(12) **PATENT**

(11) **345015** (13) **B1**

(19) NO

NORWAY (51) Int Cl.

H02J 50/80 (2016.01)
H02J 50/00 (2016.01)
H02J 5/00 (2006.01)
H02J 7/00 (2006.01)

Norwegian Industrial Property Office

(21)	Application nr.	20190218	(86)	International Filing Date and Application Number
(22)	Date of Filing	2019.02.18	(85)	Date of Entry into National Phase
(24)	Date of Effect	2019.02.18	(30)	Priority
(41)	Publicly Available	2020.08.19		
(45)	Granted	2020.08.24		

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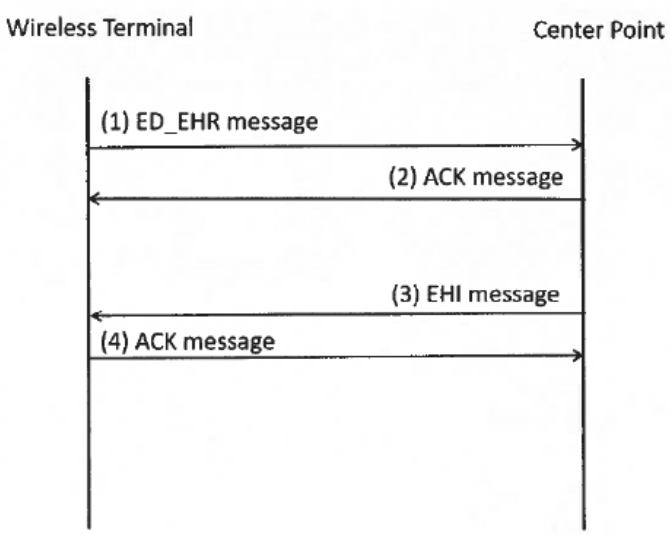
(54) Title **METHOD AND SYSTEM FOR CONTROLLING AN ENERGY HARVESTING OPERATION IN A WIRELESS TERMINAL DEVICE**

(56) References Cited:

US 2019/0044392 A1**,** KR 2019/0011585 A**,** US 2017/0147021 A1**,** US 10,193,396 B1**,**
US 2018/0109150 A1**,** US 2016/0336804 A1**,** US 10,103,552 B1**,**
PERERA, T.D.P et al., Simultaneous Wireless Information and Power Transfer (SWIPT): Recent Advances and Future Challenges, IEEE Communications Surveys & Tutorials, Vol. 20, No. 1, First Quarter 2018, pages 264-302, published 2017.12.15.
LU, X et al, Wireless Charging Technologies: Fundamentals, Standards, and Network Applications, IEEE Communications Surveys & Tutorials, Vol. 18, No. 2, Second Quarter 2016, pages 1413-1452, published 2015.11.11

(57) Abstract

A method and a system for controlling an energy harvesting operation in a wireless terminal device, WT, have been disclosed. The method comprises the steps of determining, by an energy center point device, CP, if the WT needs to harvest energy; and transmitting, by the CP, energy harvesting information to WT, the energy harvesting information identifying time slots in which the WT may harvest energy. Harvesting may be performed during the time slots identified by the energy harvesting information. Embodiments include CP initiated and WT initiated energy harvesting operations. The method and system may be implemented in a standard wireless communication protocol, such as Zigbee/IEEE 802.15.4. Energy harvesting information may be transmitted in a modified frame in the wireless communication protocol.



METHOD AND SYSTEM FOR CONTROLLING AN ENERGY HARVESTING OPERATION IN A WIRELESS TERMINAL DEVICE

TECHNICAL FIELD

The present invention relates to energy harvesting in wireless communication networks, and in particular to a method and a system for controlling an energy harvesting operation in a wireless terminal device.

BACKGROUND

Energy consumption of wireless devices has become an important issue in wireless technology (such as cellular, wireless sensor networks, etc). In conventional energy-constraint wireless networks in which nodes are powered by batteries, the frequent recharging or replacement of outage devices not only disrupts normal operation of end devices but also degrades overall network performance. In addition, it is usually not practical to recharge or replace battery for outage devices if they are deployed in remote or dangerous areas. Furthermore, powering a massive number of devices is a challenge. Therefore, for applications where sustainability and autonomy are required, energy supply becomes a severe problem.

Wireless networks where devices can harvest energy from a power resource through a radio channel is a promising technology for modern wireless technology, because it eliminates the need to manually replace outage devices. However, energy harvesting (EH) operation of a device may depend on and affect the operation of other devices. If energy harvesting operation is performed in one channel, called EH channel, no single device can always harvest energy and all devices may not harvest energy at once. In addition, the use of an EH channel of a device can prohibit others from using the EH channel. Current wireless technologies (such as LTE, LTE advanced, WiFi, Zigbee, BT, BLE, Thread, WiMAX etc.) do not consider EH operation even though many of them support energy saving features to extend networks' lifetime.

Because current wireless technologies were designed without consideration for energy harvesting technologies, the integration of energy harvesting operation and information exchange in these technologies may result in backward compatibility problems with deployed products. The reason is that the integration requires modification of the wireless standard to some extents. Not being well-designed for energy harvesting may result in a reinvent of all wireless standards and this prohibits the use of energy harvesting networks in the real world.

US-2019/0044392 A1 relates to a distributed wireless radio frequency-based charging system which includes hardware and software platforms. The hardware platform includes adaptive energy harvesters and programmable energy transmitters. The software platform manages the hardware profiles, resources (e.g., energy waveforms and transmission powers), schedules the beams of the energy transmitters, and switches between modes of wireless charging and data access point. This allows the energy transmitters to be configured adaptively based on the ambient energy availability, energy needs and number of energy-requesting devices in the network. Under the software control, the energy transmitters can cooperatively form focused beams of energy and power for transmission to energy harvesters in the energy-receiving devices, such as sensors, Internet of Things (IoT) enabled appliances, and mobile/wearable equipment. The energy harvesters can utilize the energy contained within the transmitted beams, as well as ambient RF sources, for directly powering their operation or charging a battery/capacitor for subsequent use.

