

Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Out-of-Band Wakeup Mechanism for Downlink Communication in LECIM Network]

Date Submitted: [January, 2012]

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Abstract: [A MAC Proposal for Low Energy Critical Infrastructure Networks Applications]

Purpose: [To be considered in IEEE 802.15.4k]

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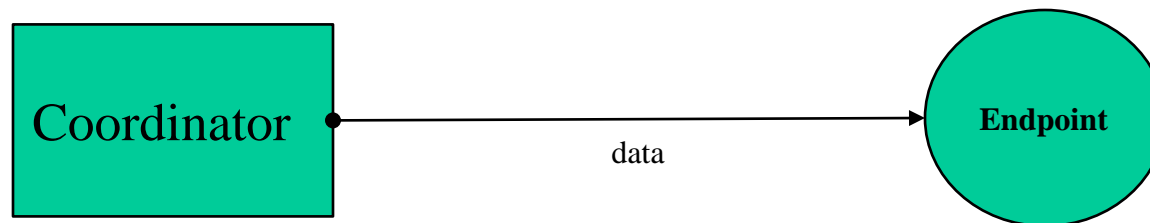
Out-of-Band Wakeup Mechanism for Downlink Communication in LECIM Network

Outline

- Downlink Communication
- Wakeup Radio Concept
- Downlink Communication in LECIM
- Downlink Communication using Wakeup Radio
- Other Uses of Wakeup Radio
 - Emergency handling
 - On-demand data communication

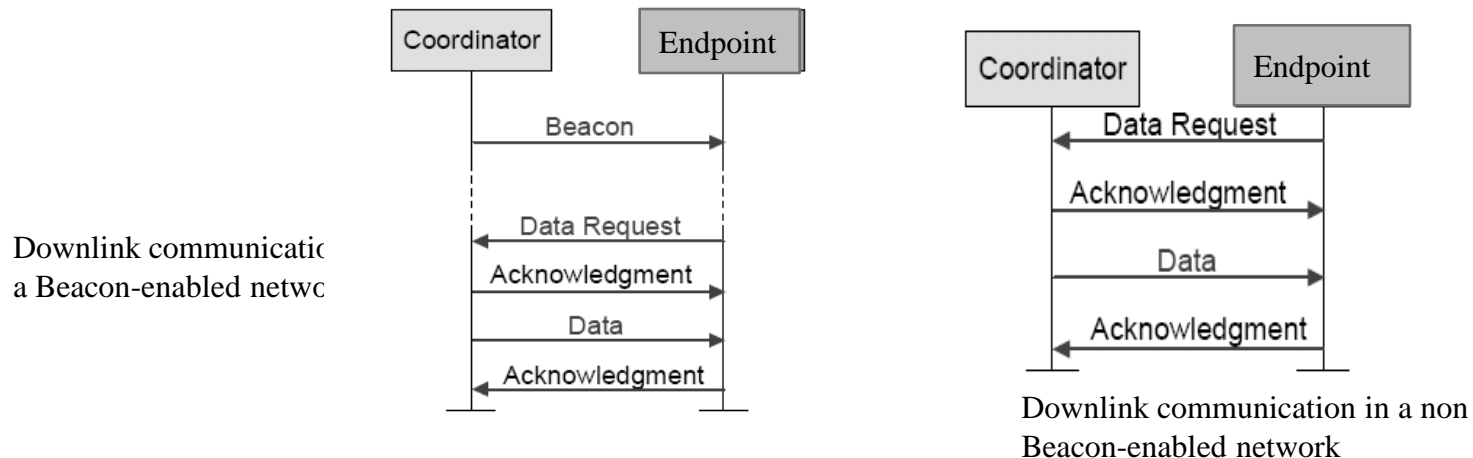
Downlink Communication (1)

- In downlink, the coordinator transmits data to an endpoint or group of endpoints
- To save power, endpoints usually remain in sleep state with main radio in OFF state when data communication is not required (duty cycle)
- Downlink is possible if the coordinator is aware that endpoint is awake or active (ready state)



