Integrated Data and Energy Network (DEIN) System

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Outline

Selected Article

- Distributed Batteryless Access Control for Data and Energy Integrated Networks: Modeling and Performance Analysis [1]


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Distributed Batteryless Access Control for Data and Energy Integrated Networks: Modeling and Performance Analysis

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I. Introduction

A. Background and Motivation

Figure: Article 1

Additional Readings

For a better understanding of the domain, we also read:

- Throughput Maximization and Fairness Assurance in Data and Energy Integrated Communication Networks [3]
- Integrated Data and Energy Communication Network: A Comprehensive Survey [2]
- Data and Energy Integrated Communication Networks for Wireless Big Data [4]
- Joint Uplink and Downlink Resource Allocation in Data and Energy Integrated Communication Networks [5]

System Components

The system is composed of:

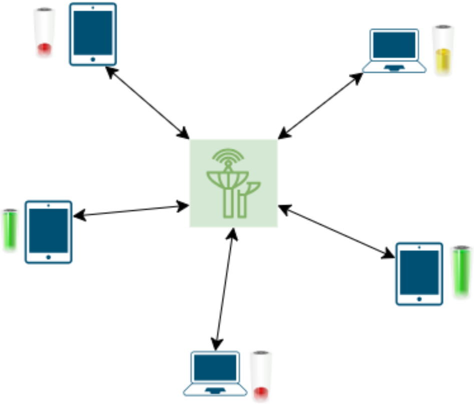
- Hybrid Access Point (HAP)

- Wireless Devices (WD)

Components Description

- Hybrid Access Point (HAP): The central component with a stable source of energy. It acts as a pivot for simultaneous data and energy transfer to wireless devices via RF signals.
- Wireless Devices (WDs): Harvest RF energy for data download and upload operations during communication with HAP.

System Architecture



System overview

- A WD requests data from a HAP. The HAP sends both data and energy to the requesting WD and transmits energy to all other WDs as down-link transmission. The requesting WD uses some of the received energy to decode the data and stores the remaining energy through energy harvesting. Non-requesting WDs store all the received energy.
- A WD can only send data to the HAP. It consumes energy from its harvested energy for this transmission.

Note regards Collision

We suppose that our system uses TDMA protocol to avoid collision.

Formal Definition of State Machine

State Machine

$P = < C, V, A, T >$

- C: finite set of control states.
- V: finite set of variables.
- A: finite set of actions on V.
- T: $\subseteq C \times A \times C$ be a finite set of transitions.

Formal Definition of the WD State Machine

State Machine for the WD

- C: Idle, DataTransmission, SignalReception.
- V: id: int, $id - sender$: int, Es: int, maxEWD: int, EneToDecode: int, EPCK: int, EWD: int.
- T: Sending Data, Data Sent,Signal Requesting,normal harvesting, parallal harvesting

How does the system work

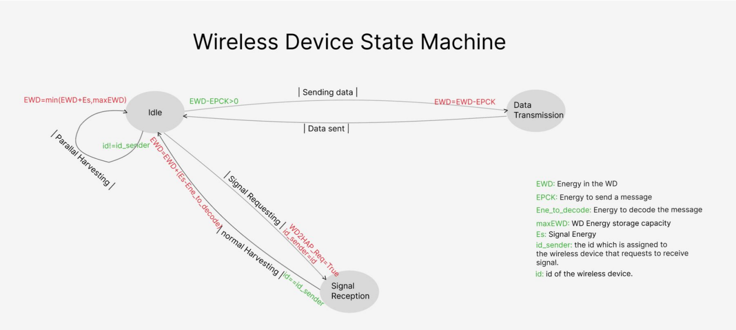


Figure: Wireless device state machine

Formal Definition of the HAP State Machine

State Machine for the HAP

- C: Idle, DataReception, SignalTransmission.
- V: id: int, $id - sender$: int.
- T: Signal Sending, Message Receiving,Finishing Data Reception,Finishing Signal Transmission