SUMMARY OF THE INVENTION

To overcome deficiencies of related art, there is a need for a method and a system for controlling an energy harvesting operation in a wireless terminal device.

The invention provides a method and a system as set forth in the appended, independent claims. Advantageous embodiments and features have been set forth in the dependent claims.

The method and system provide integration of energy harvesting operation with normal operation in current wireless technologies while avoiding or reducing compatibility problem with current standards.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram illustrating principles of message exchanges between a WT and a CP in a WT initiated embodiment of the disclosed method and system.

Figure 2 is a schematic flow chart illustrating principles of a WT initiated embodiment of the disclosed method.

Figure 3 is a schematic diagram illustrating principles of message exchanges between a WT and a CP in a CP initiated embodiment of the disclosed method and system.

Figure 4 is a schematic flow chart illustrating principles of a CP initiated embodiment of the disclosed method.

Figure 5 is a schematic diagram illustrating principles of a MAC frame format in IEE 802.15.4.

Figure 6 is a schematic diagram illustrating principles of a frame control field.

Figure 7 is a schematic diagram illustrating principles of a GTS command frame and a corresponding modified frame used in an embodiment of the method and system.

Figure 8 is a schematic diagram illustrating principles of a beacon frame structure in IEEE 802.15.4.

Figure 9 is a schematic diagram illustrating principles of an energy harvesting superframe.

Figure 10 is a schematic diagram illustrating principles of a format of an energy harvesting field.

Figure 11 is a schematic diagram illustrating principles of a format of a pending address information field.

Figure 12 is a schematic diagram illustrating principles of a MAC frame format in IEEE 801.11.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments and possible aspects of the invention will be described in closer detail with reference to the appended drawings.

Figure 1 is a schematic diagram illustrating principles of message exchanges between a WT and a CP in a WT initiated embodiment of the disclosed method and system.

In the embodiment illustrated in figure 1, the WT decides whether it has to charge energy. This decision may depend on the WT's current energy, traffics to/from it, applications and other policies. To charge energy, the WT first transmits an end device energy harvesting request message, denoted ED_EHR message, to the CP. Upon receiving the ED_EHR message, the CP replies by transmitting an ACK message back to the WT to confirm the reception of ED_EHR message. Then the CP transmits an EH information message, denoted EHI message, to the WT. The ED_EHR can be rejected by the CP if the CP does not have enough resources for WT to charge energy. Otherwise, the ED_EHR may be accepted. In case of accept, the EHI message may contain details of charging scheduling, including in which time slots WT can start and how many time slots during which WT can harvest energy. Both the rejection or acceptance of ED_EHR message may be presented in the EHI message transmitted from the CP to the WT. After receiving the EHI message, the WT transmits an ACK message back to the CP to confirm its reception of the EHI message.

Figure 2 is a schematic flow chart illustrating principles of a WT initiated embodiment of the disclosed method for controlling an energy harvesting operation in the WT.

In the first checking step 210 of the method, the WT checks to decide if the WT needs to harvest energy. The decision may be made based on the WT's current energy status and its estimation of incoming uplink and downlink traffic.

Further, in determining step 220, the WT determines if the WT needs to harvest energy. If the determining step 220 results in that harvesting energy is not necessary, the method proceeds back to the checking step 210. Otherwise, if the determining step 220 results in that harvesting energy is necessary, the method proceeds further to the transmitting step 230.

In the ED_EDR transmitting step 230, an ED_EHR is transmitted by the WT to the CP.

Further, in the ACK transmitting step 240, an acknowledgement ACK is transmitted by the CP to the WT.

Further, in the time slot checking step 250, the CP checks if it has enough available EH time slots.

Further, in the time slot availability determining step 260, the CP determines if EH time slots are available.

If the time slot availability determining step 260 results in that EH time slots are not available, the rejection message transmitting step 290 is performed, wherein the CP transmits a rejection message to the WT. Subsequent to the rejection message transmitting step 290 the method may be terminated at termination step 298 or repeated from the checking step 210.

If the time slot availability determining step 260 results in that EH time slots are available, the method proceeds to the EH information transmitting step 270. In the EH information transmitting step 270, the CP transmits EH information to the WT.

Then the method proceeds to the energy harvesting step 280, wherein the WT harvests energy during dedicated time slots.

Subsequent to the energy harvesting step 280 the method may be terminated at termination step 298 or repeated from the checking step 210.

Figure 3 is a schematic diagram illustrating principles of message exchanges between a WT and a CP in a CP initiated embodiment of the disclosed method and system.

In the embodiment illustrated in figure 3, the CP decides if a WP needs to harvest energy. To this end, the CP transmits an energy harvesting request message, denoted CD_EHR message, to the WT. Upon receiving the CD_EHR message, the WT replies by transmitting an ACK message to the CP to confirm receipt of the CD_EHR message. After receiving the ACK message from the WT, the CP transmits an energy harvesting information message, EHI message, which includes details of EH scheduling to the WT. Then, WT transmits an ACK message to CP to confirm receipt of the EHI message.

Figure 4 is a schematic flow chart illustrating principles of a CP initiated embodiment of the disclosed method.

In the first checking step 410 of the method, the CP checks to decide if the WT needs to harvest energy.

This check may, e.g., be accomplished by the following principles, although alternatives may exist: In normal operation, a network coordinator scans the network to check if there are any devices which want to join/leave the network. In IEEE 802.15.4 standard, this activity is referred to as ‘association/disassociation’ procedures, performed in medium access control (MAC) layer. To be associated with an existing network, a device may send an association request to the network coordinator. This request may include some basic information of the device such as channel, address, capability information, etc., and other specific information about the device. Based on those information, the CP can know power states of the WT. In

addition, CP is aware of uplink and downlink traffic of that WT as all traffic goes to the CP. Such information allows the CP to estimate the remaining energy of the CP. Upon specific applications or purposes, CP can then decide whether a specific WP needs to harvest energy or not.

Although the above aspects have been described with reference to a communication protocol according to IEEE 802.15.4, the skilled person will realize that similar aspects and operation features apply in various other standards, including wireline (ITU-T G. 987.2 for XG-PON) and wireless standards (IEEE 802.15.4 etc).

