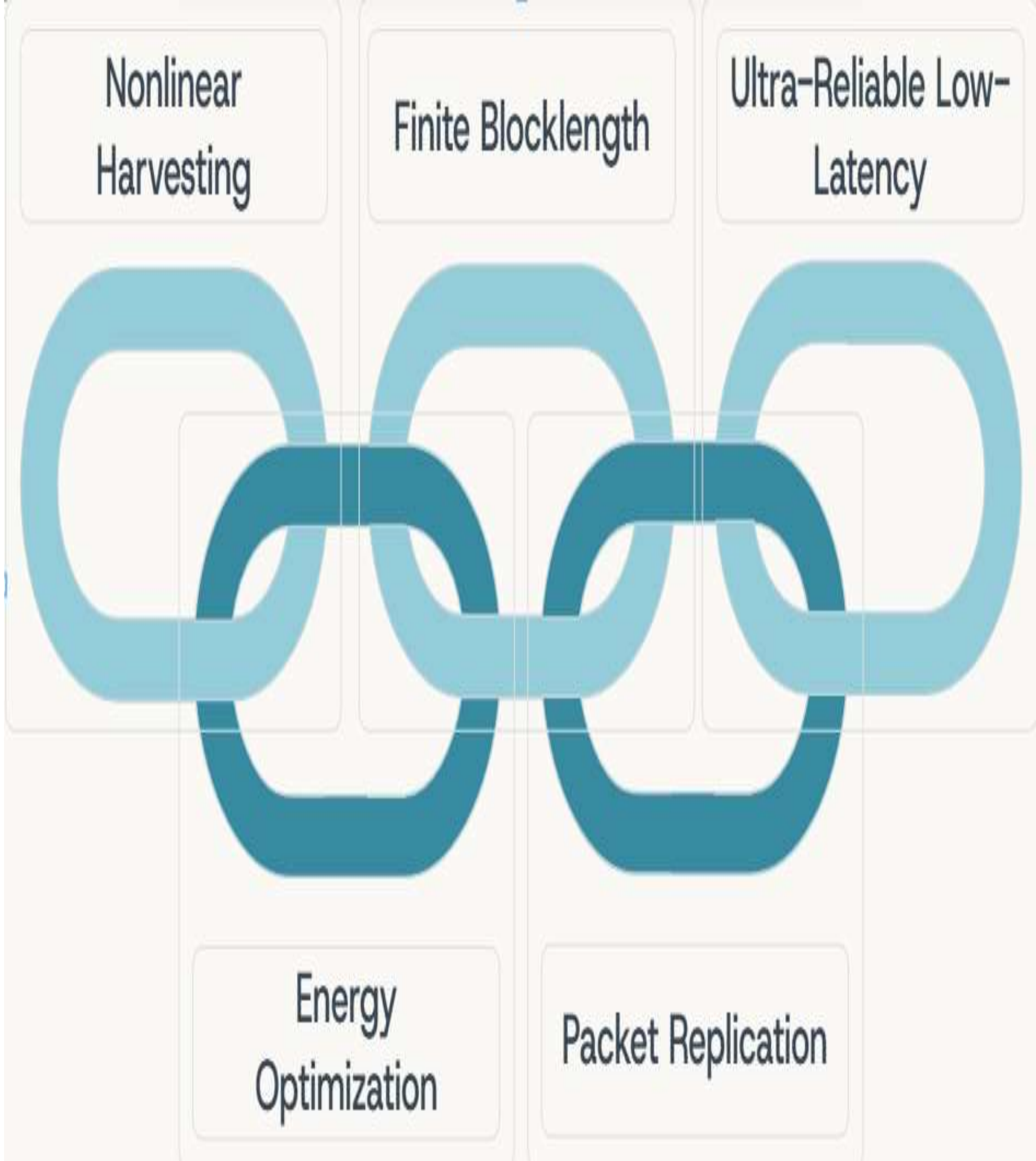
ENERGY-EFFICIENT WIRELESS-POWERED URLLC SYSTEM WITH NONLINEAR ENERGY HARVESTING AND FINITE BLOCKLENGTH ANALYSIS

Contents:

Introduction :

This project develops a smart communication system for small Internet of Things (IoT) devices that are powered wirelessly and have very limited energy. These devices need to send short but important messages quickly and with high reliability, which is essential in areas like healthcare monitoring, safety alarms, and industrial automation. To achieve this, we use a realistic model of how devices harvest energy from wireless signals, optimize the time spent collecting energy before sending data, and improve reliability using techniques like sending the same message multiple times. We also use advanced analysis methods to check performance for short messages, making the system more practical, energy-efficient, and dependable than traditional approaches.