Downlink Communication (2)

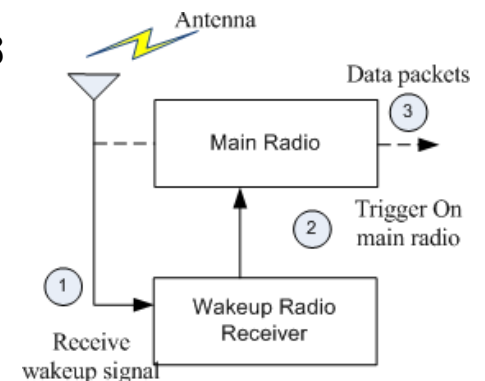
- In current existing methods such as IEEE802.15.x, the coordinator must wait till endpoint wakes up to send downlink data
- Two major concepts are in use
 - A ‘data pending’ notification using network beacon
 - A concept of ‘data request’ from endpoint is usually used



- If the coordinator wants to send urgent data to a sleeping endpoint, the existing method is unable to support it

Wakeup Radio Concept (1)

- A wakeup radio can be used for out-of-band wakeup mechanism in a network
- The basic working includes sending RF signal to a neighboring endpoint
- A new ultra low power transmitter/receiver is attached to the one of the input interrupts of the processor in the endpoint
- A circuit usually does not have own power supply but extracts power from the incoming signal
- The purpose is to wakeup an endpoint using external radio triggering
 - A wakeup receiver listens for the wakeup signal
 - It receives the wakeup signal in step-1, and triggers ON the main circuit and radio in step-2
 - The main radio starts the actual data communication in step-3



Wakeup Radio Concept (2)

- Hardware implementation is possible with very low cost
- A wakeup radio circuit consumes few μW power for operation
- The radio triggered circuit is independent of any other components on the node except the interrupt
- Wakeup radio signal contains enough power to trigger a wakeup process

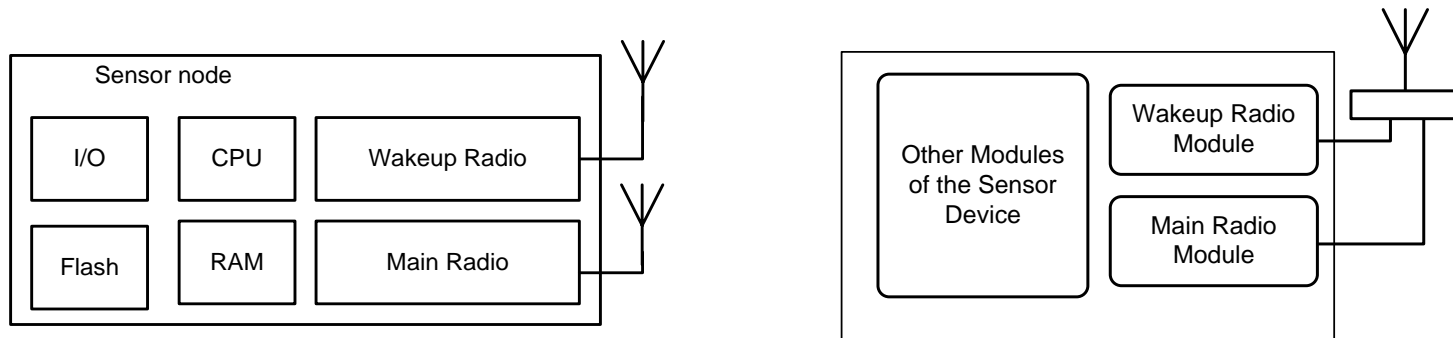


Fig. Use of a separate or common antenna for wakeup radio

Wakeup Radio Concept (3)

