TED UNIVERSITY

CMPE 491 – SENIOR DESING PROJECT I

Project Specifications Report

TEAM MEMBERS:

ASLI DÖLEK 67915217862

BERNA TANRIVERDİ 63295214002

DİLARA YARGICI 20290006896

YAŞAR MERT DİRİCAN 13630073160

1. Introduction

Electronic Shelf Label (ESL) systems are well-known and mature technology that has demonstrably optimized general retail operations by automating price updates and reducing errors [3, 4]. We acknowledge this existing technological precedent.

However, this technology fails to address the unique, high-intensity challenges of the Turkish fashion industry. The primary motivation for the PriceLink project stems from the convergence of three critical, localized issues:

1. Economic Volatility: The persistent economic volatility in Turkey necessitates frequent, often daily, price adjustments across all retail sectors.
2. Operational Burden: In the fashion industry, this translates into a significant operational burden on staff. Substantial labor hours are diverted from value-adding activities (like sales and customer service) to the inefficient, repetitive, and error-prone task of manually relabeling products.
3. Environmental Waste: This high-frequency update cycle generates considerable environmental waste, as it relies on the constant consumption and disposal of single-use paper and plastic tagging materials [5].

Existing ESL solutions are not perfectly suited to solve this problem, as their bulky, rigid form factors are aesthetically and physically incompatible with clothing.

This "technology-market gap" is the core of our project. PriceLink is not an attempt to reinvent the ESL; it is an engineering challenge to adapt, miniaturize, and redesign this technology to be compact, lightweight, and suitable for apparel. Our objective is to engineer a viable, sustainable tool that finally addresses the combined economic, labor, and environmental pressures specific to this industry, aligning our work with SDG 12 (Responsible Consumption and Production) [1].

1.1 Description

The PriceLink project is envisioned as a full-stack, integrated IoT ecosystem, to be

engineered from the ground up to address the specific limitations of traditional ESLs within the apparel and fashion retail environment.

The system's planned architecture will be a vertically integrated solution, which will encompass custom hardware, a robust cloud infrastructure, and a sophisticated management interface.

1. PriceLink Tag Hardware (The Core Innovation): This will be the project's primary engineering focus. Unlike the bulky, rigid boxes of traditional ESLs, the PriceLink tag is being designed as a compact, lightweight, and battery-powered device. It will feature an E-Ink (Electronic Ink) display and an integrated wireless communication module (such as Wi-Fi or BLE) to ensure a multi-year battery life through an ultra-low-power, "deep-sleep" architecture.

2. PriceLink Cloud Platform (Backend): This is planned to serve as the scalable "brain" of the entire system, acting as the single source of truth. It will be responsible for:
    - High-Availability Database: Maintaining the central database of all products, prices, and their real-time association with specific tag IDs (Stock keeping units).
    - Real-time Communication: Processing update requests from the management panel and instantly broadcasting these updates to thousands of individual tags using a high-throughput, low-latency protocol (such as MQTT).
    - Device Management: Actively managing the lifecycle and monitoring the health status (e.g., battery level, online/offline status) of every tag in the field.

3. PriceLink Management Panel (Frontend): This is planned as a comprehensive, web-based dashboard for store and corporate management, moving beyond simple price changes. Its core functionalities will include:
    - Batch Operations: Empowering staff to apply bulk changes simultaneously (e.g., "Apply 20% discount to all items in the 'Summer Sale' category") instead of updating one by one.

- System Analytics: A real-time dashboard to monitor the health and status of the entire tag ecosystem, including tag battery levels, network connectivity, and update confirmations.
- Inventory & Tag Association: Tools for easily linking or re-linking a physical PriceLink tag to a new product's Stock Keeping Unit (SKU) as inventory changes or items are moved.

1.2 Constraints

The PriceLink project faces several constraints that influence its design, development, and deployment. These constraints span economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability dimensions. Understanding and addressing these limitations are critical to ensuring that the system remains feasible, ethical, and beneficial to both retailers and society.

