time division multiple access (C-TDMA), coordinated Beamforming (C-BF), and joint multiple input multiple output transmission (J-MIMO). In further embodiments of the method, in response to the MAP type being C-SR, the C-MAP TWT parameters may include: an AP transmit power and an allowed transmit power from non-AP stations (STAs). In further embodiments of the method, in response to the MAP type being C-OFDMA, the C-MAP TWT parameters may include: an operation channel width for each AP within a MAP TWT service period (SP), and a punctured channel indication for each AP and its associated STAs / TWT member STAs in the MAP TWT SPs. In further embodiments of the method, in response to the MAP type being C-TDMA, the C-MAP TWT parameters may comprise time slots with the MAP TWT SPs assigned for each AP and its associated STAs/TWT member STAs. In further embodiments of the method, the MAP TWT element may include at least one of: a MAP indication field, a MAP type indication field, a MAP overlapping TWT indication field, an AP allowed transmit power field, a maximum uplink target receiver power field, an operation channel width, a punctured channel indication, a temporal primary channel and a time slot field.

[0004] A method for coordinating a target wake time (TWT) schedule is disclosed. The method may comprise negotiating, between a first access point (AP) and a second AP, coordinated multi-AP (C-MAP) TWT parameters. The parameters may include a MAP type. The MAP type may comprise at least one of: coordinated spatial reuse (C-SR), coordinated orthogonal frequency division multiple access (C-OFDMA), coordinated time division multiple access (C-TDMA), coordinated Beamforming (C-BF), and joint multiple input multiple output transmission (J-MIMO). On a condition that the MAP type is C-SR, the parameters may comprise: an AP transmit power and an allowed transmit power from non-AP stations (STAs). On a condition that the MAP type is C-OFDMA, the parameters may comprise: an operation channel width for each AP within a MAP TWT service period (SP), and a punctured channel indication for each AP and its associated STAs / TWT member STAs in the MAP TWT SPs. On a condition that the MAP type is C-TDMA, the parameters may comprise time slots with the MAP TWT SPs assigned for each AP and its associated STAs/TWT member STAs. The method may comprise transmitting a beacon frame that comprises a MAP TWT element. The MAP TWT element may comprise a MAP indication field. The MAP TWT element may comprise a MAP type indication field. The MAP TWT element may comprise a MAP overlapping TWT indication field. The MAP TWT element may comprise a TWT element from other AP field. The MAP TWT element may comprise an AP allowed transmit power field. The MAP TWT element may comprise a maximum uplink target receiver power field. The MAP TWT element

may comprise an operation channel width in the MAP TWT field. The MAP TWT element may comprise a punctured channel indication in the MAP TWT field. The MAP TWT element may comprise a temporal primary channel within the MAP TWT SPs field. The MAP TWT element may comprise a time slot field.

[0005] A method for performing coordinated multi-AP (C-MAP) transmission in overlapped target wake time (TWT) service periods (SPs) is disclosed. The method may comprise setting a broadcast TWT identification (ID). The broadcast TWT ID may be unique in a multi-AP (MAP) group. Values for a broadcast TWT ID within a first range may indicate TWTs without MAP coordination and value for a broadcast TWT ID within a second range may indicate TWTs with MAP coordination. The method may comprise using the TWT ID and an AP ID to identify a TWT schedule in a MAP group. The method may comprise sending C-MAP TWT related information in a beacon frame. The C-MAP TWT related information in the beacon frame may be sent before an overlapping TWT SP. The C-MAP TWT related information may comprise a TWT identification (ID) that indicates a TWT schedule advertised by a transmitting AP. The C-MAP TWT related information may comprise an overlapping TWT indication that indicates a TWT SP identified by a TWT ID in a beacon interval identified by a next overlapping TWT field that overlaps with another TWT SP. The C-MAP TWT related information may comprise a next overlapping TWT in Unit of Target Beacon Transmit Time (TBTT) that indicates the number of TBTTs counted from a current or next TBTT in which the TWT SP identified by the TWT ID overlaps with one or more TWT SPs from other APs in the MAP group. The C-MAP TWT related information may comprise a Per-AP Information (Info) List that comprises one or more Per-AP Info fields. Each Per-AP Info field may comprise C-MAP TWT related information about an AP in the MAP group that has a TWT schedule which may interact with the TWT schedule advertised by the transmitting AP. The C-MAP TWT related information may comprise a MAP operation Info field that comprises C-MAP related information for overlapping TWT SPs.

[0006] A method and an access point (AP) for non-overlapping TWT transmission is disclosed. An AP may send an indication that the AP supports non-overlapping target wake time (TWT) operation. The AP may indicate if an established or advertised TWT schedule allows overlapping basic service set (OBSS) transmissions. The AP may establish a TWT schedule that does not overlap with any existing TWT schedule. The AP may ignore a multi-AP (MAP) overlapping TWT field setting on a condition that a schedule is established by an AP that does not support non-overlapping TWT operation. The AP may terminate a transmission opportunity (TXOP) before an existing TWT schedule that disallows overlapping TWT transmission and is established by an AP that does not support non-overlapping TWT operation. The AP may use a backhaul link to exchange information for MAP operation. The AP may monitor a wideband channel for beacon frames from other APs. The AP may receive a beacon frame that includes a MAP critical updated field indicating that MAP related information has been updated.

[0007] A method for information exchange is disclosed. A requesting AP (AP2) may send a collaboration request frame to a responding AP (AP1). The collaboration request frame may comprise a collaboration element that indicates a suggested parameter. The suggested parameter may be an operating channel for system information exchange. The suggest parameter may be a start time of a collaboration period. AP2 may

receive, from AP1, a collaboration response frame using the suggested operating channel. AP1 may send, to a third AP (AP3), using the suggested operating channel, an unsolicited collaboration response frame that comprises the collaboration element. AP1 may suggest, to AP2, a different operating channel than the suggested operating channel. AP2 may agree to the suggested different operating channel. AP1 may send, to AP2 and AP3, an unsolicited collaboration response frame using the different operating channel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0009] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0010] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0011] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0012] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0013] FIG. 2 shows an example individual TWT operation;

[0014] FIG. 3 shows an example broadcast TWT operation;

[0015] FIG. 4 shows an example procedure for MAP TWT transmissions;

[0016] FIG. 5 shows an example of operation channel and punctured channel conditions for independent AP operation and coordinated AP operation;

[0017] FIG. 6 shows an example slot-based MAP TWT SPs;

[0018] FIG. 7 shows an example Coordinated MAP TWT operation with Silent TWT SP;

[0019] FIG. 8 shows an example TWT schedules with some TWT SPs overlapped;

[0020] FIG. 9 shows example of collaboration initiation information exchange;

[0021] FIG. 10 shows an example of collaboration initiation information exchange; and

[0022] FIG. 11 shows a flow diagram of an exemplary process.

DETAILED DESCRIPTION

[0023] FIG. 1A is a diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the

sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word discrete Fourier transform Spread OFDM (ZT-UW-DFT-S-OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0024] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network (CN) 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a station (STA), may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0025] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the CN 106, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a NodeB, an eNode B (eNB), a Home Node B, a Home eNode B, a next generation NodeB, such as a gNode B (gNB), a new radio (NR) NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0026] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, and the like. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area

that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0027] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0028] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed Uplink (UL) Packet Access (HSUPA).

[0029] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0030] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using NR.

[0031] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0032] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi)), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0033] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized

area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106.

[0034] The RAN 104 may be in communication with the CN 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104 and/or the CN 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the RAN 104, which may be utilizing a NR radio technology, the CN 106 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0035] The CN 106 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104 or a different RAT.

[0036] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0037] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone

124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0038] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0039] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0040] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0041] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0042] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access

memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0043] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0044] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0045] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors. The sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor, an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, a humidity sensor and the like.

[0046] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and DL (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the DL (e.g., for reception)).

[0047] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0048] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a.

[0049] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0050] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0051] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0052] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0053] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0054] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In

addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0055] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0056] In representative embodiments, the other network 112 may be a WLAN.

[0057] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have access or an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an "ad-hoc" mode of communication.

[0058] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0059] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0060] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two

streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0061] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz, and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications (MTC), such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0062] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode) transmitting to the AP, all available frequency bands may be considered busy even though a majority of the available frequency bands remains idle.

[0063] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0064] FIG. 1D is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0065] The RAN 104 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 104 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example,

gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0066] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0067] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0068] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, DC, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0069] The CN 106 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN)

185a, 185b. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0070] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of non-access stratum (NAS) signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and the like. The AMF 182a, 182b may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0071] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 106 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 106 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing DL data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0072] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184a, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering DL packets, providing mobility anchoring, and the like.