- Two kinds of wakeup radio can be used
 - **Passive wakeup radio**
 - Ultra low-power detector/receiver that uses energy from the wakeup signal and triggers on the main circuit (microprocessor)
 - Can be implemented in endpoints
 - **Active wakeup radio**
 - Can receive and send wakeup radio signal
 - Uses some power from internal battery
 - Can be implemented in coordinator/endpoint

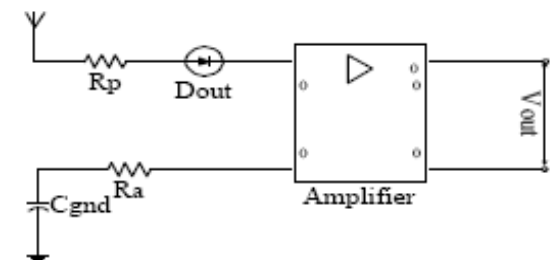
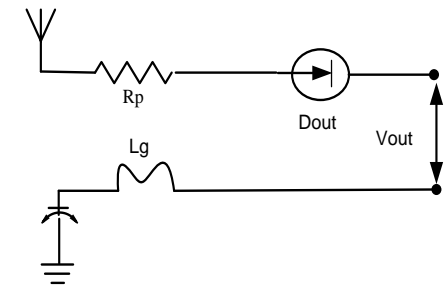


Fig. Simple wakeup radio receivers

Wakeup Packet

- A wakeup radio signal is actually a wakeup packet
- Wakeup radio can be used to unicast or broadcast downlink data
- A wakeup receiver address can use the network id of the endpoint for unique identification
- Addressing can be set to support unicast or broadcast
- A typical wakeup packet can be as shown below

Preamble	SFD	Addressing	CRC
SHR		Payload	FCS

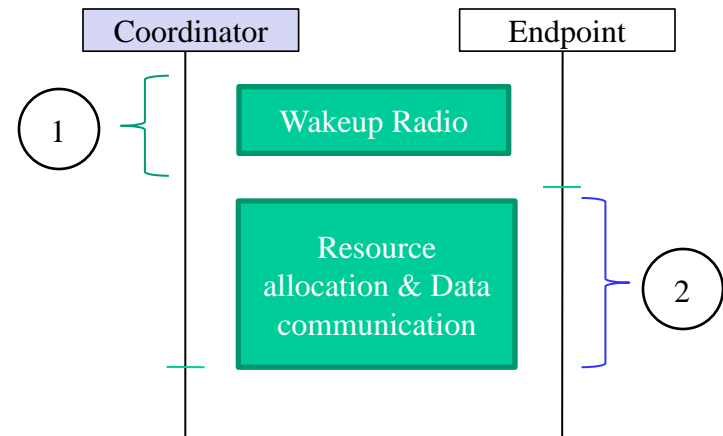
Fig. Wakeup packet

Downlink Communication in LECIM (1)

- The majority of downlink communication in LECIM network involves **network management**
- Out-of-band radio can be adopted for downlink communication as an additional option
- The coordinator can use wakeup radio transceiver and endpoint can use ultra low power wakeup radio receiver

Downlink Communication in LECIM (2)

- The communication is done in two stages
 - Stage 1: Wakeup radio
 - Stage 2: Actual data communication
- A coordinator can send wakeup radio signal to wakeup a sleeping endpoint whenever required
- Once an endpoint is awake, the communication can be completed using any of the MAC mechanisms adopted



