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

Submission Title: [Out-of-Band Radio Triggered Wakeup Mechanism for Downlink Communication in LECIM Network]
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Abstract: [A MAC Proposal for Low Energy Critical Infrastructure Networks Applications]

Purpose: [To be considered in IEEE 802.15.4k]

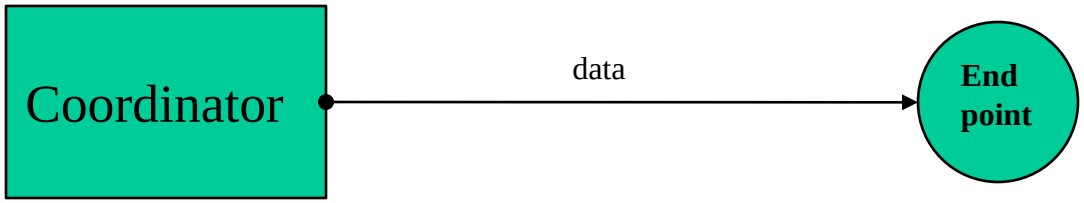
Out-of-Band Radio Triggered Wakeup Mechanism for Downlink Communication in LECIM Network

Outline

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

Downlink Communication in LECIM (1)

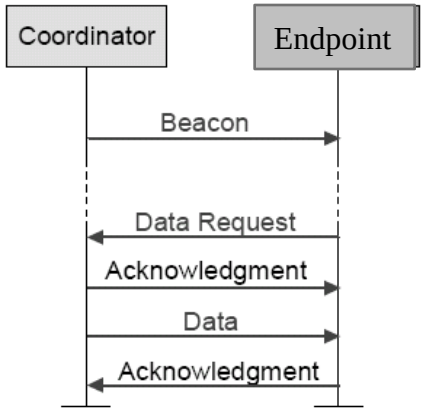
- In downlink, the coordinator transmits data to an endpoint or group of endpoints
- In LECIM, downlink communication mainly involves **network management**
- Downlink is possible if the coordinator is aware that endpoint is awake or active.
- To save power, endpoints usually remain in sleep state with main radio in OFF state when data communication is not required
- It makes difficult for the coordinator to communicate and may arise long delay



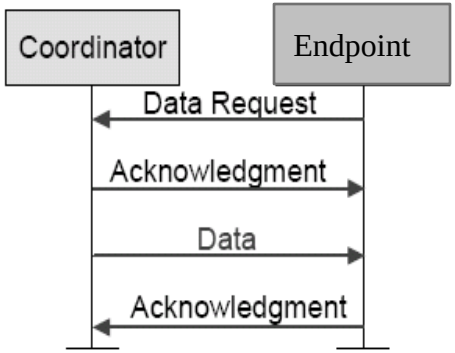
Downlink Communication in LECIM (2)

- In current existing methods such as IEEE802.15.x, the coordinator must wait till endpoint wakes up to send downlink data
- A concept of 'data request' from endpoint is usually used

Existing downlink communication mechanism in 802.15.4x



Downlink communication in a Beacon-enabled network

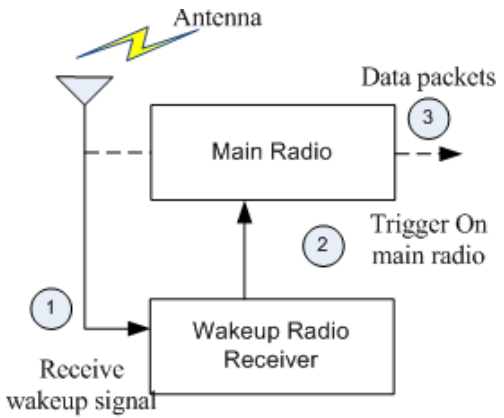


Downlink communication in a non Beacon-enabled network

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

Wakeup Radio Concept

- A wakeup radio is used for out-of-band wakeup mechanism in a network
- The basic working includes sending RF signal to a neighboring device to wake it up
- A new ultra low power transmitter/receiver is attached to the sensor devices
- A simple working of wakeup radio is shown below
  - A wakeup receiver listens for the wakeup signal
  - It receives the wakeup signal in step-1, and triggers ON the main radio in step-2
  - The main radio starts the actual data communication in step-3.



