Xsense®

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PRELIMINARIES

The operation of the logger's cellular communication channel is based on periodic short (usually less than 20 seconds) data exchange sessions. During the session, the logger's cellular communication channel (which at the hardware level is implemented by the modem) is turned on.

During the time interval between sessions, the cellular modem is completely turned off by turning off the modem's power supply.

The duration of the session is determined by the availability of the cellular network and a large number of random parameters and on average ranges from 12 to 15 seconds.

The duration of the time interval between sessions is a configurable parameter ranging from a few minutes to several hours.

INITIAL REQUIREMENTS

The list of requirements of the Project System Architect initially included (numbering does not correspond to the original document):

1. A logger can only be in two fundamental states:
   a. it keeps a log and periodically delivers log data during communication sessions with the cellular channel (modem) periodical activity; it is in an active state, or the logger is started and running.
   b. the logger does not keep a log and does not use a cellular channel (modem) at all, this state is the logger is stopped or "on the shelf".
2. A logger has two communication channels - cellular and Bluetooth. The Bluetooth channel is a service channel and is intended exclusively for advanced management of logger settings and emergency access to the log-in cases where the energy of the logger's power source (battery) is not enough to operate the cellular communication channel.
3. Because the PCB antennas of two radio channels (cellular and Bluetooth) are located on a small PCB, the simultaneous use of both radio channels is not allowed.
4. Because the cellular channel is activated (the power of the modem is turned on) periodically and for a short time during the data exchange session, activation of the Bluetooth channel during the session is prohibited.
5. The Bluetooth channel is activated exclusively by pressing the corresponding button on the logger user interface.
6. If, as a result of erroneous operator actions, an attempt is made to activate the Bluetooth channel during a data exchange session, activation of the Bluetooth channel is postponed until the end time of the session plus the additional small delay to calm down transient processes on the PCB.
7. Bluetooth channel activity temporally cancels the periodicity of cellular channel data exchange sessions for the duration of Bluetooth channel activity.

The requirements of the System Architect were fully implemented both at the hardware and firmware levels.

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HARDWARE-LEVEL

At the hardware level, independence of power management of the modem and Bluetooth channel is ensured. The Bluetooth channel can work when the modem's power is completely turned off, at the same time, the modem's power is software-controlled and independent of the Bluetooth channel's power.

The power domain of the Bluetooth channel is implemented by the following circuit:
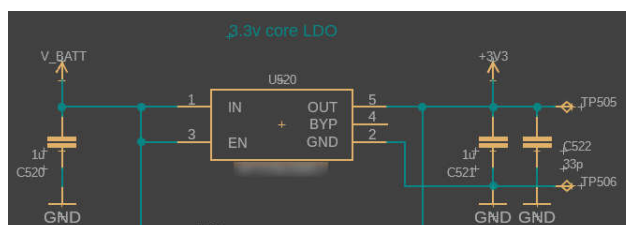
The modem power domain, as it relates to power management, is implemented by the following circuit:
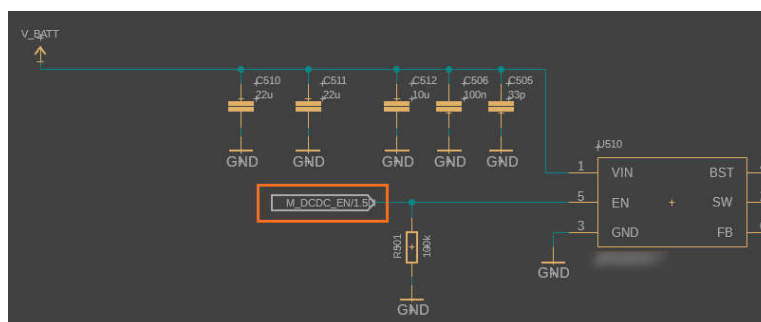
The given fragments of the logger circuitry show that:

1. Bluetooth and modem power domains share a common power supply V_BATT into two independent branches.
2. The modem domain supply voltage can be turned on or off using a traditionally designated EN(ABLE) signal M_DCDC_EN/1.5.
3. The Bluetooth domain power supply voltage does not depend on the state of the modem power domain. It means that the Bluetooth domain can work when the modem's power domain is completely disconnected from the main power source V_BATT.
4. Hardware for prohibiting the simultaneous use of both channels is not used due to the integration of the Bluetooth channel (transceiver) implementation into the main control microcontroller of the logger.
5. Further fulfilment of the System Architect's requirements is ensured at the firmware level.