Downlink Communication using Wakeup Radio

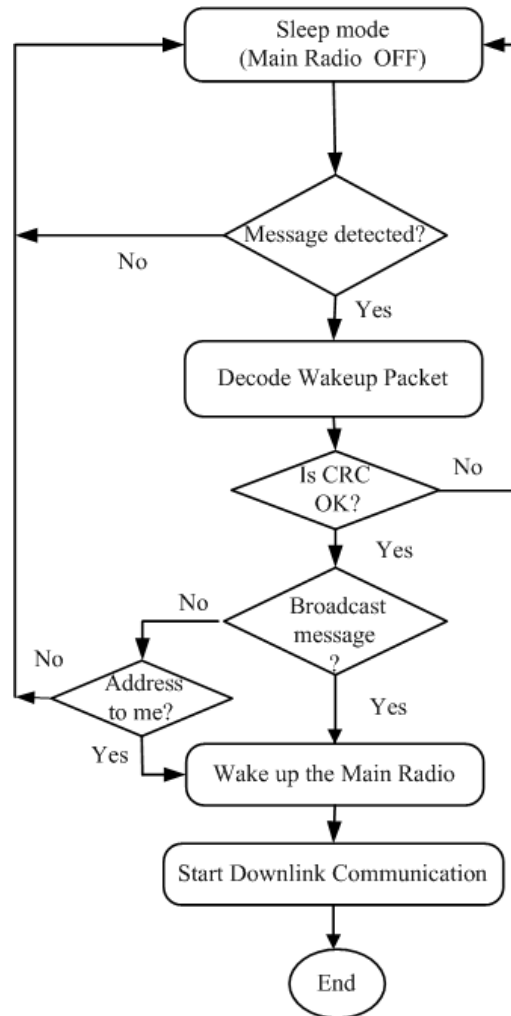
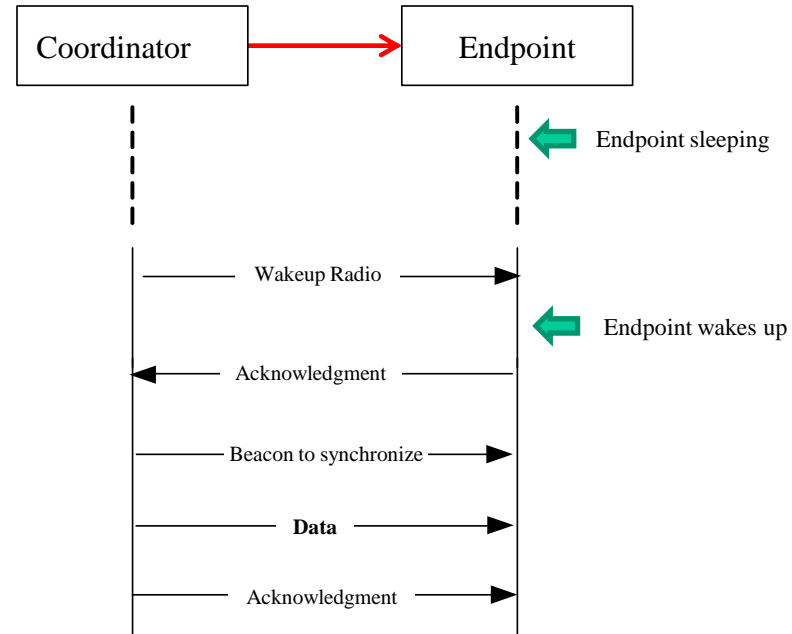


Fig. Flow chart

An example Downlink Data Transfer using Wakeup Radio

- The data transfer from **coordinator to an endpoint** in a beacon enabled mode
 - Instead of waiting for endpoint to wakeup, coordinator wakes it up using wakeup radio
 - An endpoint wakes up and sends Ack message
 - Coordinator sends the beacon
 - Endpoints grabs the beacon and synchronizes to superframe
 - Coordinator sends the data to the endpoint
 - Endpoint sends Ack message



NOTE: Once an endpoint is awake, we can use any preferred mechanism to transfer data

