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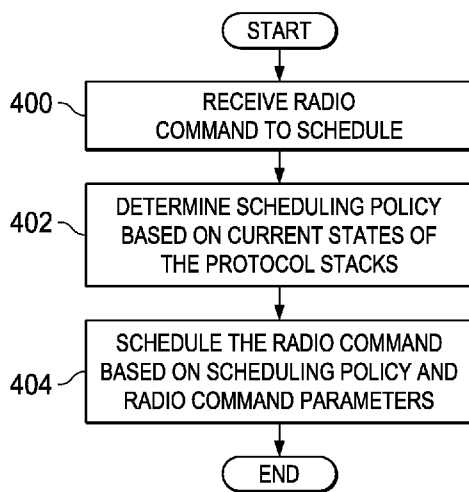
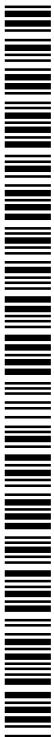


FIG. 4

(57) Abstract: In a method for concurrent execution of multiple protocols using a single radio of a wireless communication device, the method includes: receiving (400), in a radio command scheduler, a first radio command from a first protocol stack of protocol stacks executing on the wireless communication device; determining (402) a scheduling policy for the first radio command based on a current state of each protocol stack of the protocol stacks; and scheduling (404) the first radio command in a radio command queue for the radio based on the scheduling policy. The radio command scheduler uses the radio command queue to schedule radio commands received from the protocol stacks.



## CONCURRENT USE OF MULTIPLE PROTOCOLS ON A SINGLE RADIO

**[0001]** This relates to methods and apparatus for concurrent use of multiple protocols on a single radio.

### BACKGROUND

**[0002]** No single wireless protocol is ideal for every application of wireless sensor networks (WSN). For example, a lighting network can use Zigbee for communication among the light devices in the network while allowing configuration, software updates, and diagnostics via a Bluetooth smart phone or tablet. Or a home automation system can use IEEE 802.15.4-2015 to connect the devices in the system while supporting Bluetooth connectivity between one or more of the devices and a smart phone or tablet for configuration and monitoring.

### SUMMARY

**[0003]** In one aspect of a method for concurrent execution of multiple protocols using a single radio of a wireless communication device, the method includes: receiving, in a radio command scheduler, a first radio command from a first protocol stack of protocol stacks executing on the wireless communication device; determining a scheduling policy for the first radio command based on a current state of each protocol stack of the protocol stacks; and scheduling the first radio command in a radio command queue for the radio based on the scheduling policy. The radio command scheduler uses the radio command queue to schedule radio commands received from the protocol stacks.

**[0004]** In one aspect, a wireless communication device includes a radio, a radio command scheduler, and a memory storing software instructions. Execution of the software instructions causes the wireless communication device to concurrently execute multiple protocols using the radio. The software instructions include software instructions to cause the radio command scheduler to: receive a first radio command from a first protocol stack of protocol stacks executing on the wireless communication device; determine a scheduling policy for the first radio command based on a current state of each protocol stack of the protocol stacks; and schedule the first radio command in a radio command queue for the radio based on the scheduling policy. The radio command scheduler uses the radio command queue to schedule

radio commands received from the protocol stacks. A processor is coupled to the memory to execute the software instructions.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0005]** FIG. 1 is a simple example of a wireless sensor network including a node configured to execute multiple protocols concurrently.

**[0006]** FIG. 2 is a simplified block diagram of an example wireless sensor device configured to execute multiple protocols concurrently.

**[0007]** FIG. 3 illustrates the operation of a dynamic multi-protocol manager (DMM).

**[0008]** FIG. 4 is a flow diagram of a method for scheduling a radio command in the DMM of FIG. 3.

**[0009]** FIGS. 5, 6 and 7 are examples illustrating scheduling of radio commands.

#### DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

**[0010]** In the drawings, like elements are denoted by like reference numerals for consistency.

**[0011]** If a wireless sensor device has constrained power and memory resources, then concurrent execution of multiple protocols should preferably avoid wasting CPU cycles and memory resources.

**[0012]** Example embodiments provide for concurrent execution of multiple protocols (such as Bluetooth Low Energy (BLE), Zigbee, Thread, IEEE 802.15.4-2015, and/or a proprietary protocol) using a shared single radio resource in a wireless communication device, such as a wireless sensor device or a gateway device. FIG. 1 is a simple example of a wireless sensor network 100 including a node 106 configured to execute multiple protocols concurrently. The nodes 104, 106 in the network communicate with the WSN concentrator node 102 in the sub-1 gigahertz (GHz) band using a sub-1 GHz protocol such as IEEE 802.15.4-2015 or a proprietary protocol. A sub-1 GHz band can be in the range of the sub-1 GHz industrial, scientific and medical (ISM) bands, which are not the same across the world, *e.g.*, China = 433 MHz, United States = 916 MHz, and Europe = 868 MHz. For example, a node may be a control device (such as a light bulb or a door lock) or a sensing device (such as a smoke alarm or door sensor in an alarm system) or may be both a control device and a sensing device (such as a thermostat or a base station in an alarm system). The node 106 also communicates with a smart phone 108 (such as for configuration and monitoring) in the 2.4 GHz band using a 2.4 GHz protocol, such as Bluetooth Low Energy (BLE).

**[0013]** FIG. 2 is a simplified block diagram of an example wireless sensor device 200 (such as a wireless communication device) that can be deployed as a node 106 in the example wireless network 100 of FIG. 1. More specifically, the example wireless sensor device 200 is a dual-band wireless microcontroller (MCU) configured to allow concurrent execution of multiple protocols using a single multi-band radio. One example of such a wireless sensor device that can be configured to provide concurrent execution of multiple protocols is the CC1352R dual-band wireless MCU described in "CC1352R SimpleLink™ High-Performance Dual-Band Wireless MCU," SWRS196A, Texas Instruments Incorporated, January 2018, revised July 2018, which is incorporated by reference herein.

