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INDUSTRIAL IOT/SMART MANUFACTURING: A HARDWARE APPROACH TO DISCOVER LINK NEIGHBOR IN LOW-POWER AND LOSSY NETWORKS

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ABSTRACT

Techniques are provided, using a custom hardware block, to maintain a precise timestamp in restart or a power outage situation in a straightforward, cost effective manner. For connected grid mesh networks (CG-MESHs), when an entity needs to reform the network, the present techniques significantly reduce the cost of discovering a Personal Area Network (PAN) and reduce the frequency of asynchronous transmission. As a result, the performance of CG-MESH is improved.

DETAILED DESCRIPTION

In CG-MESHs, entities that restart abnormally complete the following key procedures to rejoin the network: (1) discover a PAN (i.e. a specific network in IEEE 802.15.4 terminology), (2) perform 802.1x-based mutual authentication and obtain link security keys, (3) discover a default route (e.g., by using a routing protocol for low-power and lossy networks (RPL), which may involve a number of operations), (4) configure a global IPv6 address (e.g., by using DHCPv6), and (5) advertise the global IPv6 address to configure downward routes (e.g., by using RPL).

In order to reduce the cost of network reformation, a formal fast reformation is often implemented, which saves most of the needed information, such as security keys, route information, internet protocol (IP) address, etc. in local memory. Indeed, using fast reformation may reduce cost. However, this implementation cannot reduce the cost of the first step, which is discovery of a PAN, because there is not a unicast or broadcast schedule for link transmissions synchronization. For discovering and synchronizing with other neighboring entities quickly, fast reformation with Enhanced Beacon (EB) and Enhanced

Beacon Request (EBR) protocols compliant with IEEE 802.15.4.e may be utilized. In this condition, asynchronous transmission should be considered. An asynchronous transmission typically involves transmitting frame(s) on each hopping channel in a back-to-back style, is expensive, and should be used sparingly. The present techniques provide the following benefits, mainly for an entity that needs to reform the network:

1) A significant reduction of the cost of discovering a PAN,
2) A significant reduction of the frequency of asynchronous transmission.

Accordingly, the present techniques improve CG-MESH network performance.

Using the fast reformation mechanism, a pair of command frames called fastsync request and fastsync beacon may be defined to accelerate the process of network discovery and synchronization. After restart, one entity broadcasts an EBR frame to all available channels. This transmission mechanism is referred to as "Async" (it is highly recommended not to use this mechanism to transmit frames because it introduces nondeterminancy to timeslot channel hopping communication and excessive link cost) and waits for a preferred parent to reply with an EB frame. This approach may occupy a considerable part of the total fast reformation process. Accordingly, present techniques center on how to reduce the time and link cost on discovering a PAN and synchronizing with PAN in terms of hardware. In addition, these techniques are not limited to an improvement in fast reformation, as they may also enhance other aspects of a MESH network.

In order to reduce cost when discovering and synchronizing with a PAN, the present techniques provide a hardware block using ultra low power real time clock (RTC) to maintain a unicast and broadcast schedule and channel slot information. FIG. 1 shows the designed hardware block diagram below.