Further, in determining step 420, the CP determines if it needs to harvest energy. If the determining step 420 results in that harvesting energy is not necessary, the method proceeds back to the checking step 410. Otherwise, if the determining step 420 results in that harvesting energy is necessary, the method proceeds further to the transmitting step 430.

In the CD_EHR transmitting step 430, a CD_EHR is transmitted by the CP to the WT.

Further, in the ACK transmitting step 440, an acknowledgement ACK is transmitted by the WT to the CP.

Further, in the EH information transmitting step 470, the CP transmits EH information to the WT.

Then the method proceeds to the energy harvesting step 480, wherein the WT harvests energy during dedicated time slots.

Subsequent to the energy harvesting step 480 the method may be terminated at termination step 498 or repeated from the checking step 410.

In any of the embodiments of the disclosed method, such as the embodiments illustrated in figures 1 and 2 (WT initiated), or 3 and 4 (CP initiated), respectively, the method may be implemented in an existing wireless communication protocol. The wireless communication protocol may, for instance, be a standard protocol including IEEE 802.15.4 or Zigbee. Hence, the disclosed method may be standard

dependent, in which case some details of the implementation of the method should be adapted to characteristics of the selected, standard wireless communication protocol.

To this end, in any of the embodiments of the disclosed method, the energy harvesting information may advantageously be transmitted in a modified frame in the wireless communication protocol.

In particular, the modified frame may be provided by utilizing at least one redundant bit of the frame. This has the advantage that the modification of the frame is minimized. However, a plurality of bits, or a field of bits, may be utilized. For instance, a plurality of bits or a field of bits that are redundant, superfluous or in excess according to the standard wireless communication protocol, may be assigned the energy harvesting information.

Alternatively, the modified frame may be provided by modifying a meaning or denotation of given bits and/or fields of existing frames in a specific standard. Still alternatively, the modified frame may be provided by both modifying the meaning or denotation of bits/fields and by using reserved bits of existing frames, in combination.

In particular, when the wireless communication protocol is a communication protocol in conformity with the IEEE 802.15.4 or Zigbee protocol, the energy harvesting information may be transmitted in a modified guaranteed time slot frame, GTS frame.

Aspects of a modified frame if another communication protocol is used, have been described further below with reference to figure 12.

Figure 5 is a schematic diagram illustrating principles of a MAC frame format in IEEE 802.15.4.

The illustrated MAC frame format includes a frame control field, a sequence number, four addressing fields (including a destination PAN identifier, a destination

address, a source PAN identifier and source address), an auxiliary security header, a frame payload and a frame check sequence, FCS.

Figure 6 is a schematic diagram illustrating principles of a frame control field, included in the general MAC frame format illustrated in figure 5.

In the frame control field, bits enumerated 0-2 represents frame types, bit 3 represents security enabled, bit 4 represents frame pending, bit 5 represents ACK request, bit 6 represents intra PAN, bits 7-9 are reserved, bits 10-11 represent destination addressing mode, bits 12-13 are reserved, and bits 14-15 represent source addressing mode.

When the disclosed method is implemented in the IEEE 802.15.4 standard, the ACK frame, reserved values in some fields of guaranteed time slots (GTS) command frame and beacon frame in the IEEE 802.15.4 standard may be utilized. Note that GTS command frame may be an example of MAC command frames whose frame format is described in figure 5.

Figure 7 is a schematic diagram illustrating principles of a GTS command frame and a corresponding modified frame used in an embodiment of the method and system.

The GTS command frame is shown in the left part of figure 7. The GTS command frame includes an MHR field, a reserved field and a GTS characteristic field. The GTS characteristic field has been shown in closer detail as including GTS length (bits 0-3), a command frame identifier (bit 4), a characteristic type, CT (bit 5), and reserved bits (bits 6-7). The right part of figure 7 illustrates an ED_EHR command frame, which represents an adaptation of the standard to conform to embodiments of the presently disclosed method and system. The ED_EHR command frame corresponds to the GTS command frame except that the GTS characteristic field is replaced by a corresponding EH characteristic field (1 octet). The EH characteristic field includes EH length (0-3 bits), a reserved bit (bit 4), a characteristic type, CT bit (bit 5), and reserved bits (bits 0-3).

Figure 8 is a schematic diagram illustrating principles of a beacon frame structure in IEEE 802.15.4.

The illustrated beacon frame format includes a frame control field, a sequence number, an addressing field, a superframe specification, an EH field, a pending address field, a payload field and a frame check sequence, FCS field. Details of the EH field has been shown in the lower left part of figure 8. The EH field includes a GTS specification field, a GTS direction field and an EH list. Details of the pending address field has been shown in the lower right part of figure 8. The pending address field includes a device address field, a GTS starting slot field, and an EH length field.

Figure 9 is a schematic diagram illustrating principles of an energy harvesting superframe structure.

The illustrated EH superframe format includes a frame control field, a sequence number field, an addressing field, an EH superframe specification field, a pending address field and a payload field.

Figure 10 is a schematic diagram illustrating principles of a format of an energy harvesting field.

The EH field includes an EH specification field, a reserved field and an EH list field.

Figure 11 is a schematic diagram illustrating principles of a format of a pending address information field.

The pending address information field includes a device address field, an EH starting slot field and an EH length field.

Figure 12 is a schematic diagram illustrating principles of a MAC frame format in IEEE 801.11.

As mentioned previously, in any of the embodiments of the disclosed method, the energy harvesting information may advantageously be transmitted in a modified frame in the wireless communication protocol.

The modified frame may be provided by utilizing at least one redundant bit of the frame. This has the advantage that the modification of the frame is minimized. For instance, a plurality of bits or a field of bits that are redundant, superfluous or in excess according to the standard wireless communication protocol, may be assigned the energy harvesting information.

In particular, when the wireless communication protocol is a communication protocol in conformity with the IEEE 802.11 or WiFi communication protocol, the energy harvesting information may be transmitted in a modified MAC frame format.

In such a modified MAC frame format, a Duration/Connection ID field (denoted D/I in figure 12) may be used as a duration field, indicating the time the channel will be allocated for successful transmission of a MAC frame. In some control frames, this field contains an association, or connection, identifier. This D/I can be used in the present approach to indicate the duration that a WT can harvest energy.