**[0014]** The MCU 200 incorporates a main CPU 202 for executing applications and protocol software that is implemented as a 32-bit ARM® Cortex®-M4F processor. The protocol software includes protocol stacks for the supported protocols, such as Thread , Zigbee, 6LoWPAN, Bluetooth 5, and/or proprietary protocols. General peripherals/modules 208 on the MCU 200 include a 12-bit A/D converter, interfaces for SPI, Microwire, and UART protocols, internal direct memory access (DMA), a real-time clock, multiple 16/32-bit timers, and more. The sensor interface 206 incorporates a programmable sensor controller and peripherals for interfacing with analog or digital sensors.

**[0015]** The MCU 200 also incorporates a radio frequency (RF) core 204 that implements a dual-band sub-1 GHz and 2.4 GHz RF transceiver compatible with multiple protocols including the Bluetooth 5 low energy protocol and the IEEE 802.15.4 protocol. The RF core 204 is designed to autonomously handle time critical aspects of transmitting and receiving various radio protocols. The RF core 204 includes a processor implemented as an ARM® Cortex®-M0 processor for executing software, such as software that interfaces the analog RF and base-band circuitry, handles data transmission to and from the main CPU 202, and assembles packets for transmission based on the particular protocol corresponding to the packets. The software includes a command-based application program interface (API) used by applications executing on the main CPU 202 to communicate with the RF core 204.

**[0016]** The MCU 200 also incorporates flash memory that provides nonvolatile storage for code and data, static random access memory (SRAM) that can be used for both storage of data and execution of code, and a read-only memory (ROM) storing a real-time operating system kernel. Software instructions implementing methods as described herein can be stored in a

computer readable medium on the MCU 200, such as the flash memory, the static random access memory (SRAM), or the read-only memory (ROM) on the MCU 200 and executed by the main processor 202.

**[0017]** A dynamic multi-protocol manager (DMM) executing on the main CPU 202 provides time shared access to the radio for radio commands issued by multiple protocol stacks. The DMM handles dynamic switching of the radio between radio commands issued by the protocol stacks based on scheduling policies and run-time stack states. Generally, the DMM receives radio commands from the protocol stacks and inserts the commands into a command queue based on scheduling policies associated with the current states of the stacks and timing information specified in command parameters. The DMM also dispatches commands from the command queue to the radio driver for the radio.

**[0018]** FIG. 3 shows the interaction of an example embodiment of the DMM 300 logically coupled between two protocol stacks 306, 308 and associated applications 302, 304 and a radio driver 310. The DMM 300 intercepts radio commands from the protocol stacks 306, 308 via the DMM interface 312. In some embodiments, the DMM interface 312 mimes command functions in the command execution application programming interface (API) of the radio driver 310 and uses a function mapping table to map the radio command functions to DMM functions. In some embodiments, some of the intercepted radio commands are passed through to the radio driver 310 with no further processing by the DMM 300. For example, commands that read or write radio setup parameters can be passed through to the radio driver 210 with no further processing by the DMM 300 while commands to send and receive data packets are processed by the DMM 300.

**[0019]** The radio command scheduler 314 manages the radio command queue 320, both adding radio commands to the queue 320 and dispatching radio commands from the queue 320 to the radio driver 310. The radio command scheduler 314 inspects the parameters of each intercepted radio command that needs to be scheduled to determine the start and end times specified for the radio command. The radio command scheduler 314 then attempts to add the radio command to the radio command queue 320 based on the specified start and end times and on a scheduling policy corresponding to the current states of the protocol stacks 306, 308. Each application 302, 304 notifies the radio command scheduler 314 via the DMM interface 312 each time the state of the associated protocol stack 306, 308 changes, so that the scheduler 314 knows the current state

of each stack when a new radio command needs to be scheduled.

**[0020]** Generally, the radio command scheduler 314 scans the radio command queue 320 to attempt to schedule the new radio command in view of the scheduling policies and time parameters of commands in the radio command queue 320 and the time parameters and scheduling policy of the new radio command. For example, the radio command scheduler 314 can insert the new radio command between radio commands in the radio command queue 320, preempt a currently executing radio command and place the new radio command at the head of the radio command queue 320 to be executed immediately, append the new radio command to the end of the radio command queue 320, or reject the new radio command if the new radio command cannot be added to the queue 320 given the time parameters and the scheduling policy, or, under some circumstances, change the timing of the new radio command, so that the new radio command can be added to the radio command queue 320. The scheduling of commands by the radio command scheduler 314 is described in more detail herein in reference to the method of FIG. 4 and the examples of FIGS. 5-7.

**[0021]** A policies data structure 318 (such as a table or other suitable data structure) stores the scheduling policies used by the scheduler 314. The policy manager 316 initializes the policies data structure 318 when the MCU 200 is powered up from scheduling policy definitions submitted via the DMM interface 312. In some embodiments, the scheduling policies are user-specified. In some embodiments, default scheduling policies can be changed by the user. In some embodiments, a scheduling policy can be changed dynamically by submitting changes to the policy manager 318 via the DMM interface 312.