How does the system work

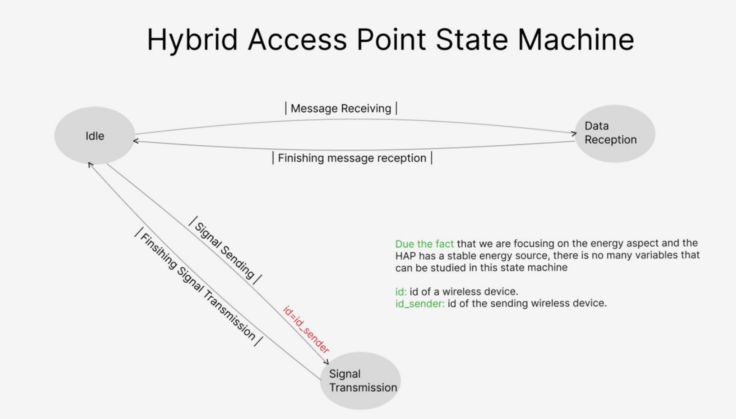


Figure: HAP state machine

Proposed Properties

Reachability

- The SignalReception state can be reached eventually by a WD (WD0,WD1 and WD2).

Liveness Properties

- When a HAP is transmitting a Signal, One WD (WD0,WD1 or WD2) should eventually be receiving it.
- When a WD is in the state of SignalReception, the other WDs should be in the state of Idle.

Proposed Properties

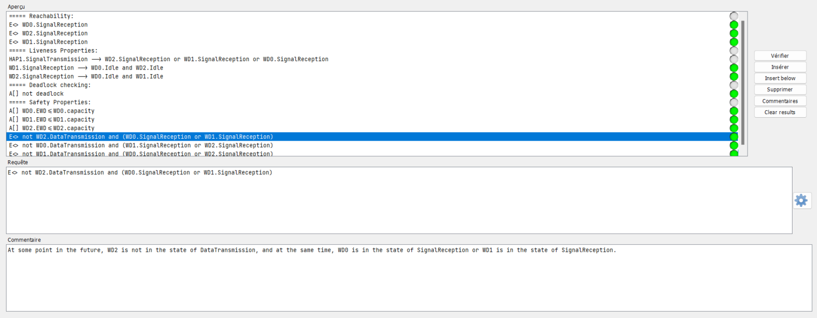
Deadlock

- Ensure that deadlock never occurs.

Safety

- Always ensure that the energy stored in WD (EWD) is less than or equal to the capacity of WD.
- In the future, A WD can never be Transmitting Data if one of the other WDs is Receiving data.

Verification of the properties with UPPAAL



CSMA/CA Based DEIN network

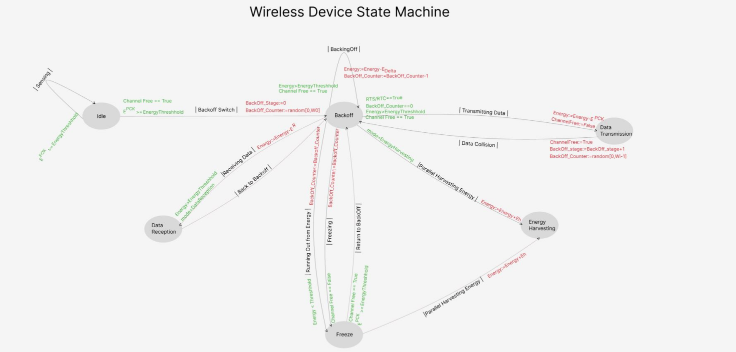


Figure: State machine of a WD Implementing CSMA/CA

[1] Xinyu Fan et al. "Distributed Batteryless Access Control for Data and Energy Integrated Networks: Modeling and Performance Analysis". In: *IEEE Internet of Things Journal* (2023).

[2] Jie Hu et al. "Integrated data and energy communication network: A comprehensive survey". In: *IEEE Communications Surveys & Tutorials* 20.4 (2018), pp. 3169–3219.

[3] Kesi Lv et al. "Throughput maximization and fairness assurance in data and energy integrated communication networks". In: *IEEE Internet of Things Journal* 5.2 (2017), pp. 636–644.

[4] Kun Yang et al. "Data and energy integrated communication networks for wireless big data". In: *IEEE access* 4 (2016), pp. 713–723.

[5] Qin Yu et al. "Joint Uplink and Downlink Resource Allocation in Data and Energy Integrated Communication Networks". In: *KSII Transactions on Internet and Information Systems (TIIS)* 11.6 (2017), pp. 3012–3028.