[0073] The CN 106 may facilitate communications with other networks. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local DN 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0074] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-b, UPF 184a-b, SMF 183a-b, DN 185a-b,

and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0075] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or performing testing using over-the-air wireless communications.

[0076] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0077] An AP may transmit a beacon on a fixed channel, such as a primary channel. This channel may be 20 MHz wide, and may be the operating channel of the BSS. This channel may also be used by the STAs to establish a connection with the AP. A channel access mechanism is Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). In this mode of operation, every STA, including the AP, may sense the primary channel. If the channel is detected to be busy, the may STA back off. Hence only one STA may transmit at any given time in a given BSS.

[0078] High Throughput (HT) STAs may also use a 40 MHz wide channel for communication. This may be achieved by combining a primary 20 MHz channel with an adjacent 20 MHz channel to form a 40 MHz wide contiguous channel.

[0079] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and 160 MHz wide channels. The 40 MHz and 80 MHz channels may be formed by combining contiguous 20 MHz channels.

[0080] A 160 MHz channel may be formed by combining eight contiguous 20 MHz channels or by combining two non-contiguous 80 MHz channels, which may also be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide it into two streams. An inverse Discrete Fourier Transformation (IDFT) operation and time-domain processing may be done on each stream separately. The streams may then be mapped to the two channels, and the data may be transmitted. At the receiver, this procedure is reversed and the combined data may be sent to the MAC.

[0081] In sub-1 GHz systems, the channel operating bandwidths and carriers are reduced. For example, 5 MHz, 10 MHz and 20 MHz bandwidths are supported in the TV White Space (TVWS) spectrum, and 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths are supported using non-TVWS spectrum. Meter Type Control (MTC) devices may have limited capabilities including only support for limited bandwidths, but also include a requirement for a very long battery life.

[0082] Some WLAN systems support multiple channels and channel widths and may include a channel which is designated as the primary channel. The primary channel may, but not necessarily, have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel is therefore limited by the STA, of all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In an example, the primary channel may be 1 MHz wide if there are STAs (e.g. MTC type devices) that only support a 1 MHz mode even if the AP and other STAs in the BSS may support a 2 MHz, 4 MHz, 8 MHz, 16 MHz, or other channel bandwidth operating modes. All carrier sensing and NAV settings depend on the status of the primary channel (i.e. if the primary channel is busy, for example, due to a STA supporting only a 1 MHz operating mode is transmitting to the AP, then the entire available frequency bands are considered busy even though a majority of it stays idle and available).

[0083] In the United States, the available frequency bands are from 902 MHz to 928 MHz. In Korea, the available bands are from 917.5 MHz to 923.5 MHz, and in Japan the available bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available is 6 MHz to 26 MHz depending on the country code.

[0084] Target wake time (TWT) operation is designed to allow an AP and its associated STAs to negotiate a wake-up time period on which the STAs may transmit and receive traffic. In some systems, the usage of TWT is extended to allow an AP to manage activity in the BSS in order to minimize contention between STAs and reduce the required amount of time that a STA utilizing a power management mode needs to be awake. A TWT element is defined to carry information used to negotiate and advertise TWT related information. Two types of TWTs are defined: broadcast TWT and individual TWT.

[0085] An example of individual TWT operation is shown in FIG. 2. A TWT scheduled STA (i.e. STA1) may send a TWT request 220 to a TWT responding STA (e.g. an AP) to setup a trigger enabled TWT agreement. At 210, the AP may respond accepting the TWT agreement. The AP may send an unsolicited TWT response to STA2 to setup a trigger enabled TWT agreement with STA2. The AP may start a trigger-enabled TWT service period (SP) comprising Multi-STA BlockAck 216, and Downlink Multiple User physical layer protocol data unit (DL MU PPDU) 218, with a trigger frame 214. STA1 and STA2 may respond with a PS-Poll frame 222, and a QoS Null frame 230 respectively to indicate they are awake and ready to communicate with the AP. The STAs may send respective BlockAcks 224, 232 during the TWT SP.

[0086] An example of a broadcast TWT operation is shown in Figure 3. A TWT scheduled STA (i.e. STA1) may negotiate 330, 310 with a TWT scheduling AP for a first wake target Beacon Transmission Time (TBTT) to listen to a beacon frame. At 312, the AP may advertise the broadcast TWT element in the beacon. At 314, the AP may start a trigger-enabled TWT service period comprising Multi-STA BlockAck 316, and DL MU PPDU

318), STA1 and STA2 may respond with a PS-Poll frame 332, and a QoS Null frame 340 respectively to indicate they are awake and ready to communicate with the AP. The STAs may send respective BlockAcks 334, 342 during the TWT SP. FIG. 3 The AP may send a subsequent beacon 320 during a listen interval, and send a further beacon 322 at the end of the listen interval.

[0087] Coordinated Multi-AP (C-MAP) transmission schemes may include: Coordinated Multi-AP OFDMA (co-OFDMA); Coordinated Multi-AP TDMA (co-TDMA); Coordinated Multi-AP Spatial Reuse (CSR). Coordinated beamforming/hulling (CBF), and Joint Transmission (JTX)

[0088] In the context of Coordinated Multi-AP, the following terms may be used: Sharing AP: an EHT AP which obtains a TXOP and initiates the multi-AP coordination; Shared AP: an EHT AP which is coordinated for the multi-AP transmission by the sharing AP; and AP candidate set: a set of APs that may initiate or participate in multi-AP coordination.

[0089] TWT coordination in C-MAP is described herein. Some target wake time (TWT) / restricted TWT (rTWT) schedules may carry important traffic such as low latency traffic and thus need to be protected from interference from overlapping BSS transmissions. With the C-MAP operation, the protection mechanism may be defined. With C-MAP, TWT operation may be better coordinated among APs in the same multi-AP (MAP) set to fulfill different purposes. With overlapping TWT/rTWT, some MAP schemes, such as coordinate spatial reuse, coordinate OFDMA, etc., may use the medium more efficiently.

[0090] In embodiments described herein, multiple APs may be coordinated together and transmit concurrently to STAs. The following terminology is used herein. Coordinated MAP (C-MAP) Set is a set of several non-collocated APs (or AP MLDs) which may perform coordinated transmissions. Multi-AP Service Set (MAP SS) is a set of devices including APs and non-AP STAs which may communicate with the APs in the C-MAP Set.

[0091] MAP TWT overlapping indication and procedures are described herein. A subfield or field, which may be referred to as MAP overlapping TWT subfield, in a TWT element, or another element/field containing MAP TWT schedule related information, may be used to indicate if there is at least one scheduled announced by another AP in a MAP SS which is overlapping or partially overlapping with the current schedule announced in the TWT element. Here overlapping or partially overlapping means the schedules are overlapping or partially overlapping in both a time domain and a frequency domain. If the two schedules are non-overlapping in either a time or a frequency domain, the two schedules are considered non-overlapping.

[0092] If this subfield is set to 0, then it may indicate that there is no overlapping or partially overlapping TWT schedule in the same MAP SS, and these TWT schedules may be referred to as MAP non-overlapping TWT schedules. In this scenario, STAs, including AP STAs and non-AP STAs, in the MAP SS which may understand this signaling may not transmit during the TWT duration and thus the TWT schedule is protected from inter and intra BSS transmission. STAs, including AP STAs and non-AP STAs, in the MAP SS which may understand this signaling as a TXOP holder may ensure the TXOP ends before the TWT which has a MAP

Overlapping TWT subfield set to 0. In this way the TWT schedule is protected from inter and intra BSS transmission

[0093] In an embodiment, an AP may negotiate with other APs in a MAP SS to set MAP non-overlapping TWT schedules for data with low latency and/or high reliability requirement or critical signaling transmissions. In an embodiment, an AP which intends to create a new TWT schedule or modify an existing TWT schedule, may check existing TWT schedules in the MAP SS and select a time-frequency resource or a series of time-frequency resources which has no overlapping with any existing TWT schedules which set MAP Overlapping TWT subfield to 0. In this embodiment, each AP in the MAP SS may need to know the existing non-overlapping TWT schedules. This information may be carried in a MAP related element and exchanged between the APs in the MAP SS. In an embodiment, all the APs in the MAP SS may broadcast all the non-overlapping TWT schedules in the MAP SS. Corresponding AP IDs or addresses may be included in the broadcast transmissions so the non-AP STAs and other APs know that the TWT scheduling AP for each non-overlapping TWT schedule. In embodiments, STAs, including APs and non-AP STAs, which support MAP Overlapping TWT, may report this capability in a capability element carried in a management or control or data frame.

[0094] In an embodiment, a MAP Overlapping TWT subfield may be added to an existing TWT element using one or more reserved bits. For example, the Control field defined in a TWT element may be modified as shown in Table 1. A MAP Overlapping TWT subfield may be added to the modified Control field.

