

Exploring Tradeoffs between Energy Consumption and Network Performance in Cellular-IoT: a Survey

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Introduction

- The Internet of Things (IoT) is growing at an unprecedented rate
- In order to accommodate such a growth, we can modify existing cellular protocols and utilize existing cellular infrastructures - Cellular IoT (C-IoT)
- With so many devices in C-IoT, improving the energy efficiency of each device can have profound impacts
- However, improving energy efficiency often comes with network performance tradeoffs
- **Our Contribution:** Existing literature on C-IoT energy efficient techniques are identified, categorized and analyzed in terms of tradeoffs. Future research directions are discussed

Scheduling

The ways time and frequency are utilized in a network is crucial to the power consumption of the network. Example: [1]

- **Uplink:** The utilization of time-frequency resources and routing of information from User Equipment (UE) to Base Station (BS)
- **Downlink:** The time-frequency resource utilization and routing from BS to UE
- **Both Uplink and Downlink:** Some technologies can be applied in both directions
- **Typical Tradeoffs:** Energy-delay and energy-throughput

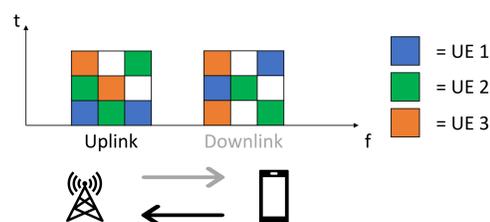


Figure 1: Example of scheduling in a cellular network

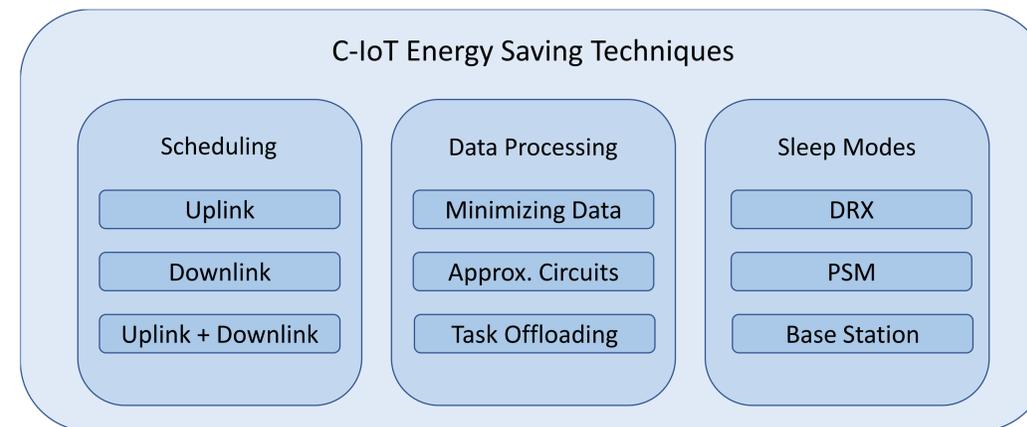


Figure 2: Categorization of cellular IoT energy saving technologies

Data Processing

By changing where, when, and how data is processed in C-IoT, energy can be saved. Example: [2]

- **Minimizing Transmitted Data:** By reducing the amount of information needed to transmit, the transmission power in the network can be reduced
- **Approximate Circuitry:** Circuits which compute approximate solutions can save energy when compared with exact circuitry
- **Task Offloading:** Through changing where a task is computed, energy can be saved in the network overall
- **Typical Tradeoffs:** Energy-accuracy and energy-complexity

Sleep Modes

By allowing a device to enter periods of time where RF activity is either reduced or stopped entirely, the device can save significant energy. Example: [3]

- **Discontinuous Reception (DRX):** Allows UEs to turn off their circuitry for brief periods of time, allowing devices to trade off delay for energy efficiency
- **Power Save Mode (PSM):** With a similar philosophy to DRX, PSM allows significantly longer periods of sleep
- **Base Station:** Base stations can also turn off their RF circuitry for short periods of time
- **Typical Tradeoff:** Energy-delay

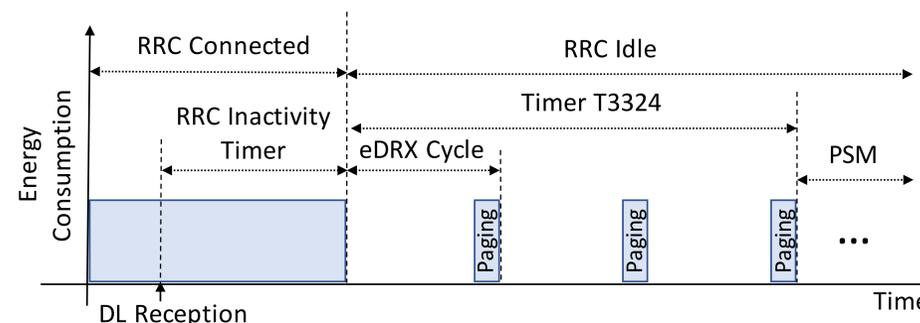


Figure 3: DRX with PSM timing diagram

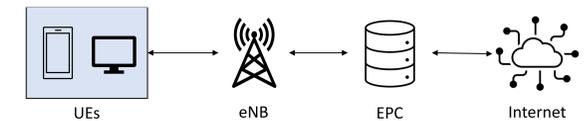


Figure 4: Typical architecture of C-IoT networks

Conclusion

In this work, the state of the art in energy-saving technologies in C-IoT was presented, and the resulting network performance tradeoffs were discussed. The literature was categorized into three categories: scheduling, data processing, and sleep modes.

Future Research Directions

We recommend future research in this area focus on:

- 1 More systematically **quantifying tradeoffs between energy and performance** to better understand the technology's operation holistically
- 2 The verification of results using **real hardware**. As opposed to simulation, which often sacrifices reality for feasibility, hardware experiments more accurately represent reality

References

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- [2] M. Osta, A. Ibrahim, H. Chible, and M. Valle. Inexact Arithmetic Circuits for Energy Efficient IoT Sensors Data Processing. In *2018 IEEE ISCAS*, pages 1–4.
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- [4] N. Accurso, N. Mastronarde, and F. Malandra. Exploring Tradeoffs between Energy Consumption and Network Performance in Cellular-IoT: a Survey. In *2021 IEEE GLOBECOM*.