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

Submission Title: [Downlink Communication for ULP Network using Wakeup Packet]
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Abstract: [A MAC Proposal for Ultra Low Power Applications]

Purpose: [To be considered in IEEE 802.15.4q]

Downlink Communication for ULP Network using Wakeup Packet

Outline

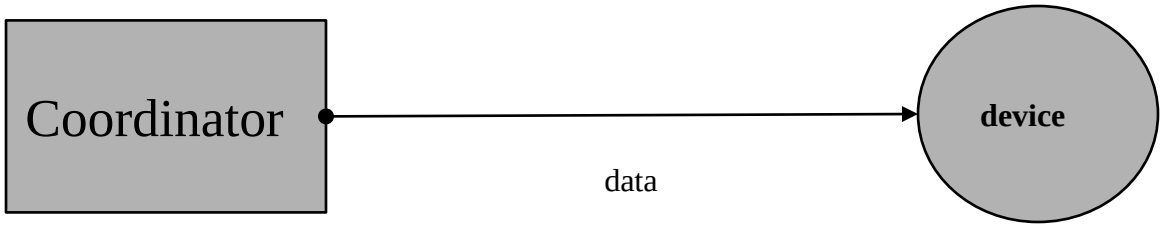
- Introduction
- Downlink Communication
- Downlink Communication for ULP
- Example of Downlink Data Transfer using Wakeup Packet
- Conclusion

Introduction

- Sleep mode power consumption is much less than idle power consumption
- Two types of wakeups for a sleeping device
- Timer-Based
  - When a node enters sleep mode, it sets a timer to wakeup at a pre-determined time
  - It is based on duty cycle and the nodes wakeup periodically whether or not other nodes have data to transmit to them
- On-Demand
  - A sleeping node can be woken at any time via wakeup radio communication
  - The wakeup packet is sent at a separate radio frequency
  - Recent low-end radio transceivers support multiple frequency operations

Downlink Communication

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



Downlink Communication

- In current existing methods such as IEEE802.15.4x, the following concepts are employed:
  - A 'data pending' notification using network beacon
    - the coordinator must wait till the network devices wakeup to send downlink data
  - A concept of 'data request' from the device

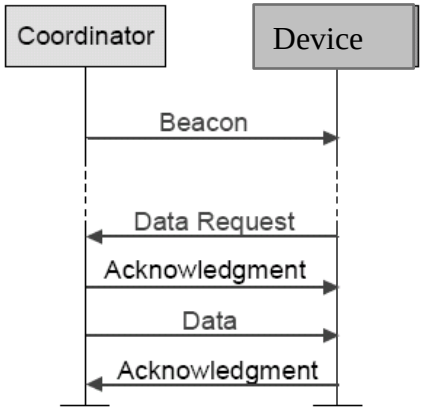


Fig. Downlink in a Beacon-enabled network

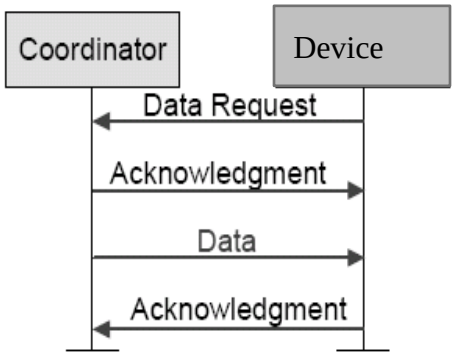


Fig. Downlink in a non Beacon-enabled network

Downlink Communication

- In **15.4x** 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
- Another method used is that 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
- Demerit: Nodes wakeup when there are no pending packets
  - Loss of power

Implementation Cost

- An ultra low power wakeup radio can be easily implemented with very low hardware cost
- Low power is achieved by:
  - Simpler hardware with a lower bit-rate and/or less decoding capability
  - Periodic listening using a radio with identical physical layer as data radio
- 10m distance can be easily covered for a receiver under -70 dBm sensitivity

Available Wakeup Radio Receivers	Wakeup power required
L.Gu Basic receiver	84 µW
Van Dam 868MHz Wakeup receiver	171 µW
RTWAC	2.6 µW @3V
Picoradio	1 µW
WuP	470 nW @2V
CargoNet	4.8 µW @3V
Durante Ultra-Low Wakeup	7.5 µW @1.5V
DBW receiver	75 µW

Downlink Communication for ULP

- A method by which a coordinator can downlink as and when required can improve the efficiency of the network
- A wakeup packet can be used to wakeup a device (unicast) or multiple devices (multicast/broadcast)
- Use of wakeup packet can eliminate the need of periodic wakeup of the network devices thereby saving energy
- Use of wakeup packet can reduce delay