Table 1: Modified Control field in TWT element to include a MAP Overlapping TWT subfield

			Last Broadcast Parameter Set	Flow Type	Broadcast TWT Recommendation	TWT Wake Interval Exponent	MAP Overlapping TWT
TWT Request	TWT Setup Command	Trigger					

[0095] In an embodiment, one or more reserved values for a Broadcast TWT Recommendation subfield carried in a Request Type subfield in a Broadcast TWT Parameter Set may be used to indicate the TWT identified by the TWT Parameters may be used to indicate MAP Overlapping TWT or combination of MAP Overlapping TWT with other TWT recommendations.

[0096] In an embodiment, when the MAP Overlapping TWT subfield is set to 0, it may indicate that the TWT/rTWT is protected from inter/intra BSS transmissions from neighboring APs and STAs. An AP which supports MAP overlapping TWT indication may ensure its TXOP ends before the start time of any active TWT SP advertised by itself or another AP in the MAP group when the MAP Overlapping TWT subfield is set to 0 (or any other value to indicate that the TWT/rTWT is protected from inter/intra BSS transmissions from neighboring APs and STAs). When the MAP Overlapping TWT subfield is set to 1, it may indicate that the TWT/rTWT schedule may be overlapping with other TWT/rTWT schedules or transmissions.

[0097] In an embodiment, an AP may choose if it may support non-overlapping TWT operation (which may be referred to as an overlapping basic service set (OBSS) TWT/rTWT protection mechanism). An AP which

may support the non-overlapping TWT operation may respect non-overlapping TWT/rTWT schedules with each other. The AP which supports non-overlapping TWT operation may follow the following rules. The AP may indicate that it is willing to support OBSS TWT/rTWT protection mechanism in a capabilities element, Operation element or other element/field. The AP which supports OBSS TWT/rTWT protection mechanism may indicate if the established and/or advertised TWT/rTWT schedule allows overlapping OBSS transmissions. New TWT/rTWT schedules established by the AP shall not overlap with any existing TWT/rTWT schedules which disallows overlapping OBSS transmissions and is established by an AP that supports OBSS TWT/rTWT protection. If the existing TWT/rTWT schedule is established by an AP which does not support OBSS TWT/rTWT protection, the OBSS TWT/rTWT protection supporting AP may ignore the MAP Overlapping TWT field setting. APs may terminate their TXOP or transmission before an existing TWT/rTWT schedule which disallows the overlapping OBSS transmissions and is established by an AP that supports OBSS TWT/rTWT protection. If the existing TWT/rTWT schedule is established by an AP which does not support OBSS TWT/rTWT protection, the OBSS TWT/rTWT protection supporting AP may ignore the MAP Overlapping TWT field setting.

[0098] MAP Coordinated Transmissions in TWT Service Periods (SPs) are described herein. A first procedure includes coordinated MAP TWT. In an embodiment, a MAP subfield may be added to a TWT element to indicate the TWT SP is a MAP TWT SP. The TWT schedule may be referred as MAP TWT schedule. A MAP TWT may allow coordinated MAP TWT transmissions. For example, for overlapping TWT SPs (either fully or partially overlapping in both time and frequency), some C-MAP transmission schemes (e.g. coordinated spatial reuse (C-SR), coordinated OFDMA (C-OFDMA), coordinated TDMA (C-TDMA), coordinated Beamforming (C-BF), joint MIMO transmission (J-MIMO) or combination of several C-MAP transmission schemes) may be allowed. With C-SR, different APs in the MAP SS may communicate with their associated STAs/TWT member STAs concurrently with coordinated transmit power. With C-OFDMA, different APs in the MAP SS may communicate with their associated STAs/TWT member STAs concurrently using different subchannels/resource unit. With C-OFDMA, different APs in the MAP SS may communicate with their associated STAs/TWT member STAs concurrently with using a different time slot within the TWT SP. The coordination between the APs in the MAP SS may be through wired or wireless medium. The APs may advertise the MAP TWT to STAs and APs in the MAP SS.

[0099] An exemplary procedure for MAP TWT transmissions is shown in FIG. 4, showing an AP1 Beacon 410, AP1 Trigger 412 an AP1 DL MUL PPDU 414, AP2 Beacon 420, AP2 Trigger 422 and an AP2 DL MUL PPDU 424. In this example, AP1 and AP2 may be within a MAP SS, and they may coordinate for a TWT schedule. In embodiments, AP1 and AP2 may negotiate the coordinated MAP TWT parameters.

[0100] In embodiments, the APS may negotiate MAP type (e.g. C-SR, or C-TDMA, or C-OFDMA, etc.) considering the MAP TWT member STAs' capabilities and sounding results. For example, if all the member STAs of the TWT scheduled AP1 report low interference level from AP2, then AP1 may inform AP2 that it may support C-SR. If AP1, AP2 and all member STAs support C-TDMA, and the two TWT schedules are

synchronized well, then both APs may consider using C-TDMA. If AP1, AP2 and all member STAs support C-OFDMA, and the two TWT schedules are synchronized well in frequency domain, then both APs may consider using C-OFDMA.

[0101] For C-SR transmissions, the APs may negotiate AP transmit power, which is the transmit power of each AP. In an embodiment, the same transmit power may be assigned for each AP. In an embodiment, each AP may have different transmit power. The APs may negotiate allowed transmit power from non-AP STAs, which is the maximum transmit power allowed by each non-AP STA which may transmit in the TWT. In an embodiment, APs may negotiate the maximum allowed received power at the AP side, so the non-AP STA may calculate the maximum allowed transmit power at the non-AP STA side.

[0102] For C-OFDMA transmissions, the APs may negotiate an operation channel width for each AP within the MAP TWT SP. The operation channel width for each AP within the MAP TWT SP may be smaller than or equal to the operation channel width announced by the AP in the Beacon frame. The APs may negotiate a punctured channel indication for each AP and its associated STAs/TWT member STAs in the MAP TWT SPs. The punctured channels in the MAP TWT SPs may be the same as or a superset of that indicated in a Disallowed Subchannel Bitmap indicated in the Beacon frame transmitted by the AP. In an embodiment, a primary channel may not be punctured. In an embodiment, a primary channel may be punctured.

[0103] In exemplary embodiment as shown in FIG. 5, in scenario 510 an AP1 may operate on an 80MHz channel with subchannel indices from Ch1 to Ch8, where Ch5 is punctured (not used by AP1 and its associated STAs/TWT member STAs). Each subchannel is a 20MHz channel in this example. AP2 may operate on an 80MHz channel with subchannel indices from Ch5 to Ch12, where Ch6 is punctured. AP1 and AP2 are considered as partially overlapping BSS in general since they both operate on subchannels Ch5 to Ch8. With C-OFDMA in a MAP TWT, AP1 and AP2 may coordinate together to better use an occupied channel. In scenario 520, after AP negotiation, AP1 may operate on an 80MHz channel with subchannel indices from Ch1 to Ch8, where Ch5 and Ch8 are punctured. AP2 may operate on an 80MHz channel with subchannel indices from Ch5 to Ch12, where Ch6 and Ch7 are punctured (not used by AP1 and its associated STAs/TWT member STAs). In this way, operation channels from AP1 and AP2 have no overlapping within the MAP TWT SP, and they may transmit concurrently without introducing interference to the concurrent transmissions. The same applied to STAs associated with AP1 and AP2 respectively.

[0104] In embodiments, for C-TDMA transmissions, the APs may negotiate a time slot within the MAP TWT SPs assigned for each AP and its associated STAs/TWT member STAs.

[0105] Each AP may transmit a Beacon frame or other type of management frame, which may include a MAP TWT element. The frames may include a TWT element and other MAP related element/fields. In this way, the receiving STA may need to understand the TWT element and MAP related element/fields to retrieve necessary information for the upcoming MAP TWT SP(s). The signaling included in the management frame may include but not be limited to the following field/subfields. Some indication(s) may be included in the TWT

element and/or the MAP related element/fields so the non-AP STA may link them and retrieve necessary information. For example, the TWT element may carry one field to indicate the TWT element is MAP related, and the receiver may need to check the information carried in the MAP related element/field. The MAP related element/field may carry one or more TWT IDs so that the receiver may know the MAP related element/field may be applied to the TWT schedules identified by the TWT IDs.

[0106] The signaling included in the management frame may include a MAP Indication field/subfield which may indicate the frame or the element or the TWT element that carries MAP related information. The MAP related information may be used for TWT transmissions. The TWT element carried in the same frame may be referred as a MAP TWT element.

