

Outline

- 1 State-of-the-art
- 2 System architecture and description
- 3 Properties
- 4 Future Work

Selected Article

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

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

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Abstract *Wireless LAN (WLAN) stacks are groups of standard protocols that implement network and hardware communication between two or more devices. This paper presents the design and implementation of a WLAN stack performance evaluation tool. The tool is capable of simulating the performance of a distributed system with multiple nodes and links. The tool is designed to evaluate the performance of a WLAN stack by measuring the throughput, latency, and packet loss. The tool is implemented in C++ and uses the NetSim simulation engine. The tool is designed to be used by network engineers to evaluate the performance of a WLAN stack before it is deployed in a real-world environment.*

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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)



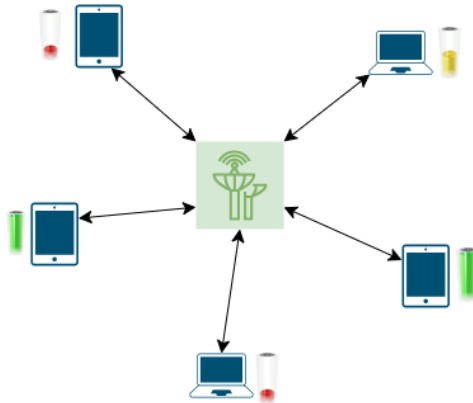
- Wireless Devices (WD)



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

$$P = \langle C, V, A, T \rangle$$

- 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: $id: \text{int}$, $id - sender: \text{int}$, $Es: \text{int}$, $\text{maxEWD}: \text{int}$, $EneToDecode: \text{int}$, $EPCK: \text{int}$, $EWD: \text{int}$.
- T: Sending Data, Data Sent, Signal Requesting, normal harvesting, parallel harvesting

How does the system work

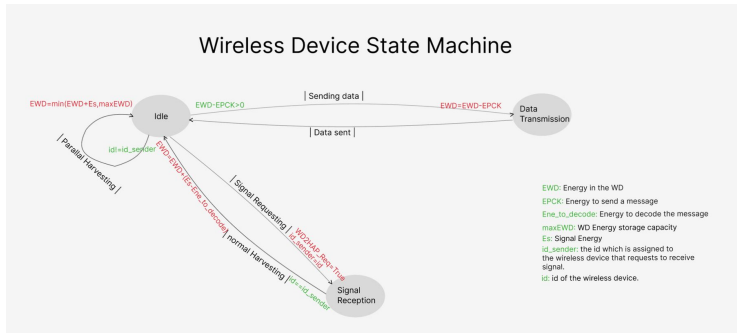


Figure: Wireless device state machine

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

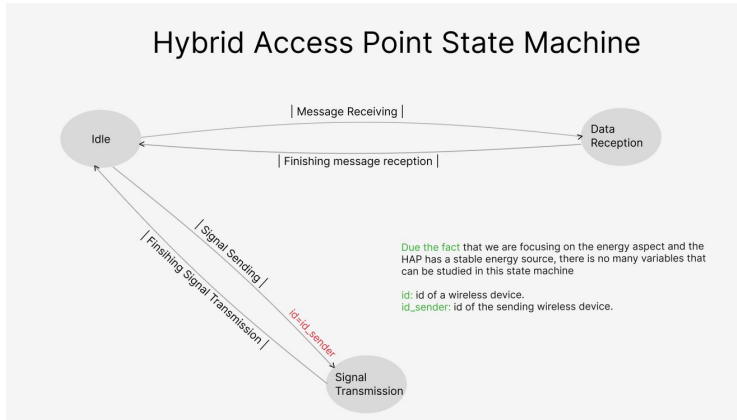


Figure: HAP state machine

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



The screenshot displays the UPPAAL model checker interface. On the left, a list of properties is shown, with the following text:

```
==== Reachability:
E<= WD0.SignalReception
E<= WD2.SignalReception
E<= WD1.SignalReception
==== Liveness Properties:
MAP1.SignalTransmission -> WD2.SignalReception or WD1.SignalReception or WD0.SignalReception
WD1.SignalReception -> WD0.Idle and WD2.Idle
WD2.SignalReception -> WD0.Idle and WD1.Idle
==== Deadlock checking:
A[] not deadlock
==== Safety Properties:
A[] WD0.EWD < WD0.capacity
A[] WD1.EWD < WD1.capacity
A[] WD2.EWD < WD2.capacity
E<= not WD2.DataTransmission and (WD0.SignalReception or WD1.SignalReception)
E<= not WD0.DataTransmission and (WD1.SignalReception or WD2.SignalReception)
E<= not WD1.DataTransmission and (WD0.SignalReception or WD2.SignalReception)
Results
E<= not WD2.DataTransmission and (WD0.SignalReception or WD1.SignalReception)
```

On the right side of the interface, there is a vertical column of 15 green circles, indicating that all properties have been successfully verified. To the right of this column is a control panel with the following buttons: Vérifier, Insérer, Insérer below, Supprimer, Commentaires, and Clear results.

Below the list of properties, there is a section labeled "Commentaire" (Comment) with the following text:

At some point in the future, WD2 is not in the state of DataTransmission, and at the same time, WD0 is in the state of SignalReception or WD1 is in the state of SignalReception.

CSMA/CA Based DEIN network

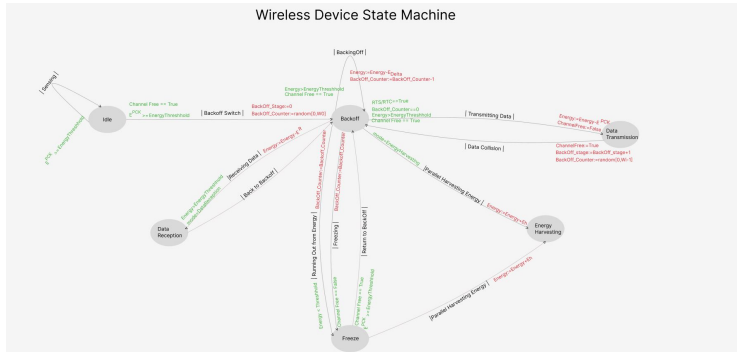


Figure: State machine of a WD Implementing CSMA/CA

- [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.
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