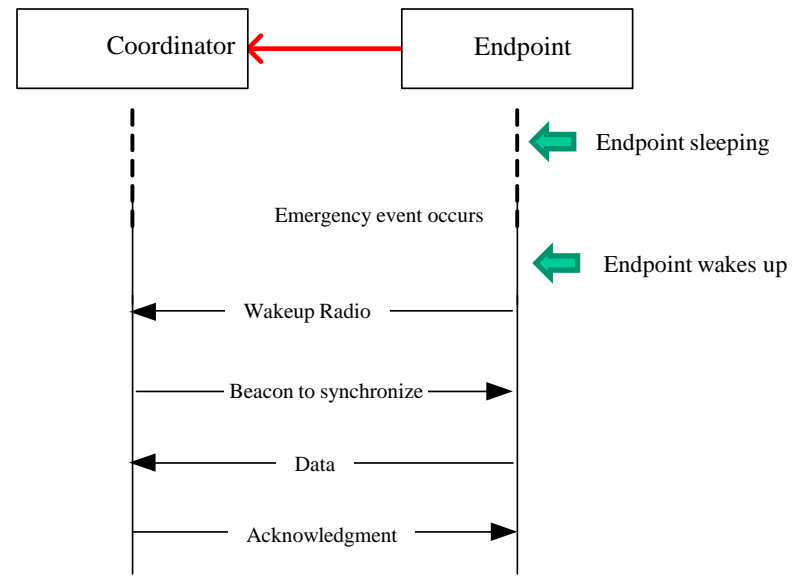
Other uses of Wakeup Radio for LECIM

Emergency Handling using Wakeup Radio

- Wakeup radio can be used to handle emergency situation
- The wakeup transceiver can respond immediately with minimal delay
- Use of wakeup radio can save power compared to contention base mechanism
- A wakeup radio uses fraction of the power compared to the conventional methods used in such a network

Emergency Handling using Wakeup Radio

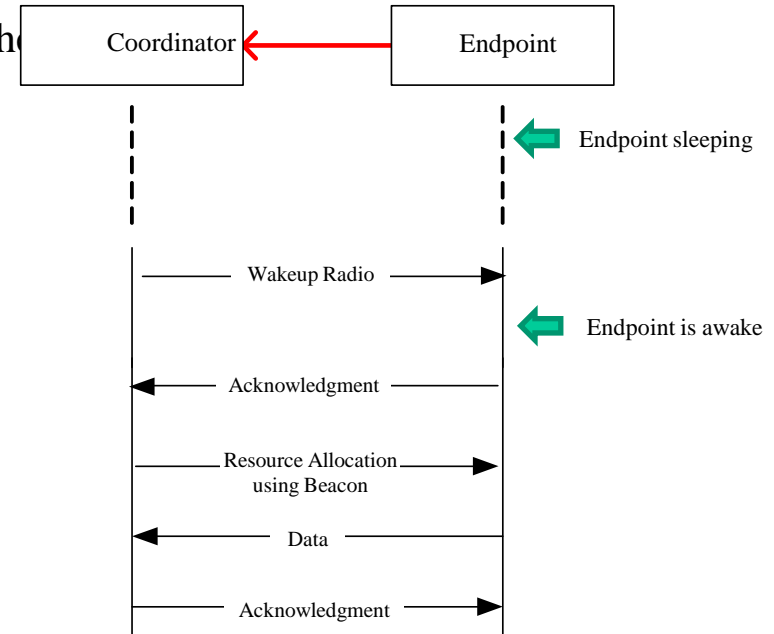
- An endpoint needs to be equipped with wakeup transceiver
- The data transfer **from endpoint to coordinator** in emergency case
 - On detecting emergency event, the endpoint triggers itself ON
 - It sends a wakeup signal to the coordinator and waits for beacon
 - Endpoints grabs the beacon and synchronizes to superframe
 - Coordinator sends the data to the endpoint
 - Endpoint sends Ack message



An example Uplink Data Transfer using Wakeup Radio

- **On-demand** data transfer from **endpoint to coordinator**

- Unscheduled data request by coordinator e.g. status report
- If a coordinator requires data from an endpoint before its schedule, wakeup radio can be used
- Coordinator sends wakeup radio to endpoint
- The endpoint wakes up and sends Ack message
- Coordinator sends the beacon to synchronize and allocate resources
 - A data request message can be piggybacked in the beacon
- Endpoint sends data to the coordinator
- Coordinator sends Ack message