[0107] The signaling included in the management frame may include a MAP Type Indication field/subfield which may indicate the type of MAP transmission involved in the TWT (e.g. C-SR, C-OFDMA, C-TDMA). In an embodiment, the MAP Type Indication field/subfield may be a bitmap where each bit may indicate a type of C-MAP transmission. In this way, more than one type of C-MAP transmissions may be used concurrently in the TWT.

[0108] The signaling included in the management frame may include a MAP Overlapping TWT Indication field/subfield which may indicate the scheduled/advertised/negotiated TWT may have at least one overlapping TWT in the MAP SS. In an embodiment, this field/subfield may be used to indicate the presence of MAP related information.

[0109] The signaling included in the management frame may include a TWT Element From Other AP, which may be a TWT element scheduled by another AP in the same MAP SS. This element may optionally be present. For example, it may be present when the MAP Overlapping TWT Indication field/subfield is set to true or MAP Indication field/subfield is set to true. In this TWT element, an AP ID/AP address may be included to indicate the AP which scheduled the TWT. A broadcast TWT ID may be included in the TWT element to indicate the specific TWT. The broadcast TWT ID may be unique in MAP SS. In an embodiment, one or more TWT elements from other APs may be included.

[0110] The signaling included in the management frame may include an AP Allowed Transmit Power field/subfield which may indicate the maximum allowed combined transmit power at the transmit antenna connector of all the antennas used to transmit in the MAP TWT SPs. This field/subfield may be optionally present when the MAP Type Indication is set to C-SR or indicate C-SR is used in the MAP TWT SPs. In an embodiment, the AP may be capable of transmitting using different transmit power over different subchannels. In that case, the field/subfield may include a maximum allow transmit power over each subchannel.

[0111] The signaling included in the management frame may include a Maximum UL Target Receive Power field/subfield which may indicate a maximum expected receive signal power, measured at the AP's antenna connector and averaged over the antennas in the MAP TWT SPs. This field/subfield may be optionally present when the MAP Type Indication is set to C-SR or indicate C-SR is used in the MAP TWT SPs. In an embodiment,

the field/subfield may contain a maximum allow transmit power over each subchannel. In an embodiment, within a MAP TWT SP, the AP may transmit a Trigger frame to trigger an UL transmission from one or more STAs. The AP may set a UL Target Receiver Power for each STA in the Trigger frame. The UL Target Receiver Power in the Trigger frame may not be greater than the value set in the Maximum UL Target Receive Power field/subfield defined here.

[0112] The signaling included in the management frame may include an Operation Channel Width in the MAP TWT field/subfield which may indicate the operation channel width used in the MAP TWT. Any transmission within the MAP TWT SP should set a bandwidth field in the PLCP header smaller than or equal to the value indicated here. The operation channel width for each AP within the MAP TWT SP may be smaller than or equal to the operation channel width announced by the AP in the Beacon frame. This field/subfield may be optionally present when the MAP Type Indication is set to C-OFDMA or indicate C-OFDMA is used in the MAP TWT SPs.

[0113] The signaling included in the management frame may include a Punctured channel indication in the MAP TWT field/subfield which may be a bitmap to indicate one or more subchannels may be punctured within the MAP TWT SPs. The allowed punctured subchannel patterns may be more than that used for a Disallowed Subchannel Bitmap field in the Beacon. The punctured channels in the MAP TWT SPs may be the same as or a superset of that indicated in the Disallowed Subchannel Bitmap indicated in the Beacon frame transmitted by the AP. This field/subfield may be optionally present when the MAP Type Indication is set to C-OFDMA or indicate C-OFDMA is used in the MAP TWT SPs. A receiving STA may combine an Operation Channel Width in the MAP TWT subfield and Punctured channel indication in the MAP TWT subfield to identify the subchannel(s) used by the AP transmitting the message. When C-OFDMA is the only C-MAP scheme used in the MAP TWT SP, the subchannels used by different APs may have no overlapping. When C-OFDMA and C-SR are used in the MAP TWT SP, the subchannels used by different APs may have overlapping.

[0114] The signaling included in the management frame may include a Temporal Primary Channel within the MAP TWT SPs. The temporal primary channel within the MAP TWT SP may be the same or different from the primary channel of the AP carried in the Beacon frame. In the MAP TWT SPs, the AP and its member STAs may use the Temporal primary channel the same way as the primary channel defined outside of the MAP TWT SPs. For example, the control and management frames within the MAP TWT may be transmitted over the temporal primary channel. The AP and non-AP STAs may monitor the temporal primary channel to set and update their NAV(s). A MAP TWT member STA may need to monitor the temporal primary channel always in the MAP TWT SPs. After the end of the MAP TWT SP, the AP(s) may help non-AP STAs to regain their NAV setting in the primary channel. In one embodiment, each AP may broadcast its NAV setting in the primary channel to the non-AP STAs. So, the non-AP STAs may use this value to set their NAVs. In another embodiment, each non-AP STA may wait for a predefined/predetermined/assigned time duration before it may try to contend the channel again. In another embodiment, the AP(s) may transmit a Trigger frame or other type of control/management frame using the primary channel of the AP's BSS after the MAP TWT SP and a

predetermined/predefined wideband channel transition delay period to solicit immediate response from the MAP TWT member STAs which participated in transmissions in the MAP TWT SP. The transmission of the Trigger frame or other type of control/management frame may be carried in an HE or EHT or EHT+ PPDU or a non-HT PPDU or a non-HT duplicate PPDU. The MAP TWT member STAs may respond with a frame in HE/EHT/EHT+ TB PPDU or non-HT duplicate PPDU to indicate that it switched from the temporal primary channel to the primary channel. The wideband channel transition delay period is a time period for the STA to switch from the temporal primary channel to the primary channel. The wideband channel transition delay period may be limited by the STA's hardware capability. A STA may report the wideband channel transition delay period needed in its capabilities element/field.

[0115] In embodiments, APs and MAP TWT member STAs may locate the resource unit allocations within the MAP TWT schedules/SPs based on Resource allocation fields, Operation Channel Width in the MAP TWT, Punctured channel indication in the MAP TWT, Temporal Primary Channel within the MAP TWT SPs.

[0116] The signaling included in the management frame may include a Time Slot field may define the time slot within the MAP TWT SPs. In an embodiment, the time slot may be defined by the Time Slot Offset subfield and the Time Slot Duration subfield. The Time Slot Offset subfield may indicate the time offset between the first time slot and the TWT SP start time. The Time Slot Duration subfield may indicate the duration of each time slot. The time slot may be used for C-TDMA transmissions, and the field/subfield may be optionally present when the MAP Type Indication is set to C-TDMA or indicate C-TDMA is used in the MAP TWT SPs. Each AP may use one or more time slots to communicate with its MAP TWT member STAs. The time slot may be synchronized between the APs which may participate in the C-TDMA transmission in the MAP TWT SPs. An example is shown in FIG. 6, the time slot and MAP TWT SPs may or may not be synchronized. A time slot offset indicated by AP1 extends from the start time for SP1 to the first AP1 trigger 610. Two time slot durations later, a second AP1 trigger 612 is sent. A time slot offset indicated by AP2 extends from the start time for SP2 to the first AP2 trigger 620. A second AP2 trigger 622 is sent after two time slot durations. In the example shown in FIG. 6, there are two MAP TWT SPs advertised by two APs which are not perfectly synchronized, and the time slot may not be synchronized with the start time of either TWT SP. A Time Slot Duration subfield may be the same among the overlapping MAP TWT SPs. Each AP may indicate the Time Slot Offset regarding its TWT SP start time. In this example, AP1 and AP2 may use a TDMA scheme to transmit within the MAP TWT SPs. AP1 may use time slot 1 and 3; while AP2 may use time slot 2 and 4. Each AP may be able to transmit only in its assigned time slot. For example, with trigger enabled TWT, the AP may transmit a Trigger frame in its assigned time slot.

[0117] The signaling included in the management frame may include a P2P Support Information. This field may be used to indicate if the MAP TWT schedule/SP may be used for P2P transmissions. If it is supported, the STAs which gain the control of the MAP TWT schedule/SP may be allowed to transmit to a peer STA. The transmission between the peer STAs may be carried in PPDU with bandwidth up to the channel width indicated in the Operation Channel Width in the MAP TWT field. The transmission between the peer STAs may not be

on any punctured channel/subchannels indicated in the Punctured channel indication in the MAP TWT field. The primary channel used in the P2P transmission may be indicated in the Temporal Primary Channel within the MAP TWT SPs field.