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FIRMWARE LEVEL

Logger Firmware is a complex software product based on RTOS.

The functionality of the cellular communication channel and Bluetooth channel is implemented by different RTOS tasks.

General control of the logic of the logger and the use of two communication channels is carried out by the third task. However, each task of managing each communication channel implements internal checks of the state of the other channel to ensure that simultaneous operation is excluded.

The simplified logic of the operation of two tasks for managing communication channels is presented in Fig. 1.
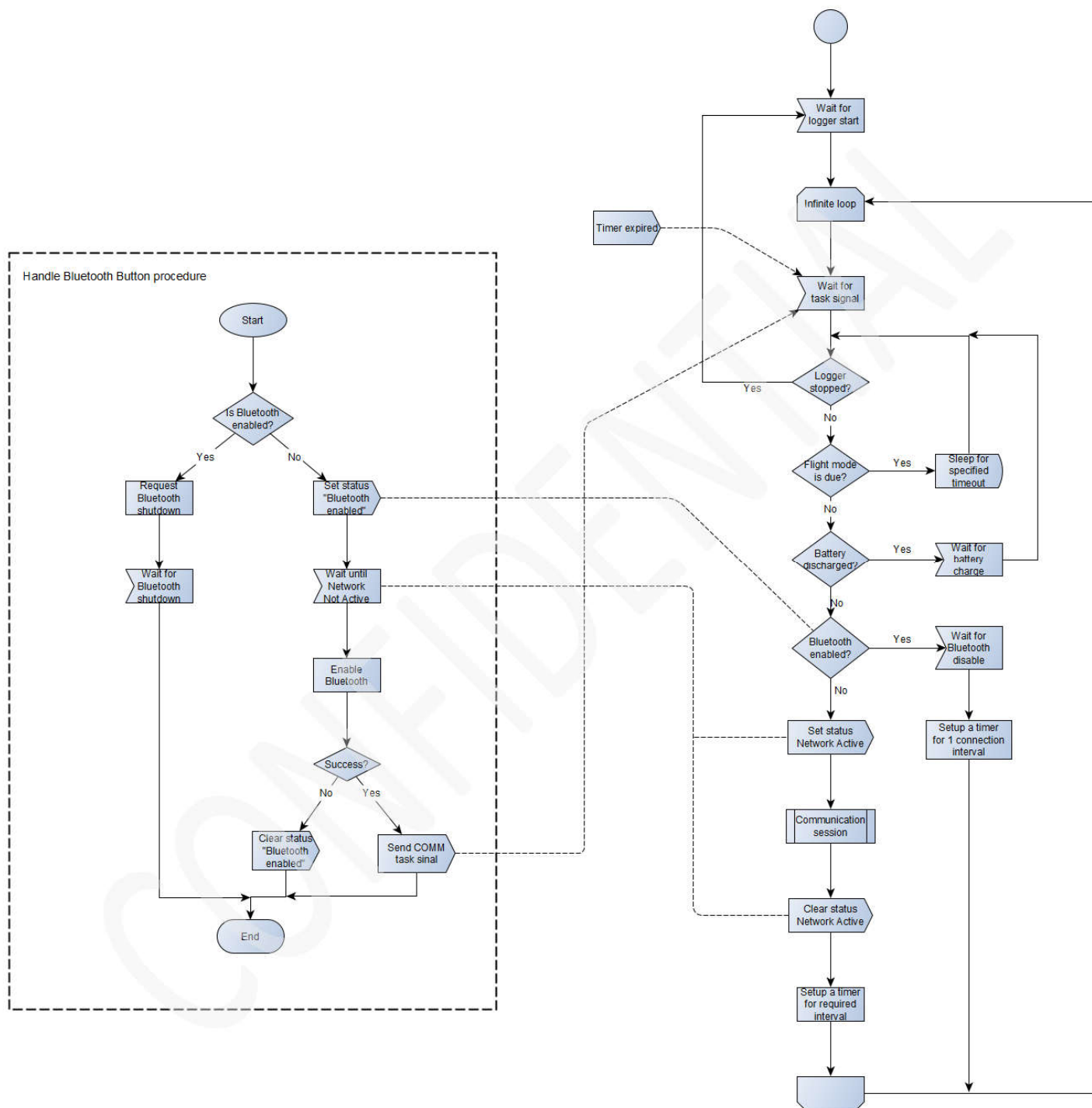
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Fig.1

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Although visually complex, the mutually exclusive activity of two communication channels is based on two variables representing the activity of the corresponding communication channel.