**[0022]** A scheduling policy corresponding to the current states of the protocol stacks informs the radio command scheduler 314 about how any scheduling conflicts for a new radio command are to be resolved. For example, a scheduling policy corresponding to the current protocol stack states can specify the priority of radio commands from each protocol stack 306, 308 and a timing constraint indicating whether radio commands from each protocol stack are time critical. If a new radio command is not time critical, the scheduler 314 can potentially modify the time parameters of the new radio command and/or modify the time parameters of an already scheduled radio command that is not time critical in order to schedule the new radio command. The policies data structure 318 includes a scheduling policy for expected combinations of protocol stack states. Further, in some embodiments, multiple stack states of one or both

protocol stacks 306, 308 can be mapped to a single scheduling policy.

[0023] For example, assume Application A 304 is acting as a BLE peripheral and protocol stack A 308 is a BLE stack and Application B 302 is a sensor application and protocol stack B 306 is for a proprietary protocol. Table 1, Table 2, Table 3 and Table 4 are example scheduling policies for the expected combinations of stack states. Table 4 illustrates a default scheduling policy that is used if the combination of stack states when a radio command is received does not match one of the stack state combinations shown in Tables 1-3.

Table 1

Stack Type	BLE	Proprietary
Stack State(s)	Advertising	Sleeping, TX, or ACK
Policy	Low priority, time critical	High priority, not time critical

Table 2

Stack Type	BLE	Proprietary
Stack State(s)	Connecting or connected	TX
Policy	High priority, time critical	Low priority, not time critical

Table 3

Stack Type	BLE	Proprietary
Stack State(s)	Connecting or connected	ACK
Policy	High priority, time critical	Low priority, not time critical

Table 4

Stack Type	BLE	Proprietary
Stack State(s)	Any	Any
Policy	High priority, time critical	Low priority, not time critical

[0024] FIG. 4 is a flow diagram of a method for scheduling a radio command in the DMM 300 of FIG. 3. The method is described assuming example scheduling policies as described hereinabove that specify the priority and timing constraint of a new radio command. Initially, the DMM 300 receives 400 a new radio command to be scheduled from one of the protocol stacks 306, 308. The DMM 300 then determines 402 the scheduling policy to be applied based on the current states of the protocol stacks 306, 308. The current protocol stack states can be used to locate the appropriate scheduling policy in the policies data structure 318. As described hereinabove, the applications 302, 304 notify the DMM 300 each time the state of the respective protocol stacks 306, 308 changes.

[0025] The radio command scheduler 314 then schedules 404 the new radio command based

on the scheduling policy and the time parameters specified in the radio command. More specifically, the radio command scheduler 314 attempts to schedule the radio command based on one or more of the following criteria: (a) the priority of the radio command as specified in the scheduling policy for the protocol stack that issued the radio command; (b) the timing constraint of the radio command as specified in the scheduling policy for the protocol stack that issued the radio command; (c) the start time of the radio command; and (d) the end time of the radio command.

**[0026]** If the new radio command is a high priority command as per the scheduling policy, the currently executing radio command is a low priority command, and the start and end time parameters of the new radio command overlap the time slot of the low priority command, the scheduler 314 aborts execution of the low priority radio command and places the new radio command at the head of the radio command queue 320 to be immediately executed. The scheduler 314 appends the aborted low priority radio command to the radio command queue 320 if the low priority command is not time critical; otherwise, the radio command scheduler 314 notifies the protocol stack that issued the low priority radio command that the radio command was aborted. If the low priority radio command is preempted and appended to the radio command queue 320, the low priority radio command will be executed from the beginning, and not resumed at the point where execution was aborted.

**[0027]** If the currently executing radio command is also high priority or the new radio command is low priority, the radio command scheduler 314 attempts to add the new radio command to the radio command queue 320. The radio command scheduler 314 scans the radio commands in the radio command queue 320 looking at the priorities, timing constraints and time parameters of the queued commands, as compared to the same for the new radio command to decide if and where the new radio command can be placed in the radio command queue 320. If the time slot specified by the start time and end time parameters of the new radio command is available between two queued radio commands (as determined by the start and end times of the new radio command and the queued radio commands), the radio command scheduler 314 inserts the new radio command in the radio command queue 320 between the two queued radio commands regardless of the priority of the new radio command and the priorities of the queued radio commands. Insertion based on start and end times can result in a low priority command being inserted in the radio command queue 320 before a high priority command. In determining



whether the specified time slot is available between two queued radio commands, the radio command scheduler 314 can consider modifying the time parameters of queued radio commands that are not time critical to defer execution to free up the specified time slot for the new radio command.

**[0028]** If the radio command scheduler 314 cannot insert the new radio command in the radio command queue 320 at the specified time slot because the time slot is occupied, completely or partially, by a queued radio command, the radio command scheduler 314 then determines whether the new radio command can preempt the queued radio command. If the new radio command is low priority, the radio command scheduler 314 cannot preempt the queued radio command occupying the specified time slot in favor of the new radio command, because a low priority radio command cannot preempt either a high priority radio command or another low priority radio command. In this instance, the radio command scheduler 314 appends the new radio command to the end of the radio command queue 320 if the scheduling policy indicates that the new radio command is not time critical; otherwise, the new radio command cannot be scheduled, and the radio command scheduler 314 rejects the new radio command.

**[0029]** If the new radio command is high priority and the queued radio command occupying the specified time slot is also high priority, the radio command scheduler 314 cannot preempt the queued radio command in the specified time slot in favor of the new radio command, because a high priority radio command cannot preempt another high priority radio command. In this instance, the radio command scheduler 314 appends the new radio command to the end of the radio command queue 320 if the scheduling policy indicates that the new radio command is not time critical; otherwise, the new radio command cannot be scheduled, and the radio command scheduler 314 rejects the new radio command.