[0118] The signaling included in the management frame may include an Overlapping TWT Bitmap. The Overlapping TWT Bitmap field may indicate the APs which have the overlapping TWT SPs with the TWT identified by TWT ID field. The size of the bitmap may be determined by the number of APs in the MAP group. Or, the size of the bitmap may be fixed to the maximum number of APs in the MAP group. The meaningful number of bits in the bitmap may be determined by the number of APs in the current MAP group. Each bit in the bitmap may represent an AP. If the bit is set to 1, the AP may have an overlapping TWT SP/schedule to the transmitting AP. Otherwise, the AP may not have overlapping TWT SP/schedule to the transmitting AP. The order of the APs in the bitmap may be explicitly or implicitly signaled. In one method, the order of the APs may follow the order of AP IDs in the MAP group where the corresponding AP may be active in the MAP group. For example, the bit position k of the bitmap may represent the AP with AP ID value $f(k)$. $f(\cdot)$ may be a predefined function. In one method $f(k)=k-1$. With this method, the maximum supported number of APs in a MAP group is N , and possible AP IDs may be in the range from 0 to $N-1$. In the MAP group, the active APs are with AP IDs 1, 3, 4, 6. The bitmap may be with size N , and the 2nd, 4th, 5th, and 7th bit in the bitmap are meaningful and are used to indicate if the TWT SP/schedule of the transmitting AP may have overlapped TWT SP/schedule with the AP identified in the Overlapping TWT Bitmap. In one embodiment, the bitmap may be with size 4 and the first bit may represent the AP with AP ID 1; the second bit may represent the AP with AP ID 3; the third bit may represent the AP with AP ID 4 and the last bit may represent the AP with AP ID 6. A Overlapping TWT Bitmap size field may be carried in the same element or other related element/field.

[0119] Non-AP STAs which intend to participate in the MAP TWT SPs may receive the Beacon frame and extract information carried in the TWT element and/or other MAP related element. Based on the information conveyed there, (e.g. C-MAP Type, Tx Power, etc.) to determine if it can participate.

[0120] In the MAP TWT SPs, the AP and member STAs may communicate using corresponding MAP schemes.

[0121] The TWT element may be modified to carry the MAP related information.

[0122] The above-mentioned procedure may be applied to overlapping TWT schedules or TWT schedules which have some TWT SPs overlapping.

[0123] STAs, including APs and non-AP STAs, which support Coordinated MAP TWT, may report a capability in a capability element carried in a management or control or data frame.

[0124] TWT element design is described herein. MAP related information may be included in an enhanced TWT element. In an embodiment, the enhanced TWT element may be modified from an existing TWT element by adding MAP related information.

[0125] In an embodiment, a MAP TWT Present subfield (which may also be called the MAP Overlapping TWT Indication subfield, or other similar name) may be added to an existing TWT element using one or more reserved bits. For example, the Control field defined in a TWT element may be modified as shown in Table 2. The MAP TWT Present subfield may be added to the modified Control field to indicate the TWT element may contain MAP related information. The MAP TWT Present subfield may indicate the presence of MAP related information.

Table 2: Modified Control field in TWT element to include MAP Overlapping TWT subfield

TWT Request	TWT Setup Command	Trigger	Last Broadcast Parameter Set	Flow Type	Broadcast TWT Recommendation	TWT Wake Interval Exponent	MAP TWT Present
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[0126] In an embodiment, the MAP TWT Present subfield may be added to a Broadcast TWT Parameter Set and/or Individual TWT Parameter Set subfields using reserved bits or reserved values in one or more existing fields.

[0127] In an embodiment, more detailed MAP related information may be included in a TWT element when a MAP TWT Present bit is set. For example, as shown in Table 3 and Table 4, a MAP Operation Info subfield may be present in a Broadcast TWT Parameter Set subfield and/or an Individual TWT Parameter Set subfield in an enhanced TWT element. This subfield may be optionally present when a MAP TWT Present subfield is set to 1.

Table 3: Modified Broadcast TWT Parameter Set subfield in TWT element

Request Type	Target Wake Time	Nominal Minimum TWT Wake Duration	TWT Wake Interval Mantissa	Broadcast TWT Info	Restricted TWT Traffic Info (optional)	<u>MAP Operation Info</u>
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Table 4: Modified Individual TWT Parameter Set subfield in TWT element

Request Type	Target Wake Time	TWT Group Assignment	Nominal Minimum TWT Wake Duration	TWT Wake Interval Mantissa	TWT Channel	NDP Paging	Link ID Bitmap	<u>MAP Operation Info</u>
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[0128] The MAP Operation Info field may carry C-MAP related information to enable C-SR, C-OFDMA, C-TDMA, etc. in the overlapping MAP TWTs/rTWTs. An exemplary MAP Operation Info subfield format is shown in Table 5. The MAP Type subfield may indicate which C-MAP scheme is used. If MAP Type indicates C-SR use, then the C-SR Info subfield may be present. If MAP Type indicates C-OFDMA use, then the C-OFDMA Info subfield may be present. If MAP Type indicates C-TDMA use, then the C-TDMA Info subfield may be present.

present. In an embodiment, a MAP Type subfield may be a bitmap where each bit may represent a C-MAP scheme. Once the bit is set, the corresponding C-MAP Info subfield may be present. C-SR, C-OFDMA, and C-TDMA are used here as examples, however, other C-MAP schemes such as C-BF, Joint MIMO, etc. may be used. Moreover, MAP Channel Sounding may be used as a C-MAP type to indicate that TWT/rTWT may be used for MAP related channel state information sounding.

Table 5: MAP Operation Info subfield format

MAP Type	C-SR Info	C-OFDMA Info	C-TDMA Info
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[0129] An example C-SR Info subfield is shown in Table 6. A C-SR Allowed subfield may indicate a C-SR is allowed during the TWT/rTWT SPs advertised or negotiated in the TWT element. A Maximum AP Transmit Power may be the maximum transmit power of the AP during the TWT/rTWT SPs advertised or negotiated in the TWT element. A Maximum Uplink Target Receive Power may be the maximum allowed receive power of the AP during the TWT/rTWT SPs advertised or negotiated in the TWT element.

Table 6: C-SR Info subfield format

C-SR Allowed	Maximum AP Transmit Power	Max UL Target Receive Power
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[0130] An example C-OFDMA Info subfield is shown Table-7. A C-OFDMA Allowed subfield may indicate C-OFDMA is allowed during the TWT/rTWT SPs advertised or negotiated in the TWT element. An Operation Channel Width may indicate the operation channel width used in the MAP TWT SPs. A Punctured Channel Indication may indicate the punctured subchannels within the MAP TWT SPs. A Temporal Primary Channel may indicate the primary channel in the MAP TWT SPs.

Table 7: C-OFDMA Info subfield format

C-OFDMA Allowed	Operation Channel Width	Punctured Channel Indication	Temporal Primary Channel
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[0131] An example C-TDMA Info subfield is shown in Table 8. A C-TDMA Allowed subfield may indicate C-TDMA is allowed during the TWT/rTWT SPs advertised or negotiated in the TWT element. A Time Slot Offset may indicate a time offset between the TWT/rTWT starting time and the first time slot boundary. A Time Slot Duration may indicate each time slot duration.

Table 8: C-TDMA Info subfield format

C-TDMA Allowed	Time Slot Offset	Time Slot Duration
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[0132] In one embodiment, the MAP Operation Information field may include other MAP related information/field(s)/element(s). For example, it may include a Per-AP Info field which may include basic information about another AP in the same MAP group as the transmitting AP. The Per-AP Info field may include the AP ID in the MAP group; the AP MLD address; the AP MAC address; AP Operation Channel information including the Channel Operation width, Disabled Subchannel bitmap; and/or a corresponding TWT element operated by the AP. In one embodiment, the MAP Operation Information field may include any information mentioned in any procedure disclosed herein.

[0133] A further procedure includes silent TWT. In an embodiment, an AP may advertise that one or more TWT SP(s) in a series of TWT SPs may be silenced. One possible reason to silence a TWT SP is that it may be overlapping with another TWT SP advertised by a Neighbor AP in the same MAP SS. FIG. 7 shows an example of a silent TWT procedure. In this example, two APs may have two TWT SP schedules which are overlapping with each other. The two APs may coordinate for MAP TWT for each pair of overlapping TWT SPs instead of the two TWT schedules (each TWT schedule contains a series of TWT SPs). For the first overlapping TWT SP, the two APs may determine to perform a MAP TWT SP 710, 720 as discussed above. For the second overlapping TWT SP, AP1 may have some critical traffic or AP1 may need to serve some TWT member STAs which may not support C-MAP transmissions. Thus, AP2 may advertise in its Beacon frame that the overlapping TWT SP 722 may be silenced in a period or the following Beacon interval. In this way, the TWT SP 712 operated by AP1 has not been impacted by the interference from AP2's BSS. The Silent TWT SP Indication may be included in the enhanced TWT element. When this field is set, the non-AP STAs notice that the TWT SP identified by the broadcast TWT ID may be silenced in a fixed period or in the Beacon interval following the Beacon frame. However, the TWT SP identified by the broadcast TWT ID may be active after the period. For the third overlapping TWT SP, AP1 may indicate its TWT SP 714 is silenced while the TWT SP 724 advertised by AP2 is operating normally. For the fourth overlapping TWT SP, the two APs may determine to perform a MAP TWT SP 716, 726 as discussed above.