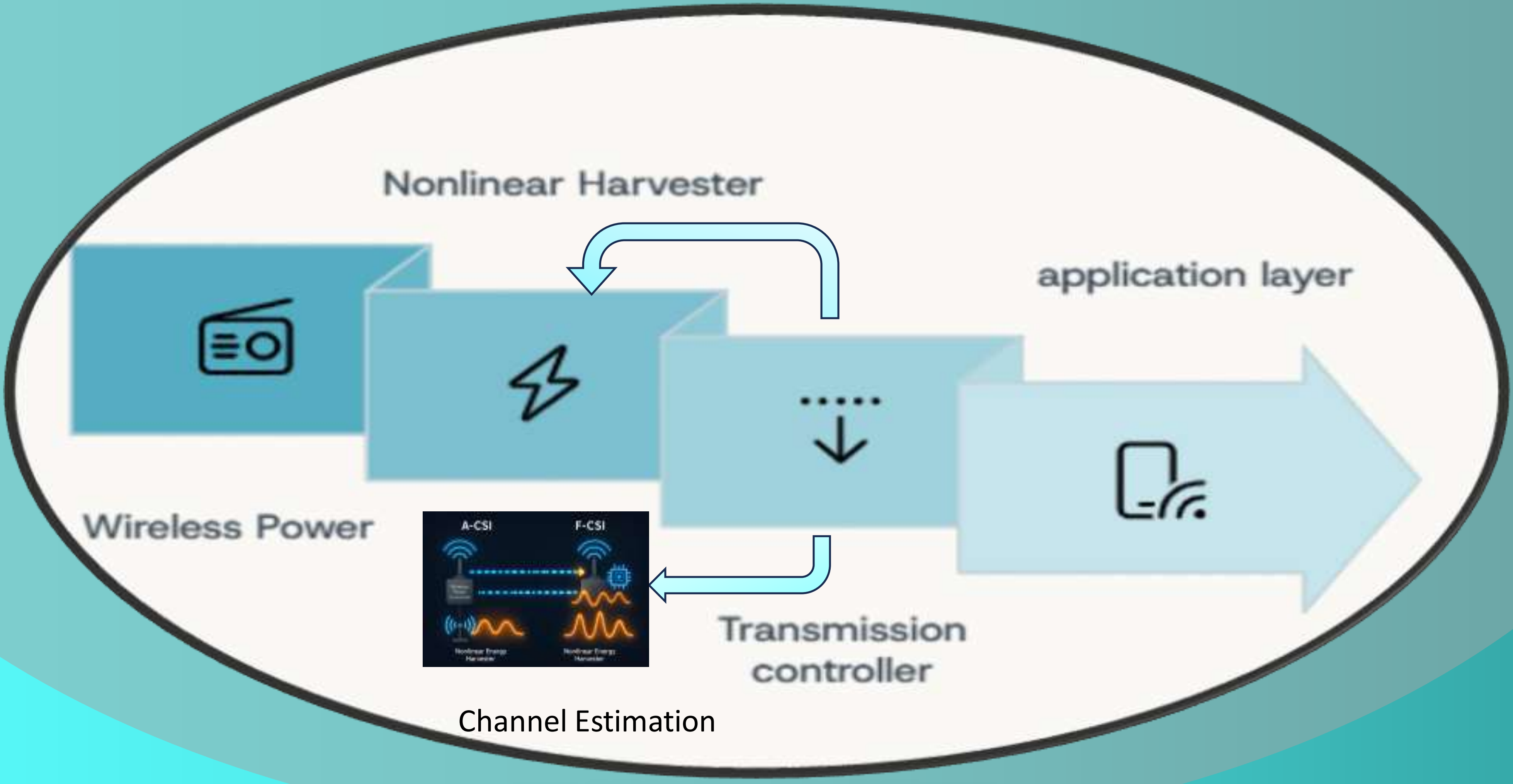
Title justification

The title **“Energy-Efficient Wireless-Powered URLLC System with Nonlinear Energy Harvesting and Finite Blocklength Analysis”** reflects the key focus areas of this project. It aims to design a communication system for devices that operate by harvesting energy from wireless signals, making them more energy-efficient and suitable for low-power IoT applications. Since the system targets **Ultra-Reliable Low-Latency Communication (URLLC)**, it ensures that data is sent quickly and with high reliability, which is essential for critical tasks. The use of a **nonlinear energy harvesting model** makes the design more realistic by accounting for actual hardware behavior, and **finite blocklength analysis** helps evaluate the performance of short data packets accurately, going beyond traditional communication models.