Wakeup Radio Concept

- Hardware implementation is possible with very low cost
- A wakeup radio circuit consumes few μW power for operation
- Wakeup radio signal contains enough power to trigger a wakeup process

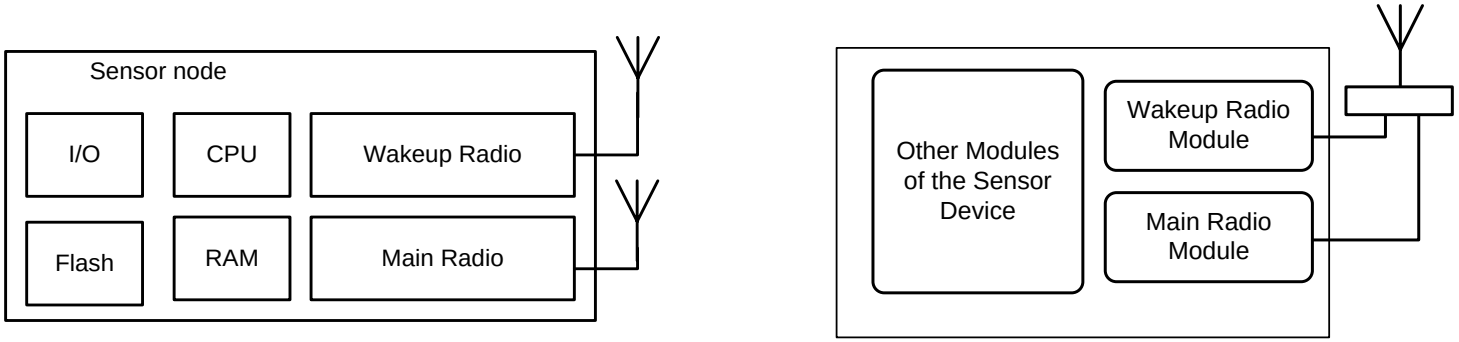
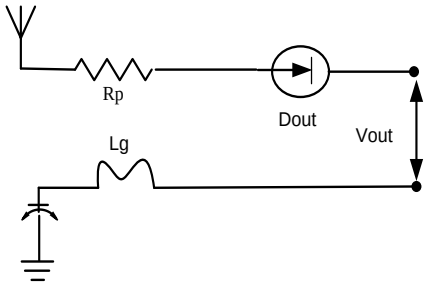


Fig. Use of a separate or common antenna for wakeup radio

Wakeup Radio Concept

- 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
    - Can be implemented in endpoints
  - **Active wakeup radio:**
    - Can receive and send wakeup radio signal
    - Uses internal power
    - Can be implemented in coordinator/endpoint