In the following, further details of an WT initiated energy harvesting protocol (EDI-EH protocol), corresponding to the method illustrated with reference to figures 1 and 2, will be disclosed.

a. If the CP does not have enough resources for the WT to harvest energy, the CP has to reject ED_EHR message transmitted from WT. With reference to figure 6, the rejection may be indicated by 'Frame pending' (FP) bit in the 'Frame control' field with FP = 0.

b. If CP has enough resources for the WT to harvest energy, the CP accepts the ED_EHR message transmitted from WT. With reference to figure 6, the acceptance is indicated by FP = 1.

The details of EH operation may be included in EHI frame as follows:

'ACK request'=1 (bit 5 in the frame control field shown in figure 6).
The list of WT devices which have available EH time slots to harvest energy may be listed in 'EH list' (cf. figure 10, subfield of 'EH field'). The size of 'EH list' subfield is defined by 'EH specification' subfield of 'EH field' (cf. figure 10).

The 'Pending address' (cf. figure 9) field describes the EH time slots that a WT can start to harvest the energy and the number of EH time slots during which the WT can harvest the energy. Possible details of harvesting information have been illustrated in figure 11.

Step 4: WT transmits an ACK to the CP to confirm its reception of the EH frame. The ACK frame is the same as ACK frame in the current standard without any modification.

In the following, further details of a center point initiated energy harvesting protocol (EDI-EH protocol), corresponding to the method illustrated with reference to figures 3 and 4, will be disclosed.

Step 1: CP transmits CD_EHR message to WT. The CD_EHR message is presented by CD_EHR frame whose structure is based on IEEE 802.15.4 beacon frame as follows:
Frame types (cf. figure 6) = 110
Frame pending (cf. figure 6) =1
ACK request (cf. figure 6) = 1

The remaining of CD_EHR frame is similar to the corresponding fields/subfields of the EHI frame. The list of devices which need to harvest energy may be included in the 'EH list' field (cf. figure 10).

Once the WT receives the CD_EHR frame, it checks the 'EH list' field to determine whether it is requested to harvest energy or not. If yes, the WT will wait for EH

information frame to see EH schedules. Otherwise, it will discard the EH information frame.

Step 2: WT transmits ACK to confirm its reception of CDI_EHR frame. The ACK frame is the same as ACK frame in the current standard without any modification.

Step 3: CP transmits the EHI message (represented by EHI frame) to the WT. The CP uses the EHI frame as defined in Step 3 of EDI_EH protocol disclosed above.

Step 4: WT transmits an ACK to the CP to confirm its reception of EH frame. The ACK frame is the same as the ACK frame in the current standard without any modification.

The invention may also be embodied as a system for controlling an energy harvesting operation. The system comprises at least one wireless terminal device, WT, and an energy center point device, CP, intercommunicating in a wireless network. The WT and the CP are configured to perform a method as disclosed in the present specification.

More particularly, the CP is configured to determine if the WT needs to harvest energy, and the CP is further configured to transmit energy harvesting information to the WT, the energy harvesting information identifying time slots in which the WT may harvest energy.

In an embodiment of the system, the WT is further configured to harvest energy during the time slots identified by the energy harvesting information.

The CP may further be configured to initiate the energy harvesting operation, and the CP may further be configured to check if the WT needs to harvest energy using an energy harvesting decision policy.

The CP may further be configured to, upon determining that the WT needs to harvest energy, sending an energy harvesting request to the WT, and the CP may further be configured to receiving an energy harvesting request acknowledgement from the WT.

In particular embodiments of the system, the WT may be configured to initiate the harvesting operation, and the CP may further be configured to determine if the WT needs to harvest energy, including receiving an energy harvesting request from the WT.

More particularly, in this embodiment, the CP may be further configured to, upon receiving the energy harvesting request from the WT, transmit an energy harvesting request acknowledgement to the WT. Even more particularly, the CP may be further configured to, subsequent to the transmitting of an energy harvesting request acknowledgement to the WT, determine if energy harvesting time slots are available; and the CP may be further configured to transmit energy harvesting information to the WT on the condition that the determining results in that energy harvesting time slots are available. More specifically the CP may be further configured to transmit a rejection message to the WT if the determining results in that energy harvesting time slots are not available, indicating that the energy harvesting request is rejected.

In other embodiments of the system, the CP may be configured to transmit the energy harvesting information in a modified frame in a wireless communication protocol. The wireless communication protocol may an IEEE 802.15.4 or Zigbee protocol. In such cases, the CP may be further configured to transmit the energy harvesting information in a modified guaranteed time slot frame, GTS frame.

Any of the disclosed embodiments of the system may be implemented to operate according to a standard wireless communication protocol, including IEEE 802.15.4 or Zigbee.

Although IEEE 802.15.3 or Zigbee have been mentioned above as wireless communication protocols that may be applied with the presently disclosed method

and system, the skilled person will realize that alternatives exist, including wireless technologies such as 5G LTE, 4G LTE, WiFi, WiMAX, Bluetooth, Bluetooth Low Energy, Thread etc., and standards such as 3GPP 5G Specification, IEEE 802.11, IEEE 802.15, IEEE 802.16, etc. Also, the disclosed method and system may provide backward compatibility with current wireless standards. The method and system may be applied for wireless power transfer (WPT) networks, various wireless networks (cellulars, wireless sensor networks, wireless body area networks) where devices have previously been powered by batteries, mobile, or resource-constraints.

CLAIMS

1. Method for controlling an energy harvesting operation in a wireless terminal device, WT, comprising the steps of

determining, by an energy center point device, CP, if the WT needs to harvest energy; and

transmitting, by the CP, energy harvesting information to WT, the energy harvesting information identifying time slots in which the WT may harvest energy,

wherein the energy harvesting information is transmitted in a modified frame in a wireless communication protocol, and wherein the modified frame is provided by utilizing at least one redundant bit of the frame.

2. Method according to claim 1, further comprising

harvesting, by the WT, energy during the time slots identified by the energy harvesting information.