**[0030]** If the new radio command is high priority and the queued radio command occupying the specified time slot is low priority, the radio command scheduler 314 preempts the queued low priority radio command to free up the specified time slot for the new radio command in the radio command queue 320 and inserts the new radio command in the radio command queue 314. The radio command scheduler 314 appends the preempted low priority radio command to the end of the radio command queue 320 if the preempted radio command is not time critical; otherwise, the radio command scheduler 314 aborts the preempted radio command and notifies the protocol stack that issued the low priority radio command that the radio command has been

preempted. In each of the above instances in which the radio command scheduler 314 appends a radio command to the radio command queue 320, the radio command scheduler 314 modifies the time parameters of the appended radio command as needed to accommodate the start time and end time deferral.

**[0031]** FIGS. 5, 6 and 7 are examples illustrating scheduling of radio commands. FIG. 5 is an example of inserting a radio command in an available time slot in the radio command queue 320. The original schedule 500 includes three radio commands A1, A2 and A3 from protocol stack A 308 and three radio commands B1, B2 and B3 from protocol stack B 306. At time T1, the radio command scheduler 314 receives a new radio command A4 from protocol stack A 308. The radio command scheduler 314 attempts to add A4 to the radio command queue 320 by scanning the radio command queue 320 for the time slot specified by the start time and end time parameters of A4. The radio command scheduler 314 locates the time slot between B1 and B2, because: the specified end time of B1 is before the specified start time of A4; and the specified start time of B2 is after the specified end time of A4. The radio command scheduler 314 inserts A4 in the time slot between B1 and B2, even if A4 is a high priority command and B1 is a low priority command. In the new schedule 502, the radio command A4 is slotted between the radio commands B1 and B2.

**[0032]** FIG. 6 is an example of preempting a queued low priority radio command in favor of a high priority radio command. The original schedule 600 includes three high priority radio commands A1, A2 and A3 from protocol stack A 308 and three low priority radio commands B1, B2 and B3 from protocol stack B 306. At time T2, the radio command scheduler 314 receives a new radio command A4 from the protocol stack A 308 that is high priority as per the scheduling policy for the current states of the protocol stack. The radio command scheduler 314 attempts to add A4 to the radio command queue 320 by scanning the queue for the time slot specified by the start time and end time parameters of A4. The radio command scheduler 314 determines that the specified time slot for A4 is between B1 and B3 and is at least partially occupied by B2, which is low priority. The radio command scheduler 314 preempts B2 in favor of A4, removes B2 from the queue 320, and places A4 between B1 and B3 in the queue 320. The radio command scheduler 314 also determines that B2 cannot be rescheduled because B2 is time critical and notifies the protocol stack B 306 that the radio command B2 has been preempted. In the new schedule 602, radio command A4 is slotted between radio command B1 and radio command B3,

replacing radio command B2.

**[0033]** FIG. 7 is an example of preempting and restarting a low priority radio command that is currently executing when a high priority radio command is received. The original schedule 700 is empty, and the low priority non-time critical radio command B1 is currently being executed by the radio driver 310. The radio command scheduler 314 receives the radio command A from the protocol stack A 308 and determines from the scheduling policy that radio commands received from the protocol stack A 308 currently have high priority. The radio command scheduler 314 also determines from the time parameters of A that the time slot needed for A overlaps that B1. The radio command scheduler 314 causes the radio driver 310 to abort execution of the low priority radio command B1 and places the new radio command A at the head of the radio command queue 320. Because B1 is not time critical, the radio command scheduler 314 reschedules B1 by appending B1 to the radio command queue 320, as shown in the new schedule 702. B1 will be executed from the beginning, and not resumed at the point the command execution was aborted.

**[0034]** Embodiments have been described herein assuming a dual-band radio. But in some embodiments, the radio is single band, and all protocols stacks share the same band. In some embodiments, the radio has more than two bands.

**[0035]** Embodiments have been described herein in reference to example scheduling policies that specify the priority and timing constraint of a new radio command. But in some embodiments, scheduling policies can include more and/or different information that the scheduler considers when scheduling new radio commands.

**[0036]** For simplicity of explanation, embodiments have been described herein assuming concurrent execution of two protocols using a single radio resource. But other embodiments provide concurrent execution of more than two protocols using a single radio resource. For example, protocol stacks for ZigBee (2.4GHz), Thread (2.4GHz) and BLE (2.4GHz) or protocol stacks for a proprietary protocol (sub-1GHz), Thread (2.4GHz) and BLE (2.4GHz) can be concurrently executed. An example application that can benefit from concurrent execution of more than two protocols is a home automation gateway that controls devices that communicate using different protocols, such as a BLE door bell, ZigBee lights, and a Thread thermostat.

**[0037]** Modifications are possible in the described embodiments, and other embodiments are possible, within the scope of the claims.

## CLAIMS

What is claimed is:

1. A method for concurrent execution of multiple protocols using a single radio comprised in a wireless communication device, the method comprising:
  - receiving, in a radio command scheduler, a first radio command from a first protocol stack of a plurality of protocol stacks executing on the wireless communication device;
  - determining a scheduling policy for the first radio command based on a current state of each protocol stack of the plurality of protocol stacks; and
  - scheduling the first radio command in a radio command queue for the radio based on the scheduling policy, wherein the radio command scheduler uses the radio command queue to schedule radio commands received from the plurality of protocol stacks.
2. The method of claim 1, wherein the scheduling policy comprises a priority and a time constraint for radio commands from each protocol stack, wherein the time constraint for a protocol stack indicates whether a radio command from the protocol stack is time critical.
3. The method of claim 2, wherein scheduling the first radio command further comprises:
  - aborting execution of a second radio command currently being executed by the radio when the first radio command has a higher priority than the second radio command; and
  - adding the first radio command to a head of the radio command queue.
4. The method of claim 3, further comprising rescheduling the second radio command in the radio command queue, wherein the second radio command is scheduled to start execution from a beginning of the second radio command.
5. The method of claim 2, wherein scheduling the first radio command further comprises:
  - scanning the radio command queue to determine whether a specified time slot for the first radio command is available; and
  - inserting the first radio command in the radio command queue at the specified time slot if the specified time slot is available.
6. The method of claim 5, further comprising:
  - preempting a second radio command occupying the specified time slot when the first radio command has a higher priority than the second radio command; and
  - inserting the first radio command in the radio command queue at the specified time slot.
7. The method of claim 6, further comprising appending the second radio command to the

radio command queue if the second radio command is not time critical.

8. The method of claim 5, further comprising appending the first radio command to the radio command queue when a second radio command occupying the specified time slot has a higher priority than the first radio command and the first radio command is not time critical.

9. The method of claim 5, further comprising rejecting the first radio command when a second radio command occupying the specified time slot has a higher priority than the first radio command and the first radio command is time critical.

10. The method of claim 6, wherein the second radio command is from a second protocol stack of the plurality of protocol stacks.

11. A wireless communication device comprising:

a radio;

a radio command scheduler;

a memory storing software instructions, wherein execution of the software instructions causes the wireless communication device to concurrently execute multiple protocols using the radio, the software instructions comprising software instructions to cause the radio command scheduler to:

receive a first radio command from a first protocol stack of a plurality of protocol stacks executing on the wireless communication device;

determine a scheduling policy for the first radio command based on a current state of each protocol stack of the plurality of protocol stacks; and

schedule the first radio command in a radio command queue for the radio based on the scheduling policy, wherein the radio command scheduler uses the radio command queue to schedule radio commands received from the plurality of protocol stacks; and

a processor coupled to the memory to execute the software instructions.

12. The wireless communication device of claim 11, wherein the scheduling policy comprises a priority and a time constraint for radio commands from each protocol stack, wherein the time constraint for a protocol stack indicates whether a radio command from the protocol stack is time critical.

13. The wireless communication device of claim 12, wherein the software instructions to schedule the first radio command further comprise software instructions to:

abort execution of a second radio command currently being executed by the radio when the first radio command has a higher priority than the second radio command; and

add the first radio command to a head of the radio command queue.

14. The wireless communication device of claim 13, further comprising software instructions to reschedule the second radio command in the radio command queue, wherein the second radio command is scheduled to start execution from a beginning of the second radio command.

15. The wireless communication device of claim 12, wherein the software instructions to schedule the first radio command further comprise software instructions to:

scan the radio command queue to determine whether a specified time slot for the first radio command is available; and

insert the first radio command in the radio command queue at the specified time slot if the specified time slot is available.

16. The wireless communication device of claim 15, wherein the software instructions further comprise software instructions to:

preempt a second radio command occupying the specified time slot when the first radio command has a higher priority than the second radio command; and

insert the first radio command in the radio command queue at the specified time slot.

17. The wireless communication device of claim 16, wherein the software instructions further comprise software instructions to append the second radio command to the radio command queue if the second radio command is not time critical.

18. The wireless communication device of claim 15, wherein the software instructions further comprise software instructions to append the first radio command to the radio command queue when a second radio command occupying the specified time slot has a higher priority than the first radio command and the first radio command is not time critical.

19. The wireless communication device of claim 15, wherein the software instructions further comprise software instructions to reject the first radio command when a second radio command occupying the specified time slot has a higher priority than the first radio command and the first radio command is time critical.

20. The wireless communication device of claim 16, wherein the second radio command is from a second protocol stack of the plurality of protocol stacks.

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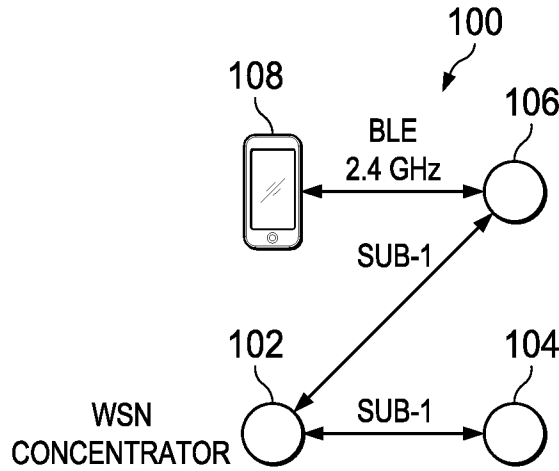