Conclusion

- Downlink in LECIM is used for network management
- We present an optional radio triggered wakeup mechanism for downlink communication in LECIM network
- Additionally wakeup radio can be used to initiate emergency and on-demand data communication
- Wakeup radio can be used with little extra cost to the system

The End

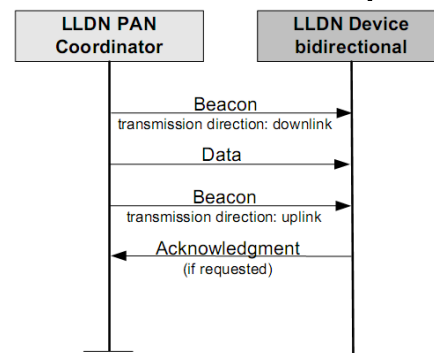
Thank You

Downlink Data Transfer

- **802.15.4a/4i**
- When the coordinator wishes to transfer data to a device in a beacon-enabled network, it indicates in the network beacon that the data message is pending.
- The device periodically listens to the network beacon and, if a message is pending, transmits a MAC command requesting the data, using slotted CSMA-CA or ALOHA, as appropriate.
- The coordinator acknowledges the successful reception of the data request by transmitting an optional acknowledgment frame.
- The pending data frame is then sent using slotted CSMA-CA or ALOHA, as appropriate.
- The device acknowledges the successful reception of the data by transmitting an acknowledgement frame.

Downlink Data Transfer

- **802.15.4e in Low Latency Deterministic Network**
- When the LLDN PAN coordinator wishes to transfer data to an LLDN device assigned to a bidirectional time slot in an LLDN, it indicates in the network beacon that the transmission direction is downlink.
- At the appropriate time, the LLDN PAN coordinator transmits its data frame to the device without using CSMA-CA.
- The device may acknowledge the successful reception of the data by transmitting an acknowledgment frame to the LLDN PAN coordinator in the same time slot of the next superframe.
- In order to do so, the transmission direction has to be uplink in that superframe.



An example receiver

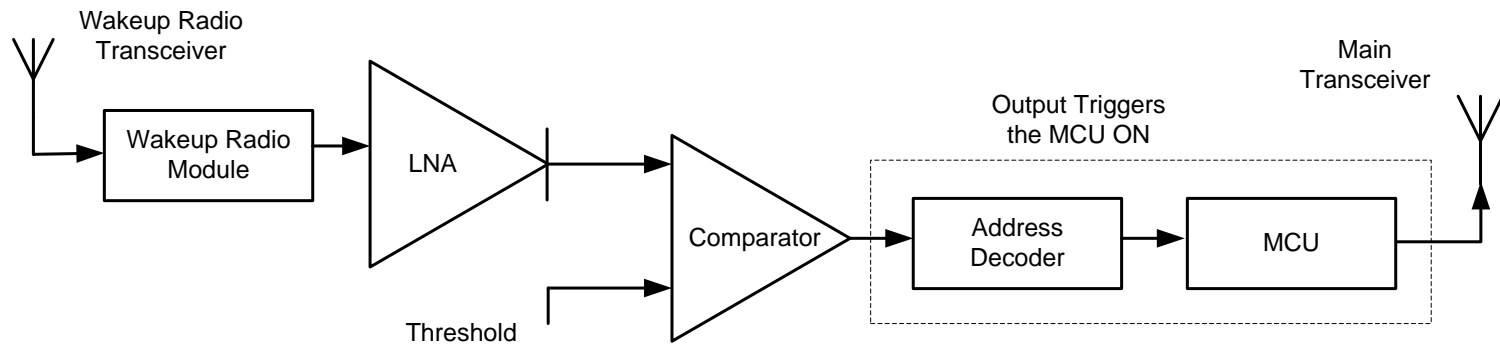


Fig. A low power wakeup radio structure for LECIM