[0134] In an embodiment the TWT silence period may be explicitly signaled in an enhanced TWT element. For example, when a broadcast TWT Parameter Set may be silenced, the TWT Parameter Set may be identified by a broadcast TWT ID and thus one or more subfields in a TWT Parameter Set field may be repurposed to indicate the silence period. Alternatively, an additional subfield/field may be added to the TWT Parameter Set to indicate the silence period. In an embodiment, the TWT silence period may be predefined. For example, the TWT silence period may be one beacon interval starting from the end of the frame which carries the TWT element. In an embodiment, a new element may be defined for the purpose of TWT silencing. This new element may be referred to as a TWT Silencing element. The element may include one or more TWT SPs to be silenced in a fixed period (e.g. a beacon interval). Broadcast TWT IDs may be used in the element to indicate the TWT SPs to be silenced. In this way, the AP may silence more than one TWT SP by using this element. In one embodiment, the TWT schedules may resume after the fixed silence period with or without explicit signaling.

[0135] When an AP silences its TWT/rTWT SP(s), the AP may include a TWT/rTWT SP from another AP in the same MAP SS so that the non-AP STA which may have traffic may switch to the other AP to participate the TWT/rTWT. Each TWT Parameter Set may include an AP ID subfield or MAP Bitmap subfield which may indicate the AP(s) which schedule the TWT schedule, as shown in Table 9. If the AP ID is set to a default value (e.g. 0) or the MAP Bitmap is set to all 0, then the TWT identified by the TWT Parameter Set is scheduled by the AP which transmits the TWT element. Otherwise, the TWT identified by the TWT Parameter Set may be scheduled by the AP identified by the AP ID or the MAP Bitmap subfield.

Table 9: Modified Broadcast TWT Parameter Set subfield in TWT element

Request Type	Target Wake Time	Nominal Minimum TWT Wake Duration	TWT Wake Interval Mantissa	Broadcast TWT Info	<u>Restricted TWT Traffic Info (optional)</u>	<u>AP ID</u>
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[0136] For example, within one broadcast TWT element, the AP may include two broadcast TWT Parameter Sets. The first TWT Parameter Set may indicate the TWT SP scheduled by the transmitting AP is silenced in a given period. The second TWT Parameter Set may indicate a TWT SP scheduled by another AP in the same MAP SS which may allow inter-BSS STAs to participate.

[0137] The above-mentioned procedure may be applied to partially overlapping TWTs or TWT schedules which have some TWT SPs overlapping.

[0138] STAs, including APs and non-AP STAs, which support silence TWT, may report this capability in a capability element carried in a management or control or data frame. APs which support carrying TWT element from other APs in the same MAP SS may report this capability in a capability element carried in a management or control or data frame.

[0139] The capability element may include a TWT non-AP member STA or a non-AP STA may transmit a frame (e.g., a TWT Silencing Request frame) to request its associated AP to silence one or more TWT SPs for the STA or for the BSS if the STA observes overlapping BSS transmissions. In the TWT Silencing Request frame, the STA may include the following fields as described below.

[0140] The capability element may include a An Enhanced TWT element/field and/or a TWT Silencing element/field may indicate the TWT schedule of the participating STA and the silencing period the STA requested. The STA may indicate it requests to silence the TWT SP or the entire TWT schedule. The STA may indicate it requests to silence the TWT for itself or silence the TWT for all the member STAs. The STA may indicate the reason for the silencing request. For example, one reason code may indicate the STA may expect high interference during the TWT SP/schedule. One reason code may indicate the STA may expect an overlapping TWT from an OBSS AP. One reason code may indicate the OBSS AP may request the STA to relay its TWT related information so the MAP coordinated TWT transmission may be achieved.

[0141] The capability element may include an OBSS operation element/field. If the STA may expect interference from an OBSS, the STA may include this element/field. The OBSS operation element/field may include one or more of OBSS AP ID/address, OBSS Operation Channel width, OBSS disabled subchannel bitmap, OBSS primary channel, and/or SINR/SNR/RSSI/Pathloss report between the OBSS AP and the STA.

[0142] The capability element may include an Overlapping TWT element. If the STA may expect interference from an OBSS TWT, the STA may include this element/field. The element may include full or partial information about the overlapping TWT from an OBSS AP.

[0143] The AP may respond with a frame (e.g., TWT Silencing Respond frame) to indicate if it will silence the TWT SP(s) for the STA or for the entire BSS. The response frame may include one or more of the following elements.

[0144] The response frame may include an Enhanced TWT element/field and/or TWT Silencing element/field which may indicate the TWT schedule the AP may silence and the silencing period.

[0145] The response frame may include a OBSS operation element/field. If the AP coordinates with an OBSS TWT, the AP may include the OBSS operation element/field which may include one or more of OBSS AP ID/address, OBSS Operation Channel width, OBSS disabled subchannel bitmap, OBSS primary channel, and/or SINR/SNR/RSSI/Pathloss report between the OBSS AP and the STA.

[0146] The response frame may include an Overlapping TWT element. If the AP coordinates with an OBSS TWT, the AP may include the element which may include full or partial information about the overlapping TWT from an OBSS AP.

[0147] In one embodiment, the AP may use TWT Information frame to indicate the silencing of one or more TWT SPs due to MAP operation.

[0148] A C-MAP TWT element is described herein. A TWT schedule may refer to a series of TWT SPs. An AP may be able to advertise a TWT schedule that comprises a series of periodic or aperiodic TWT SPs.

[0149] In a C-MAP TWT element embodiment, the TWT schedules may be negotiated between an AP and non-AP STAs without considering coordinated MAP transmissions. However, one or more TWT SPs in a TWT schedule may be overlapping with other TWT SPs operated by a neighboring AP in the same MAP group. The embodiments disclosed herein may allow the APs to perform C-MAP transmissions on the overlapped TWT SPs.

[0150] Different periodic TWT schedules may have different periodicity. Periodic TWT schedules from non-collocated APs may overlap with TWT SPs sometimes but not always, as shown in FIG. 8. In this example, AP1 and AP2 are two non-collocated APs. AP1 has a periodic TWT schedule 810, 814 with TWT ID equal to 1 and AP2 has a periodic TWT schedule 820, 822, 826 with TWT ID equal to 2. The two TWT schedules have different periodicity values. In this example, the first TWT SP 810 of TWT schedule 1 and the first and second TWT SPs 820, 822 of TWT schedule 2 are not overlapping. However, the last TWT SPs of TWT schedule 1 814 and TWT schedule 2 826 are overlapping. In this case, if AP1 and AP2 both support C-MAP TWT operation,

they may coordinate and use methods described herein to share the overlapped resources. Since the TWT schedules are not totally overlapping but overlaps from time to time, instead of being carried in the TWT element, the C-MAP TWT related information may be carried in the Beacon frames 812, 824 or other type of frame before the overlapping TWT SPs.

[0151] In an embodiment, APs which have C-MAP TWT capability and intend to coordinate with each other may set a broadcast TWT ID in a way that the broadcast TWT ID is unique in a MAP group. For example, if one broadcast TWT ID is used by an AP in the MAP group and the corresponding TWT schedule is alive or active, the other APs in the MAP group may not assign that value to its broadcast TWT ID. Alternatively or additionally, APs may exchange an available broadcast TWT ID list or exchange frames to report broadcast TWT ID collision and request reassigning a broadcast TWT ID.

[0152] In an embodiment, the values of a broadcast TWT ID subfield within a first range (i.e. range 1) (e.g. [a, b]) may be used to identify TWTs without any MAP coordination. The values of a broadcast TWT ID subfield within a second range (i.e. range 2) (e.g. [0, a-1]) may be used to identify TWTs with MAP coordination.

[0153] In an embodiment, the TWT ID may be used together with an AP ID or other type of ID to uniquely identify a TWT schedule in a MAP group.

[0154] In an embodiment, each AP may carry information for its own TWT SP in the C-MAP TWT transmissions, so in this case, the TWT ID may not need to be unique among the MAP group.

[0155] In an embodiment, C-MAP TWT related information may be carried in an element or a field or a frame, which may be referred to as C-MAP TWT element/field/frame. The C-MAP TWT element/field may be carried in a Beacon frame or other type of frames. The C-MAP TWT frame may be transmitted before the overlapping TWT SPs. The C-MAP TWT related information may include the following.