FIG. 1

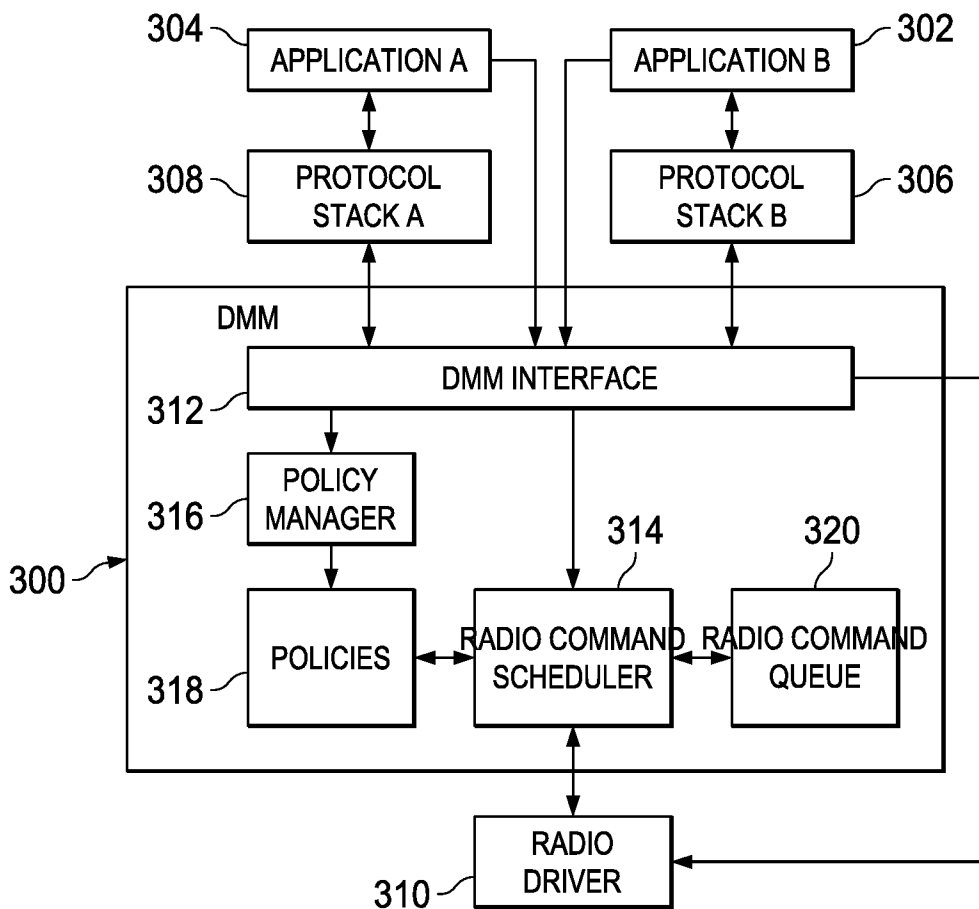


FIG. 3

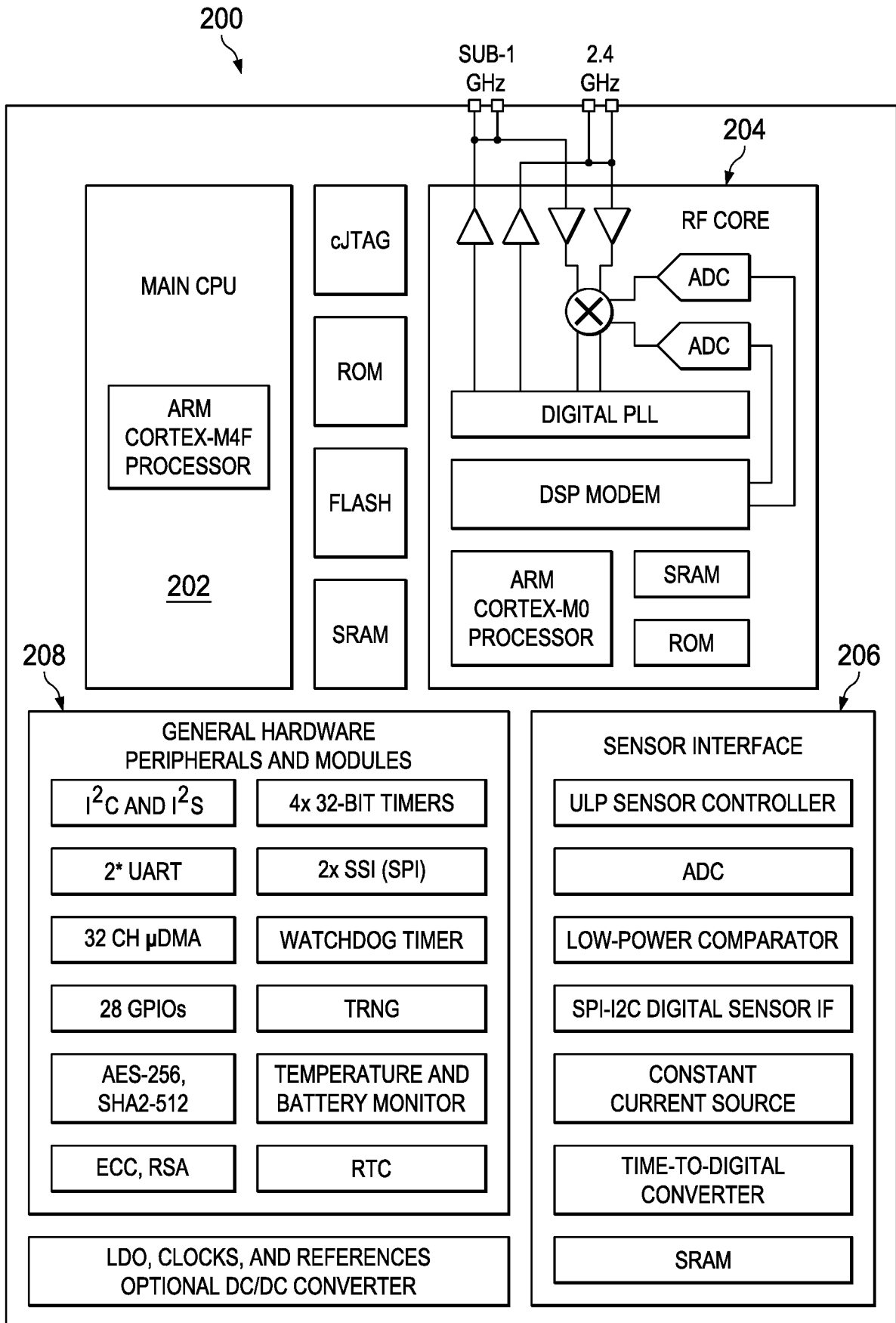


FIG. 2



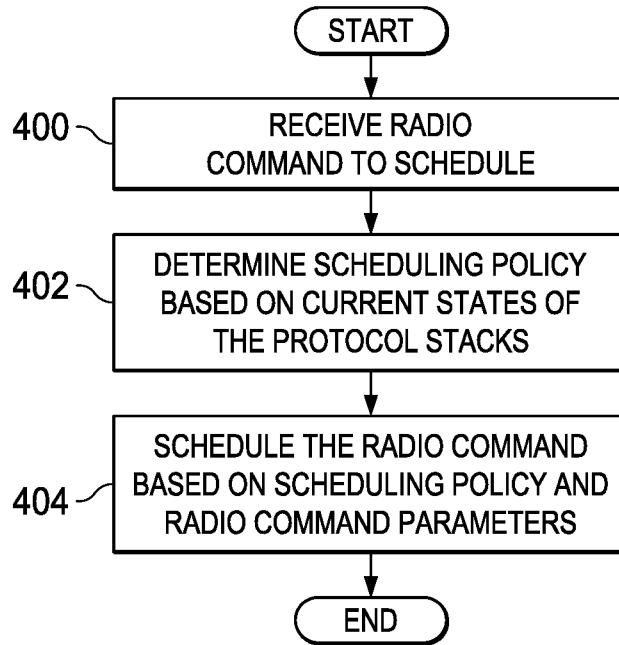