Objectives:

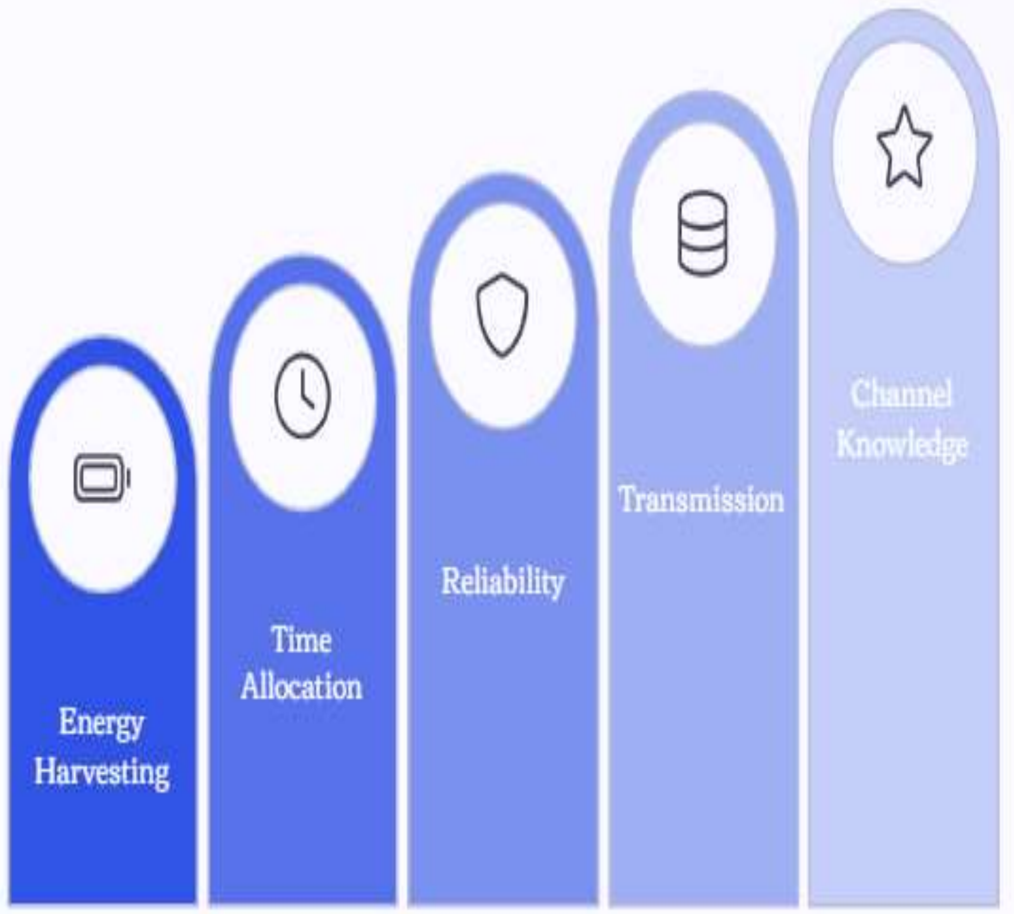
1. **Model realistic energy harvesting** by considering nonlinear efficiency and saturation in wireless-powered devices.
2. **Optimize harvest–transmit scheduling** to maximize energy efficiency while meeting communication deadlines.
3. **Adapt transmission strategies** for both full and average channel state information scenarios.
4. **Achieve ultra-reliable low-latency communication** for short data packets using finite blocklength theory.
5. **Validate the proposed system** through simulations, showing improvements in reliability and energy usage over existing methods