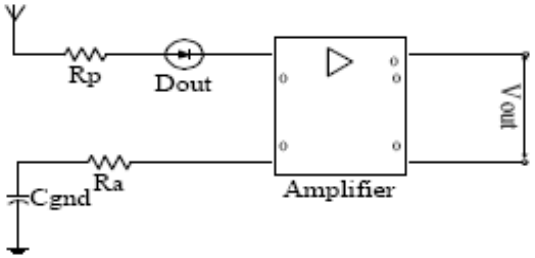
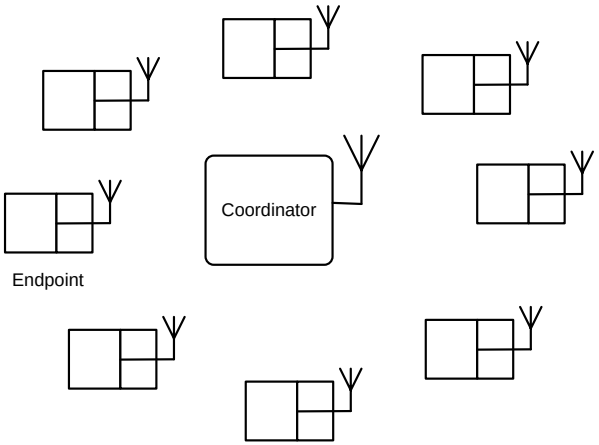
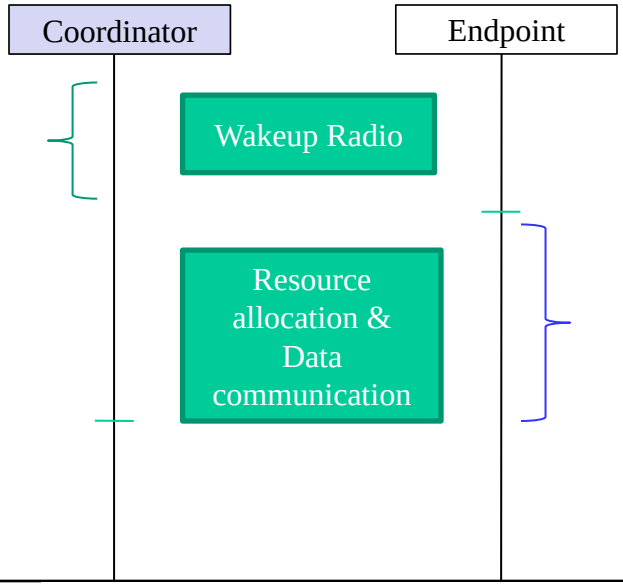


Fig. Simple wakeup circuits

Wakeup Radio for Downlink Communication

- Wakeup radio can be adopted in a LECIM for downlink communication
- Coordinator can use wakeup radio transceiver and end device can use ultra low power wakeup radio receiver
- 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 mechanism adopted for LECIM