3. Method according to claim 1 or 2, wherein the energy harvesting operation is initiated by the CP,

wherein the step of determining, by the CP, if the WT needs to harvest energy, includes:

checking, by the CP, if the WT needs to harvest energy, using an energy harvesting decision policy.

4. Method according to claim 3,

further comprising the steps of, by the CP,

upon determining that the WT needs to harvest energy, sending an energy harvesting request to the WT; followed by

receiving an energy harvesting request acknowledgement from the WT.

5. Method according to claim 1 or 2, wherein the energy harvesting operation is initiated by the WT,

wherein the step of determining, by the CP, if the WT needs to harvest energy, includes:

receiving an energy harvesting request from the WT.

6. Method according to claim 5,

further comprising the steps of, by the CP,

upon receiving the energy harvesting request from the WT, transmitting an energy harvesting request acknowledgement to the WT.

7. Method according to claim 6,

wherein the transmitting of an energy harvesting request acknowledgement to the WT is followed by:

determining, by the CP, if energy harvesting time slots are available; and

wherein the step of transmitting, by the CP, energy harvesting information to WT, is performed on the condition that the determining step results in that energy harvesting time slots are available.

8. Method according to claim 7,

wherein, if the determining step results in that energy harvesting time slots are not available, the method further comprises

transmitting, by the CP, a rejection message to the WT, indicating that the energy harvesting request is rejected.

9. Method according to one of the claims 1-8,

wherein the wireless communication protocol is an IEEE 802.15.4 or Zigbee protocol, and

wherein the energy harvesting information is transmitted in a modified guaranteed time slot frame, GTS frame.

10. Method according to one of the claims 1-9,

implemented in a standard wireless communication protocol, including IEEE 802.15.4 or IEEE 802.11.

11. System for controlling an energy harvesting operation,

the system comprising at least one wireless terminal device, WT, and an energy center point device, CP, intercommunicating in a wireless network,

the WT and the CP being configured to perform a method as set forth in one of the claims 1-10.

PATENTKRAV

1. Fremgangsmåte for å kontrollere en energihøstingsoperasjon i en trådløs terminalinnretning, WT, omfattende trinnene
å bestemme, av en energisenterpunktinnretning, CP, om WT-en trenger å høste energi; og
å sende, av CP-en, energihøstingsinformasjon til WT-en, der energihøstingsinformasjonen identifiserer tidsluker som WT-en kan høste energi i; hvor energihøstingsinformasjonen sendes i en modifisert ramme i en trådløs kommunikasjonsprotokoll, og hvor den modifiserte rammen er tilveiebrakt ved å utnytte minst en overflødig bit i rammen.

2. Fremgangsmåte ifølge krav 1, videre omfattende
å høste, av WT-en, energi i løpet av tidslukene som er identifisert av energihøstingsinformasjonen.

3. Fremgangsmåte ifølge krav 1 eller 2, hvor energihøstingsoperasjonen initieres av CP-en,
hvor trinnet med å bestemme, av CP-en, om WT-en trenger å høste energi, innbefatter:
å sjekke, av CP-en, om WT-en trenger å høste energi ved å bruke en energihøstingsbeslutningspolicy.

4. Fremgangsmåte ifølge krav 3, videre omfattende trinnene, av CP-en, etter bestemmelse av at WT-en trenger å høste energi, å sende en energihøstingsforespørsel til WT-en; etterfulgt av
å motta en energihøstingsforespørselsbekreftelse fra WT.

5. Fremgangsmåte ifølge krav 1 eller 2, hvor energihøstingsoperasjonen initieres av WT-en,
hvor trinnet med å bestemme, av CP-en, om WT-en trenger å høste energi, innbefatter:

å motta en energihøstingsforespørsel fra WT-en.

6. Fremgangsmåte ifølge krav 5, videre omfattende trinnene, av CP-en, etter mottak av energihøstingsforespørselen fra WT-en, å sende en energihøstingsforespørselsbekreftelse til WT-en.

7. Fremgangsmåte ifølge krav 6,
hvor sendingen av en bekreftelse av energihøstingsforespørselsbekreftelse til WT-en etterfølges av:
å bestemme, av CP, om energihøstingstidsluker er tilgjengelige; og
hvor trinnet med å sende, av CP, energihøstingsinformasjon til WT, utføres under forutsetning av at bestemmelsestrinnet resulterer i at energihøstingstidslukene er tilgjengelige.

8. Fremgangsmåte ifølge krav 7,
hvor, hvis bestemmelsestrinnet resulterer i at tidslukene for energihøsting ikke er tilgjengelige, fremgangsmåten videre omfatter
å sende, av CP-en, en avvisningsmelding til WT-en, som indikerer at energihøstingsforespørselen er avvist.

9. Fremgangsmåte ifølge ett av kravene 1-8,
hvor den trådløse kommunikasjonsprotokollen er en IEEE 802.15.4 eller Zigbee-protokoll, og
hvor energihøstingsinformasjonen overføres i en modifisert garantert tidslukeramme, GTS-ramme.

10. Fremgangsmåte ifølge et av kravene 1-9,
implementert i en standard trådløs kommunikasjonsprotokoll, innbefattende IEEE 802.15.4 eller IEEE 802.11.

11. System for å kontrollere en energihøstingsoperasjon,
der systemet omfatter minst en trådløs terminalinnretning, WT, og en energisenterpunktinnretning, CP, som samkommuniserer i et trådløst nettverk,

hvor WT-en og CP-en er konfigurert til å utføre en fremgangsmåte som angitt i et av kravene 1-10.