Downlink Communication for ULP

- The downlink communication can be done in two stages
  - Stage 1: Wakeup packet transmission
  - Stage 2: Actual data communication
- The coordinator transmits wakeup packet to wakeup a sleeping device whenever required
- Once a device is awake, the communication can be completed using any of the adopted MAC mechanisms

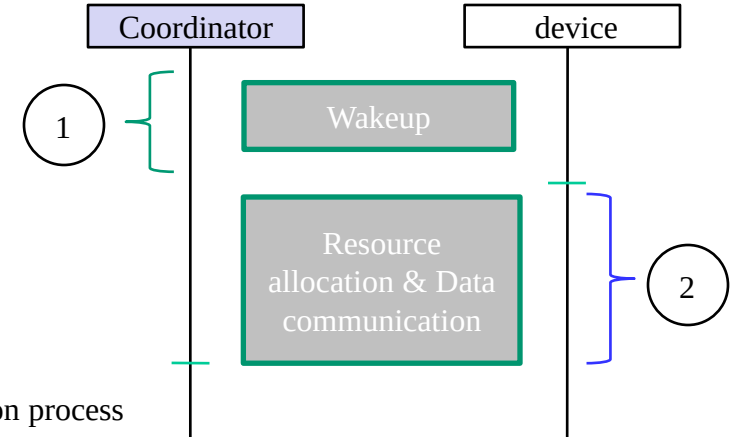


Fig. Communication process

Wakeup Packet

- A wakeup packet can be used to unicast or broadcast downlink data
- Unicast wakeup can use immediate ACK while broadcast wakeup can use group Ack policy
- A sender/receiver address can be used for identification

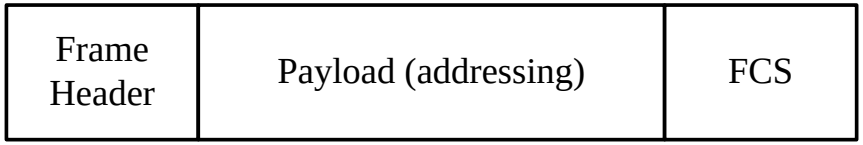
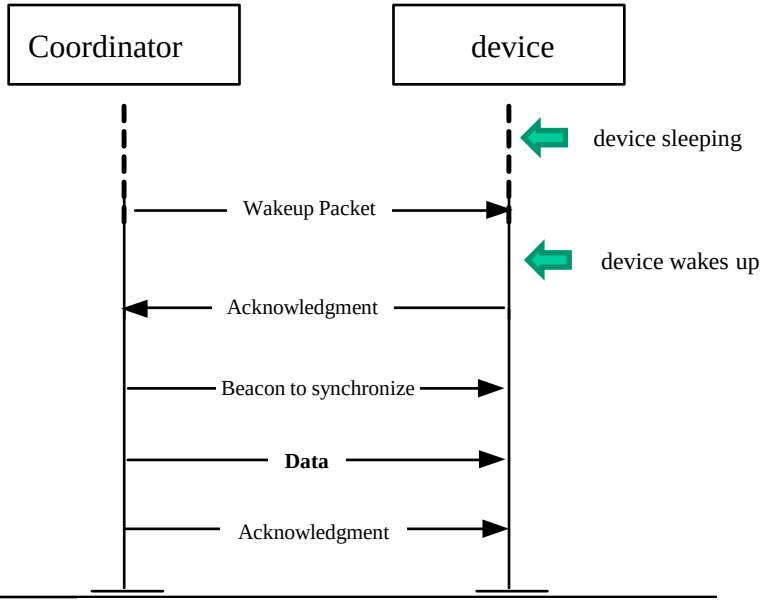


Fig. Wakeup packet

Example of Downlink Data Transfer using Wakeup Packet

- The data transfer from coordinator to a device in the beacon enabled mode
  - Instead of waiting for device to wakeup, coordinator sends the wakeup packet to the device(s)
  - The device wakes up and sends Ack packet
  - The device grabs the beacon and synchronizes to the superframe
  - Coordinator sends the data to the device
  - The device sends Ack packet



NOTE: Once a device is awake, we can use any preferred mechanism to transfer data

Conclusion

- An optional radio triggered wakeup mechanism for downlink communication for ULP network is discussed
- This method can conserve energy by reducing periodic listening of the network devices
- Wakeup radio can be used with little extra cost to the system
- We propose that alongside the traditional 802.15.4x downlink mechanisms, wakeup by wakeup packet be adopted for downlink communication as an additional option

The End

Thank You