Downlink Communication using Wakeup Radio

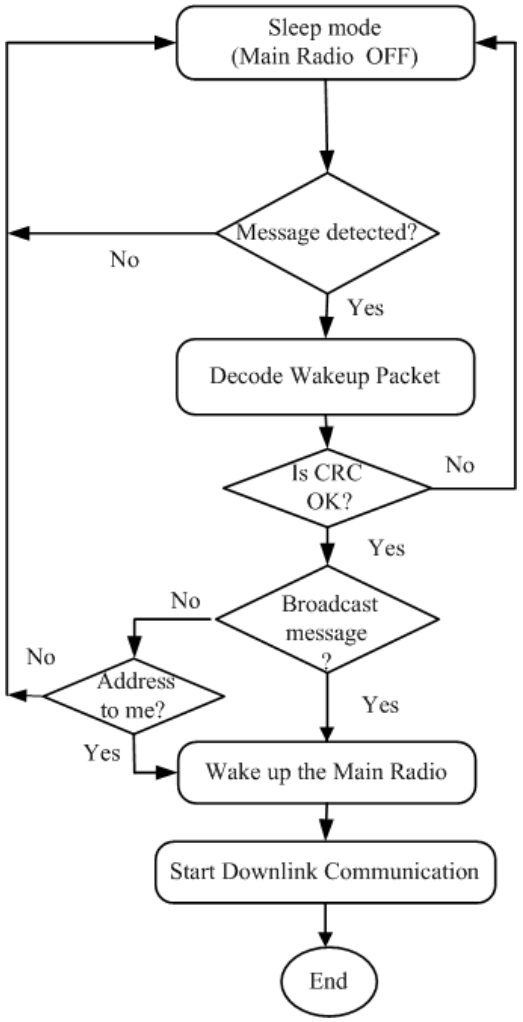


Fig. Flow chart

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

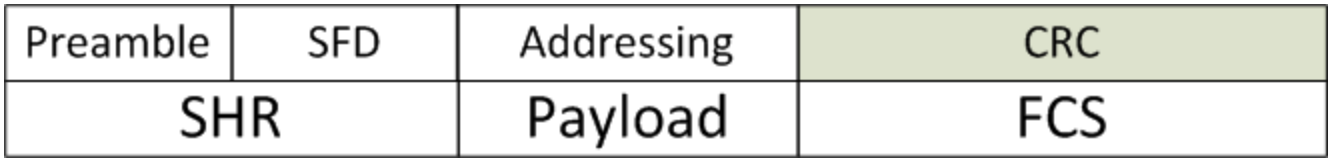
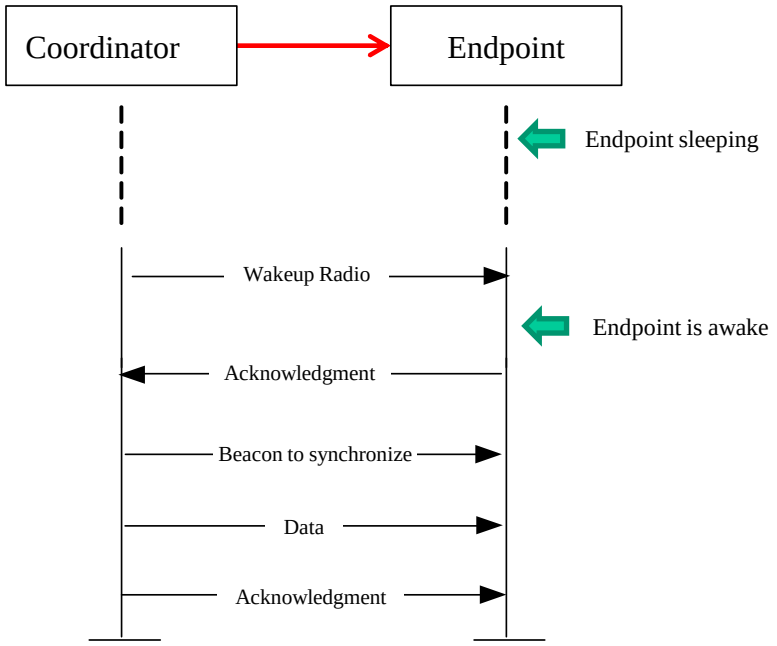


Fig. Wakeup packet

An example Downlink Data Transfer using Wakeup Radio

- The data transfer from coordinator to an endpoint
  - Instead of waiting for endpoint to wakeup, coordinator wakes it up using wakeup radio
  - The 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



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

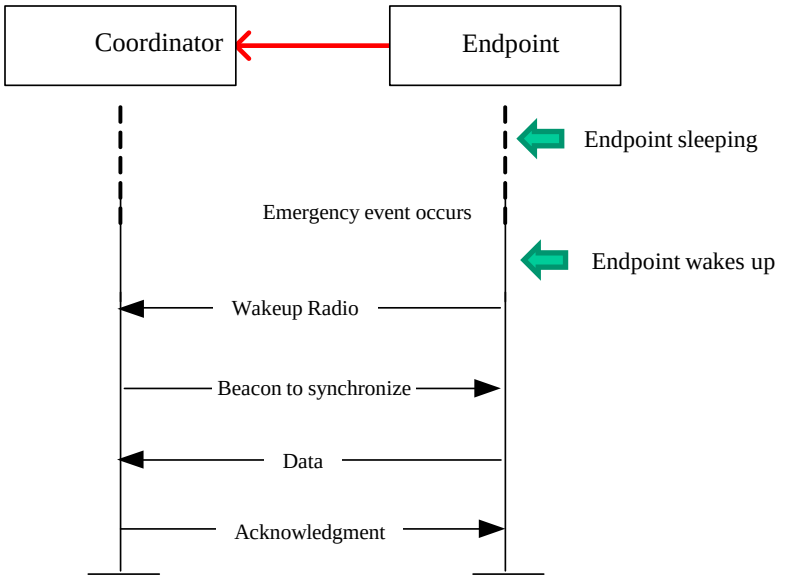
Other uses of Wakeup Radio for LECIM

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 based mechanism
- A wakeup radio uses fraction of the power compared to the conventional methods used in such a network