After transferring the logger to the first fundamental state of logging, the logger checks the activity of the Bluetooth channel in an endless loop before the start of each session:
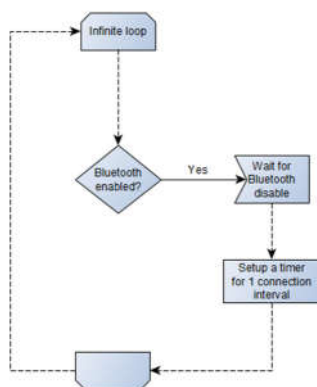
From this fragment, it is obvious that if the Bluetooth channel was activated in the interval between sessions (between modem activity), while the Bluetooth channel is active or even just enabled, sessions of the cellular channel are skipped, and simultaneous operation of both channels is impossible.

On the other hand, the asynchronous event "Bluetooth activation button is pressed" may not cause an immediate response, because control of Bluetooth channel activity depends on the current state of the logger. The "Handle Bluetooth Button procedure" part of the diagram shows that even if the Bluetooth activation button is pressed while a cellular channel session is active (the modem is turned on), the response to an attempt to activate the Bluetooth channel is not an action (it is requested only) and is not instantaneous and is delayed until the end of the session ("Wait until Network Not Active" block):
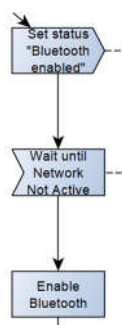
Since the above diagrams mostly show the exchange of messages between firmware logger tasks, the following typical fragments of firmware implementation code can be cited, which demonstrate the mutually exclusive logic of managing communication channels.

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In this code fragment, for example, it is obvious that the Bluetooth channel is launched (BLE_Start) strictly after the "cellular channel is active" (STATUS_NETWORK_ACTIVE) state ends or the logger is not in active cellular channel state:

```
390            if (!SYNC_IsEventSet(STATUS_BLUETOOTH_ACTIVE)) {
391                SYNC_EventSet(STATUS_BLUETOOTH_ACTIVE);
392                SYNC_WaitEvent(STATUS_NETWORK_ACTIVE, 0, 0); /* Wait for network task to finish session */
393
394                if (BLE_Start()) {
```

On the other hand, before each session, the activity of the Bluetooth channel is checked and if the channel is active, the logger is in a state of waiting for the completion of the Bluetooth session and does not use the cellular channel:

```
141
142        /* If Bluetooth or JIG session is ongoing, wait for it to finish */
143        if (wakeup_reason == Wakeup_BLESession || wakeup_reason == Wakeup_JIGSession ||
144            SYNC_IsEventAnySet(STATUS_BLUETOOTH_ACTIVE | STATUS_JIG_CONNECTED)) {
145            SYNC_WaitAllEvents(STATUS_BLUETOOTH_ACTIVE | STATUS_JIG_CONNECTED, 0, 0);
146
```

Thus:

1. Activation of the logger's Bluetooth channel can only be requested by pressing the corresponding button on the logger's user interface.
2. A request to activate a Bluetooth channel does not cause immediate action, even if at the time of the Bluetooth activation request a cellular channel is active (the activity of the cellular channel is reflected by the user interface) and the operator violates the rules of the Operation Manual, the actual activation of the Bluetooth channel will certainly occur after the cellular channel is completely turned off.
3. When the Bluetooth channel is active, the use of the cellular channel is blocked for the duration of the Bluetooth channel activity.

This in general is evidence that the Bluetooth and cellular channels of the logger cannot be active at the same time, even if the logger's operator violates the requirements of the Operation Manual.