[0156] The C-MAP TWT related information may include a TWT ID. This TWT ID field may indicate a TWT schedule advertised by the transmitting AP in a TWT element. In an embodiment, TWT ID may refer to the broadcast TWT ID.

[0157] The C-MAP TWT related information may include an Overlapping TWT Indication. The Overlapping TWT Indication field may indicate the TWT SP identified by the TWT ID in a current Beacon interval or a future Beacon interval identified by the Next Overlapping TWT field may overlap with another TWT SP.

[0158] The C-MAP TWT related information may include a Next Overlapping TWT in Unit of Target Beacon Transmit Time (TBTT). This field may indicate the number of TBTTs counted from a current or next TBTT in which the TWT SP identified by the TWT ID may overlap with one or more TWT SPs from other APs in the MAP group. In this way, an AP may indicate an overlapping SP which may happen in a future beacon interval. For example, the C-MAP TWT element/field/frame may be transmitted after Beacon frame 1. The estimated TWT overlapping may be in the third Beacon Interval and we may refer the current Beacon Interval as the first Beacon Interval. Then the Next Overlapping TWT in Unit of Target Beacon Transmit Time (TBTT) field may be set to 3.

[0159] The C-MAP TWT related information may include an Overlapping TWT Bitmap. The Overlapping TWT Bitmap field may indicate the AP(s) which has the overlapping TWT SPs with the TWT identified by TWT ID field. The size of the bitmap may be determined by the number of APs in the MAP group. Or the size of the bitmap may be fixed to the maximum number of APs in the MAP group. But the meaningful number of bits in the bitmap may be determined by the number of APs in the current MAP group. Each bit in the bitmap may represent an AP. If the bit is set to 1, the AP may have an overlapping TWT SP/schedule to the transmitting AP. Otherwise, the AP may not have overlapping TWT SP/schedule to the transmitting AP. The order of the APs in the bitmap may be explicitly or implicitly signaled. In one embodiment, the order of the APs may follow the order of AP IDs in the MAP group where the corresponding AP may be active in the MAP group. For example, the bit position k of the bitmap may represent the AP with AP ID value $f(k)$. $f(\cdot)$ may be a predefined function. In one embodiment $f(k)=k-1$, the maximum supported number of APs in a MAP group is N , and possible AP IDs may be in the range from 0 to $N-1$. In the MAP group, the active APs are with AP IDs 1, 3, 4, 6. The bitmap may be with size N , and the 2nd, 4th, 5th, and 7th bit in the bitmap are meaningful and are used to indicate if the TWT SP/schedule of the transmitting AP may have overlapped TWT SP/schedule with the AP identified in the Overlapping TWT Bitmap. In one embodiment, the bitmap may be with size 4 and the first bit may represent the AP with AP ID 1; the second bit may represent the AP with AP ID 3; the third bit may represent the AP with AP ID 4 and the last bit may represent the AP with AP ID 6. A Overlapping TWT Bitmap size field may be carried in the same element or other related element/field.

[0160] The C-MAP TWT related information may include a Per-AP Info List. The Per-AP Info List may carry one or more Per-AP Info fields. Each Per-AP Info field may carry C-MAP TWT related information about an AP in the MAP group that may have a TWT schedule which may interact with the TWT schedule advertised by the transmitting AP. The Per-AP Info field may carry one or more of the following fields: (i) an AP ID which may be used to identify the AP in the MAP group. We may refer to the AP identified by the AP ID as a reported AP, and the AP which transmits the C-MAP TWT element/field/frame as a reporting AP; (ii) a TWT ID, which may indicate a TWT schedule advertised by the transmitting AP in a TWT element. The TWT ID may refer to the broadcast TWT ID; (iii) a TBTT Offset, which may indicate the time TBTT offset between the reporting AP and reported AP. A receiving STA may use this information to estimate the TWT SP starting time of the reported AP.

[0161] The C-MAP TWT related information may include a MAP Operation Info. This field may carry C-MAP related information for the overlapping TWT SPs. The detail of this field are discussed above related to the MAP coordinated transmissions in TWT SPs embodiments.

[0162] With C-MAP, APs may need to monitor the Beacon transmissions or MAP related transmissions from other APs. A Beacon frame is usually transmitted on the primary 20MHz subchannel so that a STA may need to operate on the primary 20MHz to obtain the information carried in the Beacon frame. However, with a MAP scenario, different APs may not always operate on the same primary 20MHz subchannel even though

their operation channels may have overlapping. Therefore, an AP may miss a Beacon frame from its neighboring AP in the same MAP SS.

[0163] AP to AP transmissions are described herein. In embodiments disclosed herein, APs may need to monitor the Beacon transmissions or other transmissions from other APs in the same MAP SS. A Beacon frame is usually transmitted on the primary 20MHz subchannel so that a STA may need to operate on the primary 20MHz to obtain the information carried in the Beacon frame. However, with a MAP scenario, different APs may not always operate on the same primary 20MHz subchannel. Therefore, an AP may miss a Beacon frame from its neighboring AP in the same MAP SS.

[0164] In the case that some APs in the MAP SS may be wired connected, the APs may exchange information through the wired connections.

[0165] In the case that some APs in the MAP SS may not be wired connected with others, the following methods may be used to increase the chance that the APs may hear or monitor the Beacon transmissions from each other.

[0166] In a method, there may be a backhaul link for communications between APs. APs may use the backhaul link to exchange necessary information for MAP operations, for example, Timing Synchronization function (TSF), TSF offset (e.g., between APs), TBTT, TBTT offset (e.g., between APs), operation bandwidth, and a primary channel. In this way, APs in the same MAP SS may be synchronized.

[0167] In a method, APs may need to monitor a wideband channel from time to time. The wideband channel may be the entire operation channel of the AP, or the channel with *channel width* = $\min(x \text{ MHz}, \text{operation channel width})$ that includes the primary 20MHz channel. Here x may be for example, 80, 160, 320 etc. When the AP is operating in the wideband channel, it may have a chance to monitor Beacon frames from other APs. A MAP Critical Update field/subfield may be defined and carried in the Beacon frame or other management frame to indicate that MAP related information has been updated critically so that the neighboring APs may need to monitor the Beacon from of the reporting AP.

[0168] In a method, a MAP Beacon frame may be defined. The MAP Beacon frame may carry necessary information for MAP operations, for example, TSF, TSF offset, TBTT, TBTT offset, operation bandwidth, primary channel etc. In this way, APs in the same MAP SS may be synchronized. It may also carry a MAP Critical Update field/subfield to indicate the operation information of the reporting AP is critically updated and the other APs may need to check the Beacon frame to acquire the updated information. The MAP Beacon frame may be coded and modulated and repeatedly transmitted on each 20MHz subchannel so that a neighboring AP for which the primary 20MHz is overlapping with a 20MHz subchannel carrying the MAP Beacon frame may acquire this information. The MAP beacon frame may be transmitted over its operating bandwidth using, for example a non-HT duplicate (DUP) physical layer protocol data unit (PPDU).

[0169] In a method, each AP may carry MAP related information of other APs or other neighboring APs in its Beacon frames or other type of management frames or other type of frames so that its associated STAs or STAs in its coverage range may acquire this information.

[0170] Procedures of information exchange between APs are described herein. A collaborating group of STAs or MLDs may have one or more of the following features. APs within the collaborating group may collaborate with each other in certain channel(s). The collaboration may be present in one or more forms, such as joint transmission, coordinated TDMA, coordinated FDMA, coordinated spatial reuse, and coordinated beamforming. A STA associated with an AP affiliated with an AP MLD may communicate with another AP affiliated with another AP MLD. A STA associated with an AP affiliated with an AP MLD may communicate with another AP affiliated with the same AP MLD.

[0171] Before APs form a collaborating group, these APs may have different primary channels and have not established an agreement on the communication channels (e.g. what channel is used for communication between APs). This communication may include system information exchange, data communication, etc. Therefore, there is a need to design a procedure to enable the information exchange between these collaborating APs.

[0172] In an embodiment, before collaboration takes place between two APs or two AP MLDs, an AP may use its own primary channel as one channel to initiate the system information exchange with another AP which may be affiliated with another AP MLD or neighboring APs affiliated with other AP MLDs. This channel may be used as a dedicated channel for system information exchange between APs. Alternatively, the channel may be changed after a negotiation and/or an agreement between APs is established. Alternatively, or additionally, a link may be assigned for the dedicated link for the collaboration system information change. Alternatively, or additionally, different pair of collaboration APs within the same collaborating group may use different dedicated channels (or links) for collaboration system information exchange.