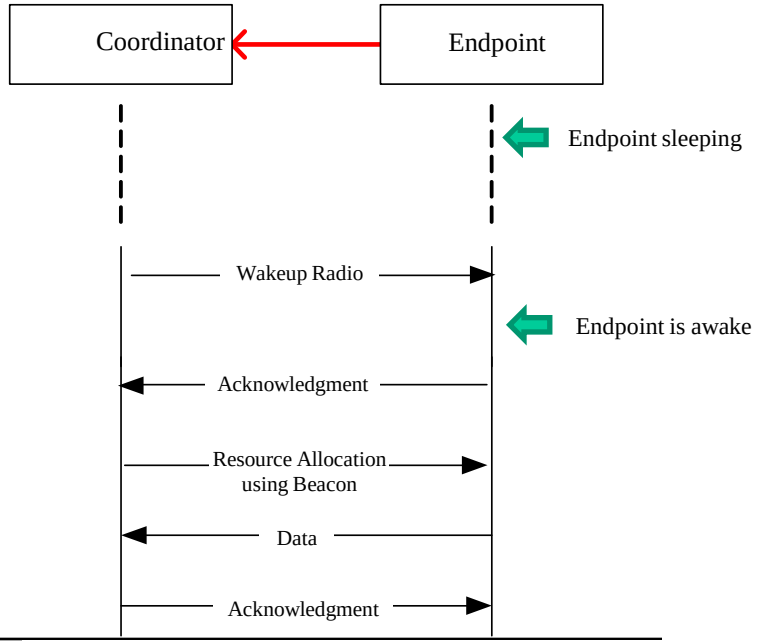
Emergency Handling using Wakeup Radio

- 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
  - 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 and 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

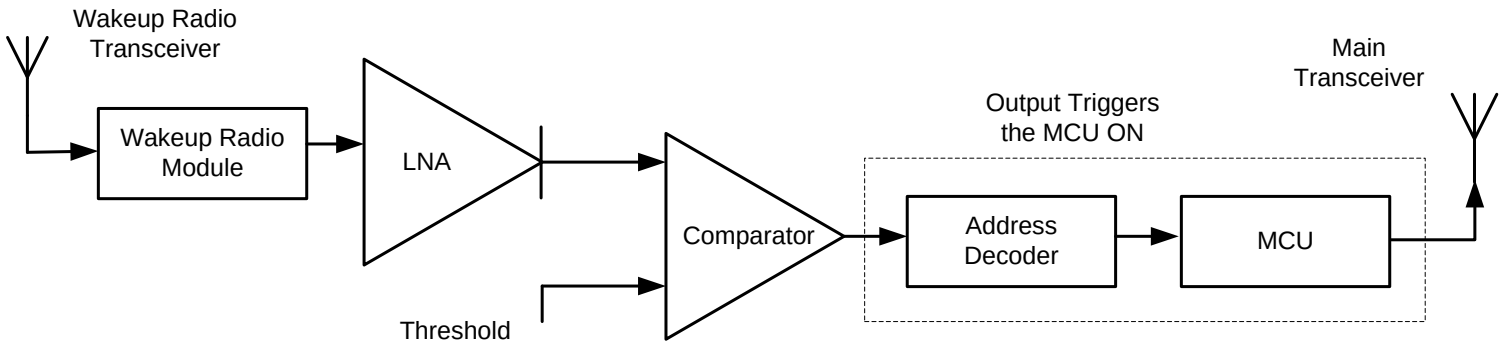


Fig. A low power wakeup radio structure for LECIM