FIG. 4

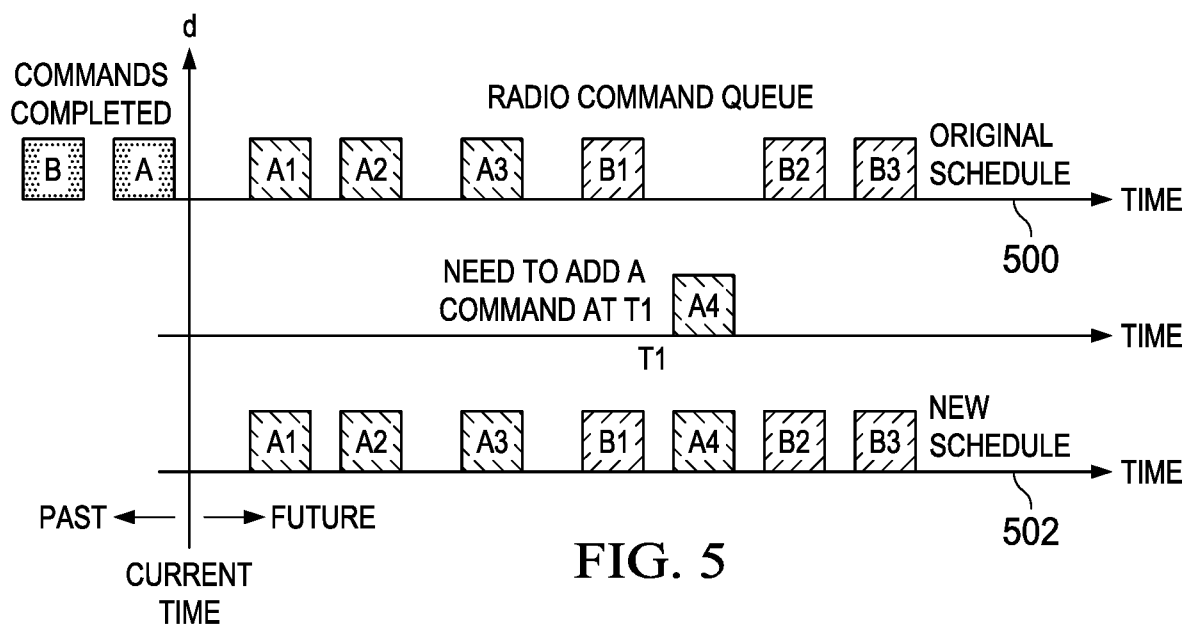
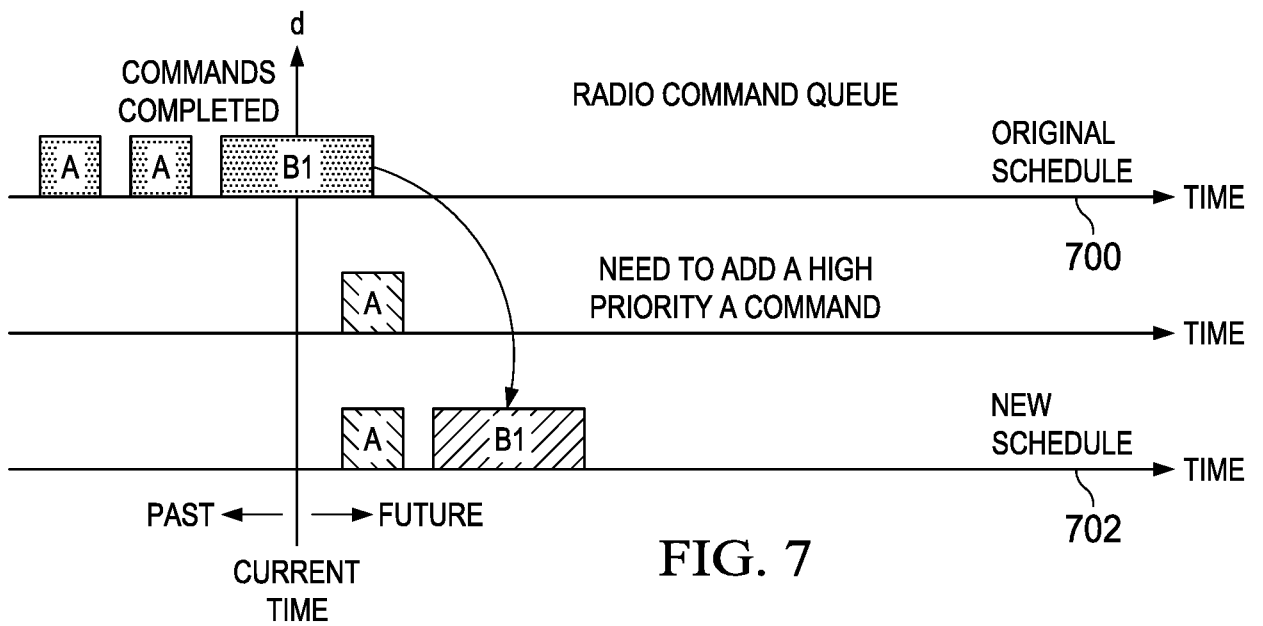
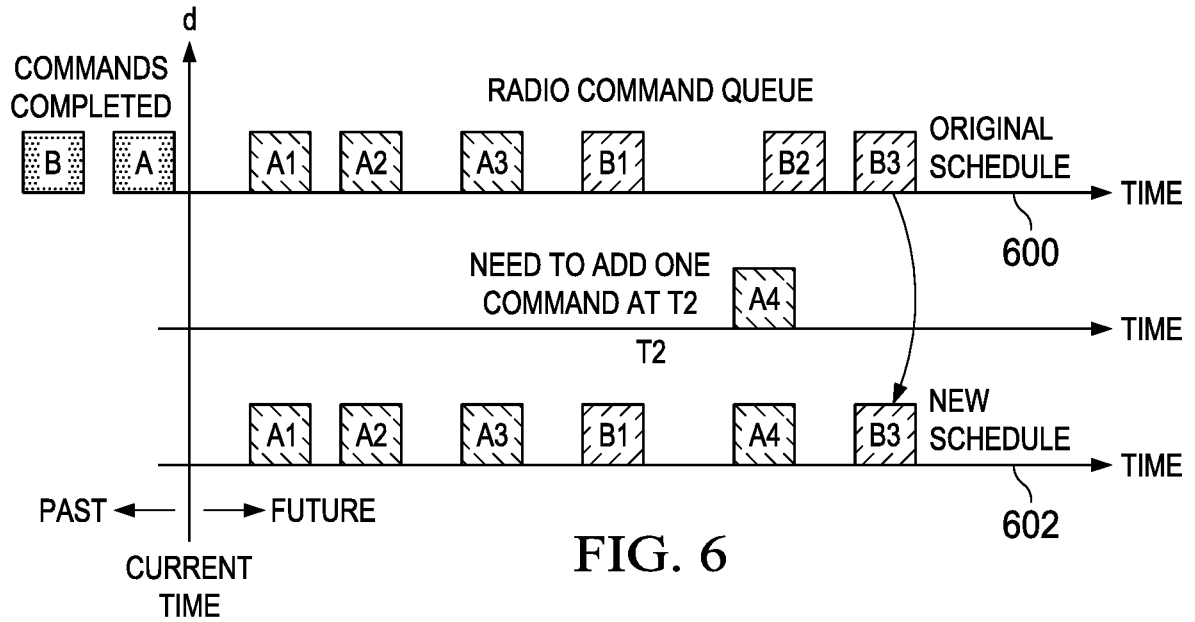