Block Diagram

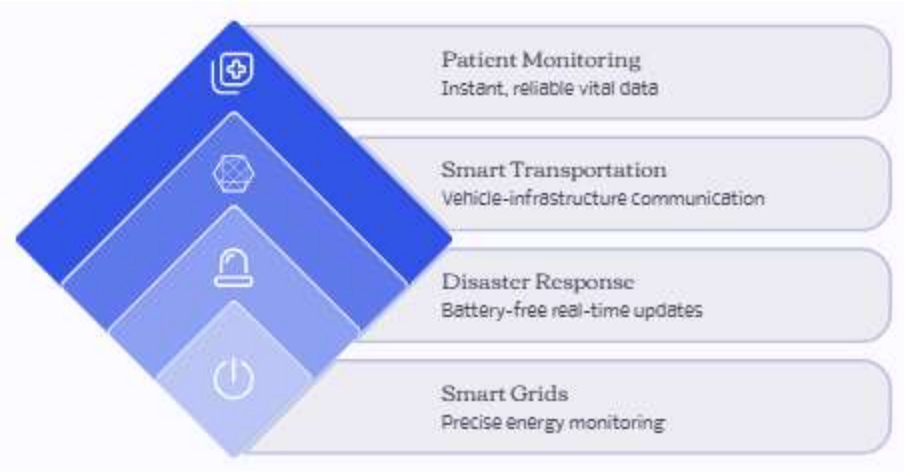


Existing and Proposed methods

Aspect	Existing Methods	Proposed Methods
Energy Harvesting Model	Linear EH model (constant efficiency)	Nonlinear EH model (efficiency variation, saturation effects)
Harvest–Transmit Time Allocation	Fixed time split	Dynamic optimization (adapts to channel conditions)
Reliability Analysis	Shannon capacity (infinite packet length assumption)	Finite blocklength theory (accurate short-packet assessment)
Transmission Strategy	Single transmission	Packet replication/diversity
Channel Knowledge	Full CSI only	Supports Full CSI and Average CSI



Applications :



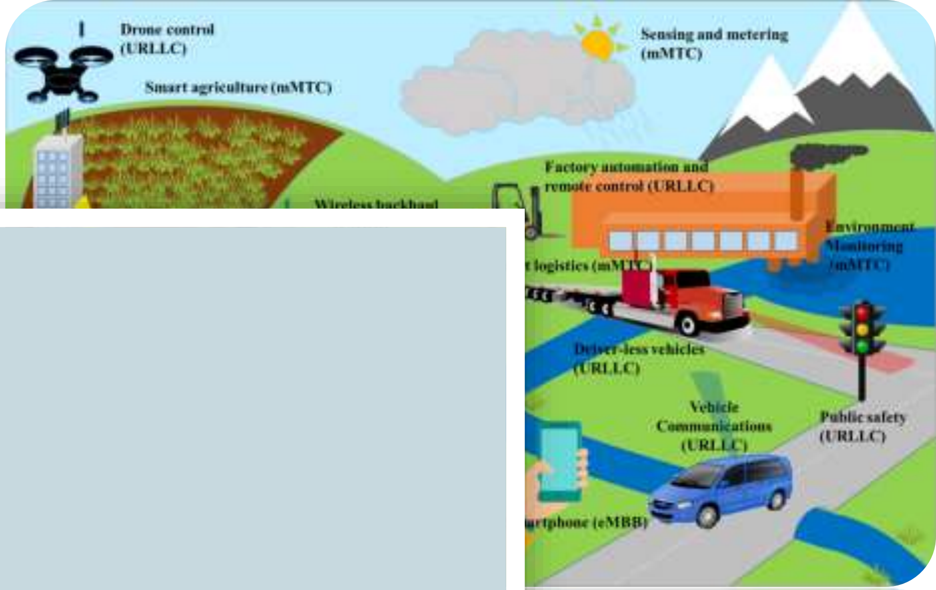
1. **Industrial Automation**
   Achieving real-time, wireless control of machinery for enhanced precision, safety, and efficiency in smart factories.

2. **Healthcare Monitoring**
   Enabling continuous, battery-free monitoring of vital signs and immediate alert systems for critical patient care.

3. **Smart Transportation**
   Facilitating instantaneous vehicle-to-everything (V2X) communication for autonomous driving and advanced traffic management.

4. **Disaster Management**
   Deploying self-sustaining IoT sensors for real-time environmental data collection and critical communication in emergency zones.

5. **Smart Grids & Energy**
   Ensuring ultra-reliable data exchange for dynamic power distribution, fault detection, and optimized energy flow across grids.


Drone control
(URLLC)
Sensing and metering
(mMTC)
Smart agriculture (mMTC)
Factory automation and
remote control (URLLC)
Environment
Monitoring
(mMTC)
Driver-less vehicles
(URLLC)
Vehicle
Communications
(URLLC)
Public safety
(URLLC)

Thank you


99.999 % reliability
< 1 ms latency