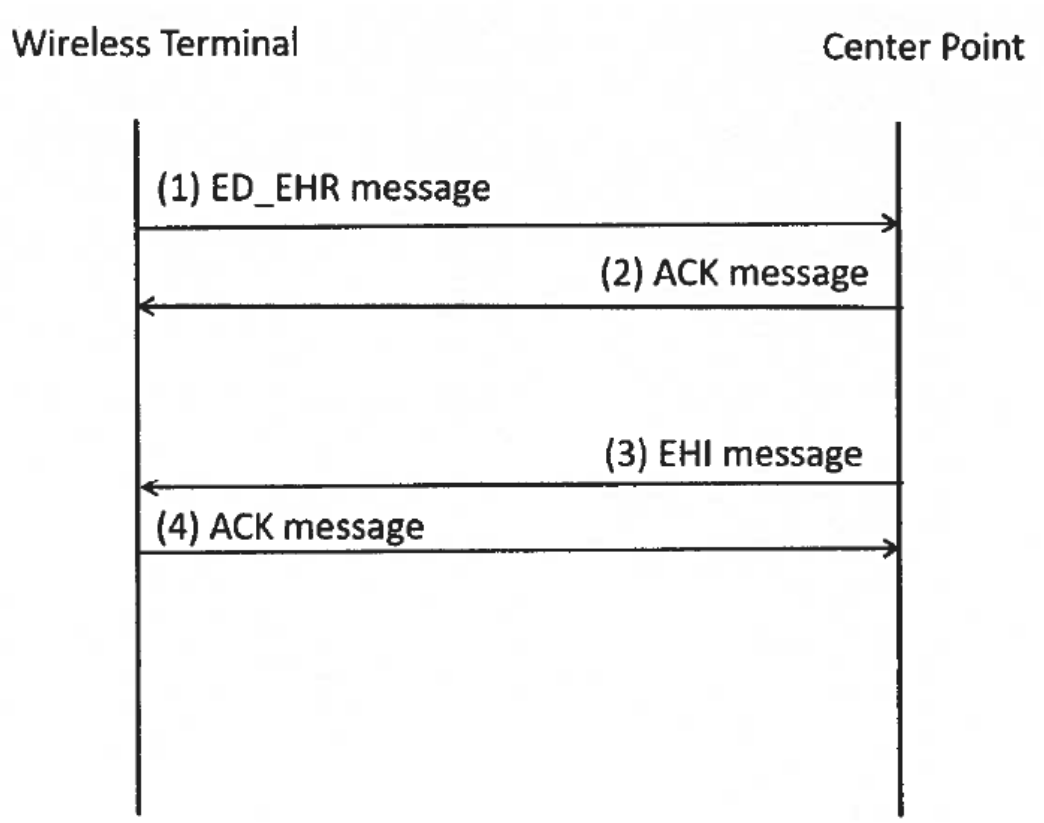


Fig. 1. Message exchanges in EDI-EH protocol

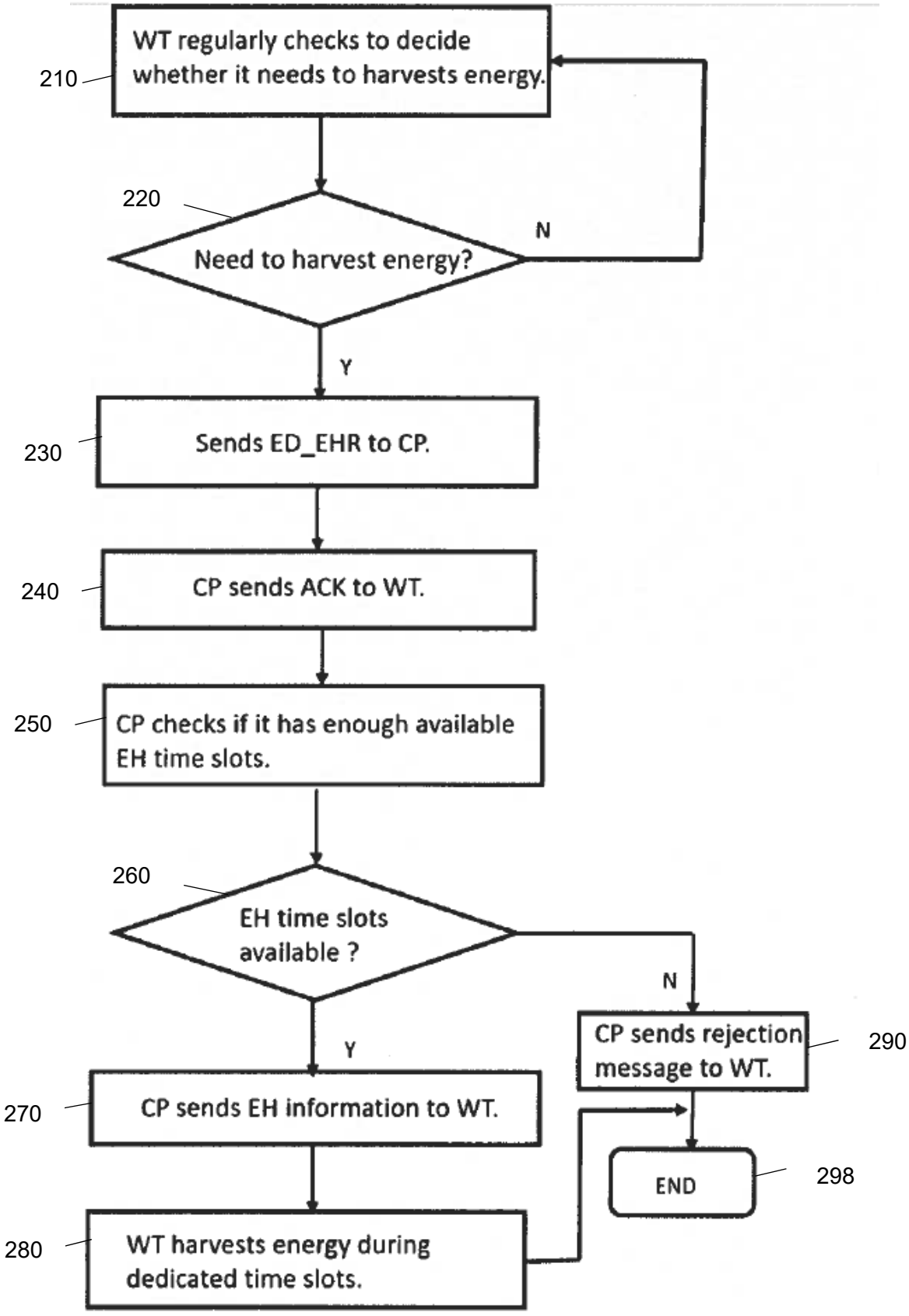


Fig. 2. Flow chart which describes the details of EDI-EH protocol.