[0173] A Collaboration element may be included in a frame transmitted by an initiating AP and/or a responding AP. This element may be included in a management frame, action frame, or control frame, such as the beacon frame or the collaboration request/response frame transmitted by the initiating AP or the responding AP. The element may include one or more information of the following: link or channel used for collaboration system information exchange between APs; associated STAs information; Tx power used in this transmission; link or channel used for data frame exchange between APs; puncture channel information; operating BW for the channel used for collaboration system information exchange between APs; operating BW for the channel used for data frame exchange between APs; collaboration starting time; and collaboration duration and/or period.

[0174] FIG. 9 shows an example of collaboration initiation information exchange, where a responding AP accepts a collaboration operation (e.g. operating channel used for system information) suggested by a requesting AP. In Figure 9, the requesting AP (AP2) sends a Collaboration Request frame 920 to AP 1 which

includes a Collaboration element indicating suggested parameters (e.g. using channel 1 as collaboration system information exchange, a starting time of collaboration period, etc.). AP1 agrees with the suggested parameters and uses channel 1 to transmit a Collaboration Respond frame 910 to AP2. Subsequently, AP1 sends an unsolicited Collaboration response 912 to AP3 (e.g. a Collaboration Respond frame which includes the Collaboration element on Channel 1). The Collaboration Period 914-916 in which AP1, AP2 and AP3 may be collaborating with each other starts at the time 914 which is indicated in the agreed parameters included in the Collaboration element. AP1, AP2 and AP3 may need to follow the collaboration agreement indicated in the Collaboration element, which may be included in the most recently received Collaboration Respond frame.

[0175] FIG. 10 shows an example of collaboration initiation information exchange, where a responding AP does not accept a collaboration operation (e.g. operating channel used for system information) suggested by a requesting AP. In FIG. 10, the requesting AP (AP2) sends a Collaboration Request frame 1020 to AP 1, which includes a Collaboration element indicating suggested parameters (e.g. using channel 1 as collaboration system information exchange, the starting time of collaboration period, etc.). AP1 does not agree with the suggested channel used for collaboration system information exchange and suggests 1010 using channel 2 for collaboration system information exchange, which is agreed by the collaboration requesting AP, AP2. Subsequently, AP1 uses channel 2 to transmit an unsolicited Collaborating Respond frame 1012 to AP2 and AP3 to announce the collaboration agreement between AP1 and AP2. The Collaboration Period in which AP1, AP2 and AP3 may be collaborating with each other starts at the time which is indicated in the agreed parameters included in the Collaboration element. AP1, AP2 and AP3 may need to follow the collaboration agreement indicated in the Collaboration element, which may be included in the most recently received Collaboration Respond frame.

[0176] Alternatively, the Collaboration Request frame and/or Collaboration Response frame may be transmitted over the operating bandwidth of the transmitter using a non-HT DUP PPDU.

[0177] The responding AP may suggest a different link for collaboration system information exchange. The dedicated channel for collaboration system information exchange may be applicable to the dedicated link for collaboration system information exchange. The communication channel or link used in the collaboration period may be the same or different channel or link from the one used for the collaboration system information exchange.

[0178] In an embodiment, if the responding AP punctures the primary channel of the collaboration request AP, the responding AP may need to un-puncture this channel or monitor the information transmitted on this channel. Similarly, if the collaborating request AP punctures the primary channel of the responding AP, the requesting AP may need to un-puncture this channel or monitor the information transmitted on this channel. Furthermore, the collaborating APs may negotiate the channels indicated as punctured in their own BSS.

[0179] FIG. 11 shows an exemplary method for coordinating a target wake time (TWT) schedule. In embodiments, at 1110 the method may include negotiating by a first access point (AP) coordinated multiple AP

target wake time (C-MAP TWT) parameters with another AP, wherein the C-MAP TWT parameters include one or more of a TWT Tx power, Tx slot, and/or Tx subchannel. At 1112, the first AP transmits a beacon frame including a C-MAP TWT element including an indication of whether a TWT service period (SP) overlaps with a TWT SP of the another AP, and C-MAP TWT parameters of the TWT SP. At 1114 the first AP communicates with a STA during the TWT SP using the negotiated C-MAP TWT parameters transmitted in the beacon frame.

[0180] Although the features and elements of the present invention are described in the preferred embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the preferred embodiments or in various combinations with or without other features and elements of the present invention. Although the solutions described herein consider specific protocols, it is understood that the solutions described herein are not restricted to this scenario and are applicable to other wireless systems as well. Although SIFS is used to indicate various inter frame spacing in the examples of the designs and procedures, all other inter frame spacing such as RIFS, AIFS, DIFS or other agreed time interval may be applied in the same solutions. Although four RBs per triggered TXOP are shown in some figures as example, the actual number of RBs/channels/bandwidth utilized may vary.

[0181] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

CLAIMS

What is Claimed:

1. An access point (AP) comprising:
a processor configured to negotiate coordinated multiple AP target wake time (C-MAP TWT) parameters with another AP, wherein the C-MAP TWT parameters include one or more of a TWT Tx power, Tx slot, and/or Tx subchannel; and
a transceiver configured to transmit a beacon frame including a C-MAP TWT element including an indication of whether a TWT service period (SP) overlaps with a TWT SP of the another AP, and C-MAP TWT parameters of the TWT SP;
the processor and the transceiver configured to communicate with a station (STA) during the TWT SP using the negotiated C-MAP TWT parameters transmitted in the beacon frame.
2. The access point of claim 1, wherein the C-MAP TWT parameters of the TWT SP include a MAP type.
3. The access point of claim 2, wherein the MAP type comprises at least one of: coordinated spatial reuse (C-SR), coordinated orthogonal frequency division multiple access (C-OFDMA), coordinated time division multiple access (C-TDMA), coordinated Beamforming (C-BF), and joint multiple input multiple output transmission (J-MIMO).
4. The access point of claim 2 or 3, wherein in response to the MAP type being C-SR, the C-MAP TWT parameters comprise: an AP transmit power and an allowed transmit power from non-AP stations (STAs).
5. The access point of claim 2 or 3, wherein in response to the MAP type being C-OFDMA, the C-MAP TWT parameters comprise: an operation channel width for each AP within a MAP TWT service period (SP), and a punctured channel indication for each AP and its associated STAs / TWT member STAs in the MAP TWT SPs.
6. The access point of claim 2 or 3, wherein in response to the MAP type being C-TDMA, the C-MAP TWT parameters comprise time slots with the MAP TWT SPs assigned for each AP and its associated STAs/TWT member STAs.
7. The access point of any of claims 1 to 6 wherein the MAP TWT element comprises at least one of: a MAP indication field, a MAP type indication field, a MAP overlapping TWT indication field, an AP allowed transmit power field, a maximum uplink target receiver power field, an operation channel width, a punctured channel indication, a temporal primary channel and a time slot field.
8. A method for coordinating a target wake time (TWT) schedule, the method comprising:
negotiating by a first access point (AP) coordinated multiple AP target wake time (C-MAP TWT) parameters with another AP, wherein the C-MAP TWT parameters include one or more of a TWT Tx power, Tx slot, and/or Tx subchannel;

transmitting by the first AP a beacon frame including a C-MAP TWT element including an indication of whether a TWT service period (SP) overlaps with a TWT SP of the another AP, and C-MAP TWT parameters of the TWT SP; and

communicating by the first AP with a station (STA) during the TWT SP using the negotiated C-MAP TWT parameters transmitted in the beacon frame.

9. The method of claim 8, wherein the C-MAP TWT parameters of the TWT SP include a MAP type.
10. The method of claim 9, wherein the MAP type comprises at least one of: coordinated spatial reuse (C-SR), coordinated orthogonal frequency division multiple access (C-OFDMA), coordinated time division multiple access (C-TDMA), coordinated Beamforming (C-BF), and joint multiple input multiple output transmission (J-MIMO).
11. The method of claim 9 or 10, wherein in response to the MAP type being C-SR, the C-MAP TWT parameters comprise: an AP transmit power and an allowed transmit power from non-AP stations (STAs).
12. The method of claim 9 or 10, wherein in response to the MAP type being C-OFDMA, the C-MAP TWT parameters comprise: an operation channel width for each AP within a MAP TWT service period (SP), and a punctured channel indication for each AP and its associated STAs / TWT member STAs in the MAP TWT SPs.
13. The method of claim 9 or 10, wherein in response to the MAP type being C-TDMA, the C-MAP TWT parameters comprise time slots with the MAP TWT SPs assigned for each AP and its associated STAs/TWT member STAs.
14. The method any of claims 8 to 13 wherein the MAP TWT element comprises at least one of: a MAP indication field, a MAP type indication field, a MAP overlapping TWT indication field, an AP allowed transmit power field, a maximum uplink target receiver power field, an operation channel width, a punctured channel indication, a temporal primary channel and a time slot field.