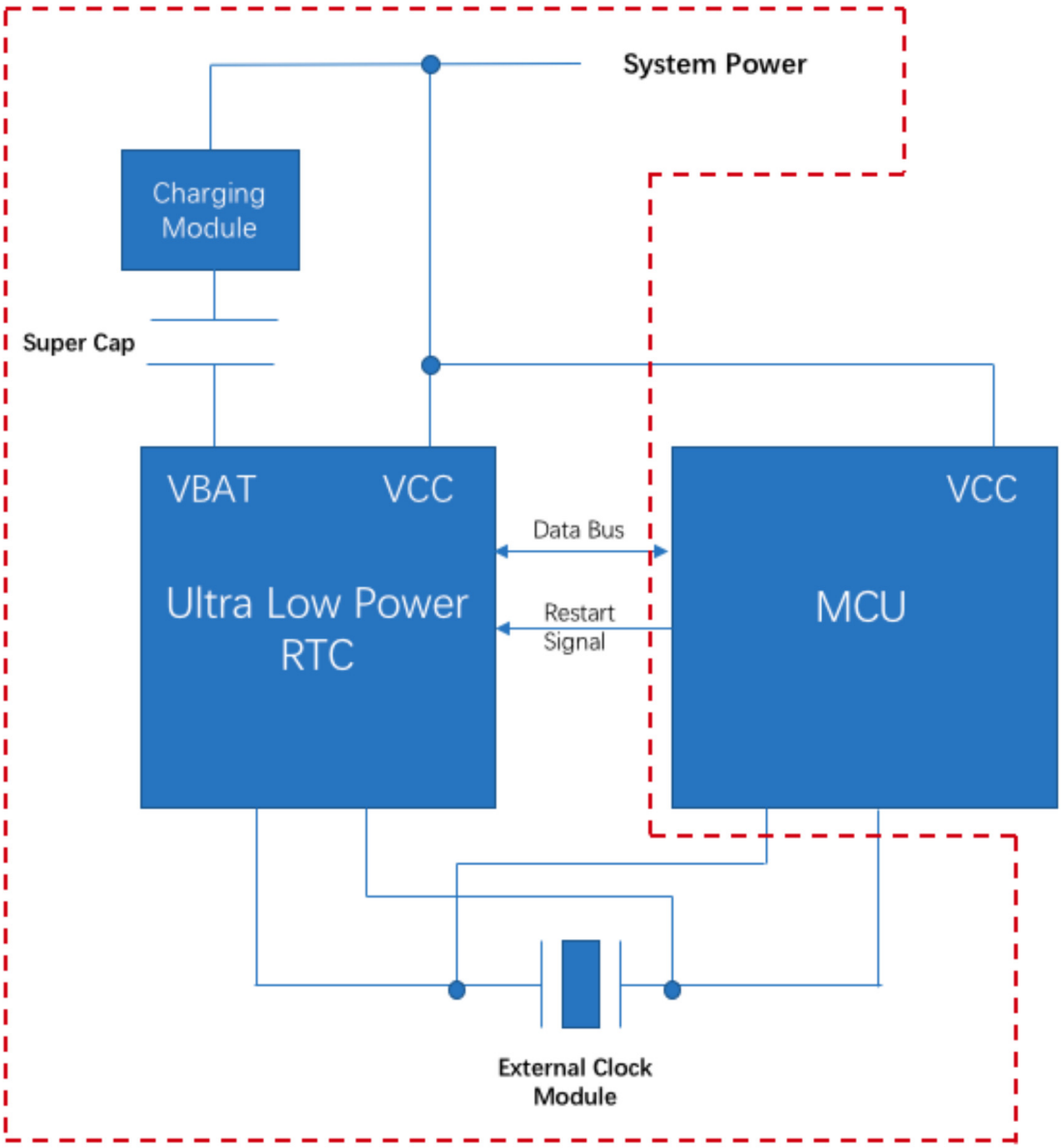

FIG. 1

Referring to FIG. 1, the block diagram (red dash) includes a charging module, a super cap, an ultra low power RTC, and an external clock module that provides a hardware solution that in any condition of restart (including a power outage) provides the following features:

1) an accurate continuous incremental time tick; and

2) ability to save the timestamp by the RTC, when the multipoint control unit (MCU) restart occurs.

With an accuracy in milli-seconds, the RTC module supports the MCU's task of maintaining schedule and channel slot information. When the entity recovers from a restart, the MCU may grasp the saved and current timestamp in milli-seconds from the RTC module. Using previous schedule information already saved by the fast reformation implementation, the MCU calculates the new schedule information precisely and immediately. Using the new schedule information, both unicast and broadcast packets may be sent in a short period of time. Taking advantage of these techniques, the cost of discovering a PAN may be reduced and the network reformation may greatly speed up.

Using the hardware block from FIG. 1, the software component performs the following operations:

1) Maintain the precise broadcast and unicast schedule periodically,
2) Trigger a restart signal indication to the RTC module,
3) Read a timestamp from the RTC module, and
4) Calculate the new precise broadcast and unicast schedule.

The following FIG. 2 illustrates an example procedure using an entity that calculates the new broadcast and unicast schedule in a power outage situation.

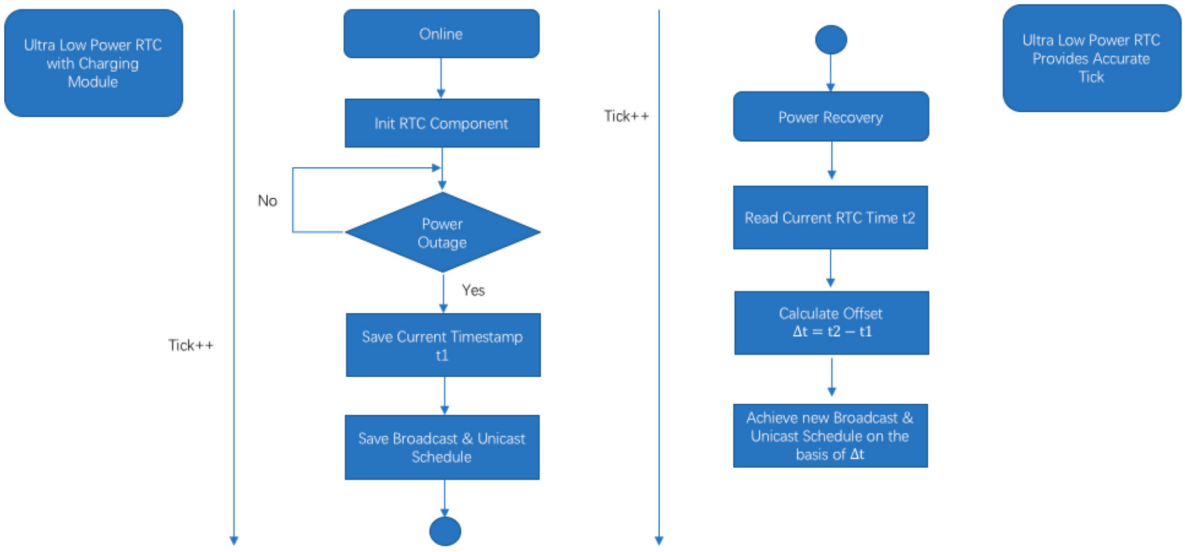

FIG. 2

In summary, the techniques provided herein, using a designed hardware block, maintain a precise timestamp in restart or during a power outage in a straightforward, cost effective manner. As a result, the performance of CG-MESH is improved.