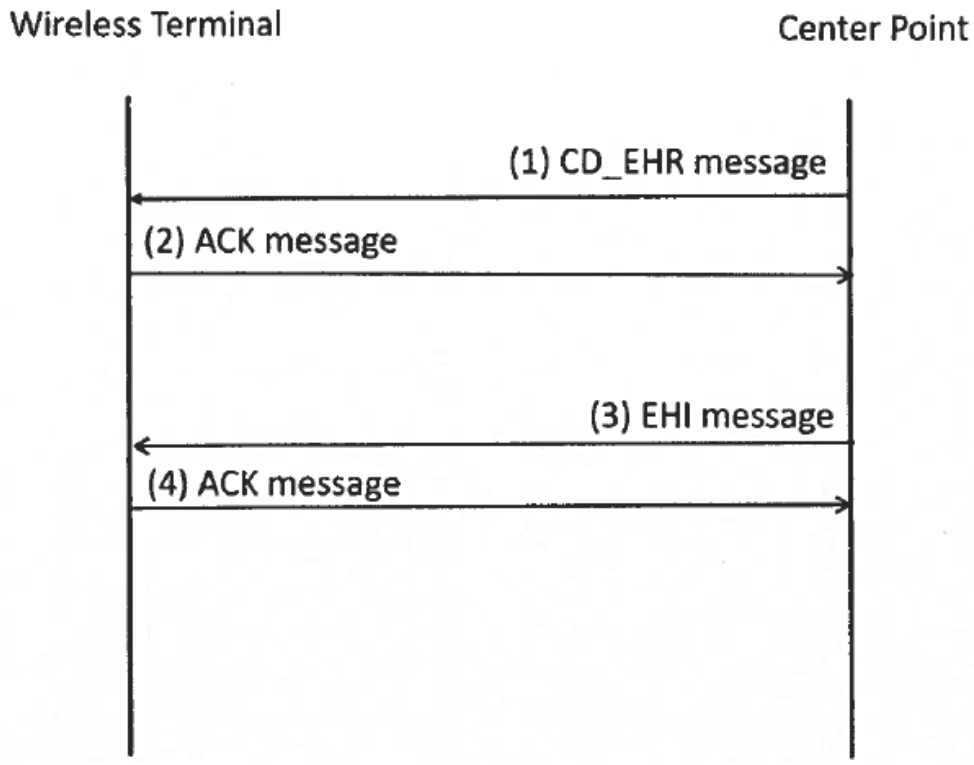


Fig. 3. Message exchanges in CDI-EH protocol

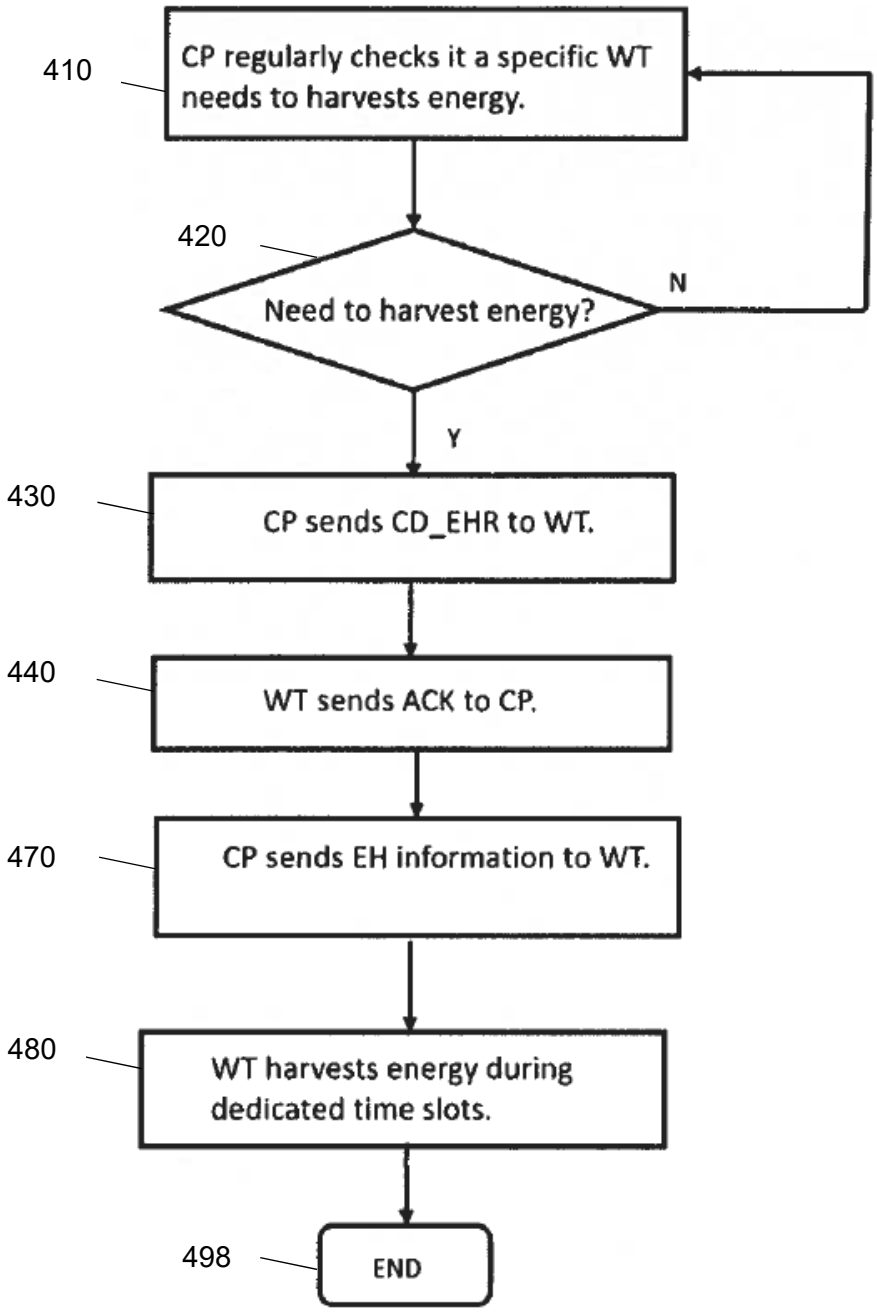


Fig. 4. Flow chart which describes the details of CDI-EH protocol.