FIG. 5



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/046527

A. CLASSIFICATION OF SUBJECT MATTER		
<i>H04L 12/865 (2013.01)</i> <i>H04H 40/09 (2008.01)</i>		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
G06F 1/00, 1/04-1/14, 5/00-5/16, 13/00-13/42, 15/00, 15/17-15/177, H04B 1/00, 1/38-1/58, 7/00-7/26, 15/00-15/06, H04L 12/00, 12/70-12/879, H04M 1/00, H04W 4/00, 72/00, 80/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PatSearch (RUPTO internal), USPTO, PAJ, K-PION, Esp@cenet, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7949364 B2 (NOKIA CORPORATION) 24.05.2011, abstract, col. 1, lines 6-10, col.3, lines 36-39, 61-67, col. 4, lines 1-6, col. 7, lines 8-9, 29-61, col. 9, lines 8-13, col. 16, line 65-col.17, line 21, col.18, lines 1-41, col.19, line 1-col.21, line 39, claims 1, 5, 8-9, 17	1-2, 5-12, 15-20
Y		3-4, 13-14
Y	US 2009/0157936 A1 (TEXAS INSTRUMENT CORPORATION) 18.06.2009, paragraphs [0323]-[0334], [0427], claims 8-10	3-4, 13-14
A	US 2008/0291890 A1 (KABUSHIKI KAISHA TOSHIBA) 27.11.2008	1-20
A	US 2005/0223191 A1 (GAVIN ROBERT FERRIS) 06.10.2005	1-20
A	US 2007/0238482 A1 (GIORA RAYZMAN et al.) 11.10.2007	1-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
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"E"	earlier document but published on or after the international filing date	
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O"	document referring to an oral disclosure, use, exhibition or other means	
"P"	document published prior to the international filing date but later than the priority date claimed	
Date of the actual completion of the international search		Date of mailing of the international search report
29 October 2018 (29.10.2018)		08 November 2018 (08.11.2018)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer  I. Meshkova  Telephone No. (495) 531-65-15