Octets: 2	1	0/2	0/2/8	0/2	0/2/8	0/5/6/10/14	variable	2
Frame control	Sequence number	Destination PAN identifier	Destination Address	Source PAN identifier	Source Address	Auxiliary Security Header	Frame Payload	FCS
		Addressing fields						
MHR							MAC Payload	MFR

Fig. 5. General MAC frame format in IEEE 802.15.4.

Bits: 0- 2	3	4	5	6	7-9	10-11	12-13	14-15
Frame types	Security enabled	Frame pending	ACK request	Intra PAN	Reserved	Destination addressing mode	Reserved	Source addressing mode

Fig. 6. Format of the frame control field

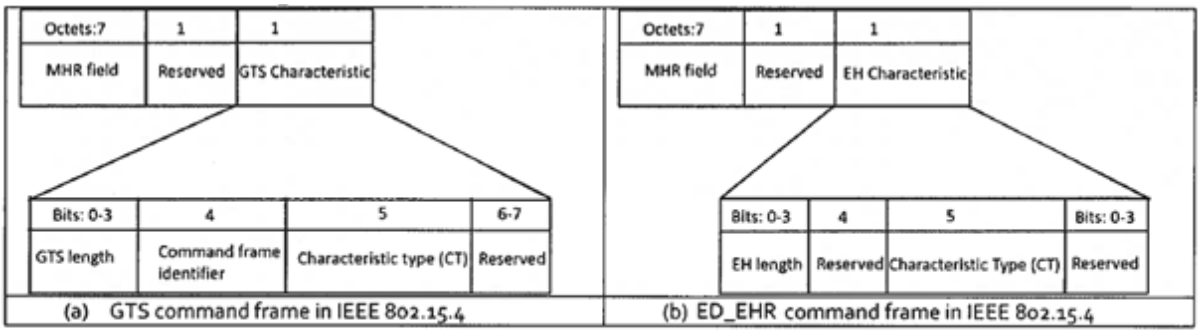


Fig. 7. GTS command frame in IEEE 802.15.4 and proposed ED_EHR command frame

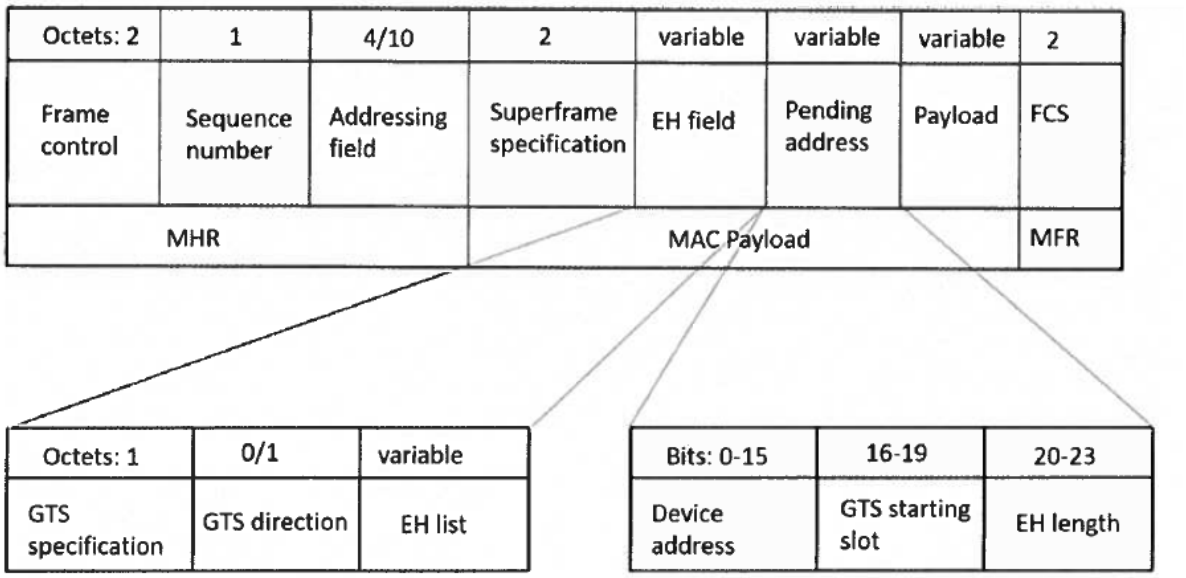


Fig.8. Beacon frame structure in IEEE 802.15.4 standard.

Octets: 2	1	4/10	2	variable	variable	variable	
Frame control	Sequence number	Addressing field	EH Superframe specification	EH field	Pending address	Payload	
MHR			MAC Payload				

Fig.9. EH superframe structure.

Octets: 1	0/1	variable
EH specification	Reserved	EH list

Fig.10. Format of the EH field

Bist: 0-15	16-19	20-23
Device address	EH starting slot	EH length

Fig.11. Format of Pending address information field

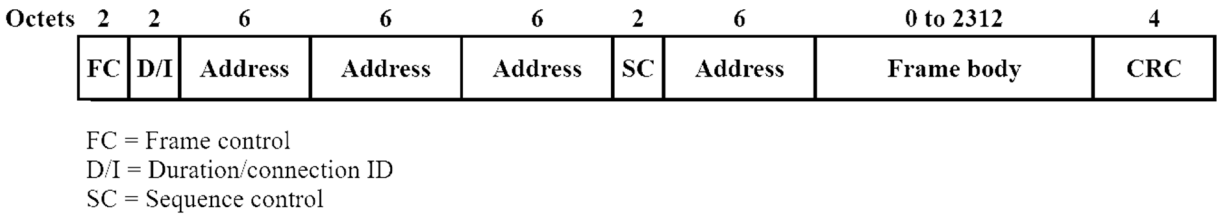


Fig. 12. Format of an IEEE 801.11 MAC frame