Economic Constraints

Careful cost control is necessary while developing small, low-power electronic shelf labels (ESLs) that work with apparel. When compared to conventional printed tags, components like microcontrollers, low-energy wireless modules (Wi-Fi/BLE), and E-Ink screens are somewhat costly. Therefore, in order to guarantee cost and scalability for retail adoption, the project must optimize design choices. Cost-efficiency is a key design objective because changes in the Turkish economy and exchange rates may also have an impact on the cost of purchasing and maintaining gear.

Environmental Constraints

A key component of PriceLink's purpose is the environmental aspect. Due to their frequent replacement during sales and promotions, traditional paper and plastic price tags produce a large amount of waste. The system lowers electronic waste, gets rid of single-use materials, and uses less energy by using E-Ink technology. Electronic components still present difficulties for disposal at the end of their useful lives, nevertheless. Therefore, in accordance with UN Sustainable Development Goal 12: Responsible Consumption and Production, the project must guarantee the use of recyclable materials and promote responsible e-waste management (United Nations, n.d.).

Social Constraints

Workforce roles may change if automated pricing control systems are implemented. Automation increases productivity, but it may also eliminate the need for manual labeling. PriceLink prioritizes employee empowerment over replacement in order to reduce any negative societal effects, freeing up staff to concentrate on higher-value duties like customer service. To guarantee seamless workforce adaption, training programs for system maintenance and usage will be crucial (Bynum & Rogerson, 2023).

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Ethical Constraints

The management of sensitive retail data is the main source of ethical concerns. To guarantee data privacy, openness, and equity in all design processes, the team adheres to the IEEE Code of Ethics (Principle 1) and the ACM Code of Ethics (1.6, 1.7). To avoid unwanted access or exploitation, user rights will be tightly regulated and all price and administrative data sent over the system will be encrypted (IEEE, 2025; ACM, 2025). Fair teamwork, open communication with stakeholders, and making sure automation complements human labor rather than replaces it are all examples of ethical responsibility.

Health and Safety Constraints

Hardware safety is still a worry even though the PriceLink technology does not physically engage with clients. Risks including overheating, leakage, and electrical short circuits are introduced when battery-operated electronic tags are used. In order to remedy this, the hardware will pass stringent durability and dependability tests and adhere to CE safety regulations. Additionally, low-power design will guarantee safe use in retail settings by reducing electromagnetic exposure.

Manufacturability Constraints

A manufacturing challenge is to create a lightweight, compact design that incorporates wireless communication modules with E-Ink screens. Miniaturization, durability, and cost management must all be balanced in this project. Scalable production must be possible without compromising component quality in manufacturing processes. To cut expenses and simplify logistics, collaborations with regional producers might be given top priority.

Sustainability Constraints

Every phase of the PriceLink project, from material selection to long-term usability, is driven by sustainability. E-Ink technology guarantees low power usage and longer gadget life. Batteries that can be recharged or replaced will improve sustainability even more. The technology supports the green digital transformation of the retail industry and is in line with global sustainability goals by encouraging responsible manufacturing and minimizing paper waste (Kwatra, 2023).

1.3 Professional and Ethical Issues

In developing the Price Link system, our team is committed to following the ethical principles defined by the ACM Code of Ethics, the IEEE Code of Ethics, and the Software Engineering Code of Ethics and Professional Practice. Since our project involves the collection and management of retail product information through a centralized digital platform, several ethical concerns must be carefully addressed.

First, we must respect privacy and safeguard sensitive information in compliance with the ACM Code of Ethics (1.6 & 1.7). Product details, pricing information, and possibly store administration credentials will all be handled by the system. As a result, all private information will be safely stored and sent over encrypted channels. No store or customer information will be disclosed to outside parties without express permission. To ensure accountability and prevent data exploitation, access permissions will be limited to authorized personnel only.

Based on the IEEE Code of Ethics (Principles 1 and 5), we are required to prioritize the welfare of the public and prevent any harm that may arise from our product. Therefore, the system needs to be developed in a way that reduces risks like price inaccuracies or technical

malfunctions that could lead to financial losses for businesses or consumers. We will establish thorough testing and verification processes to guarantee the reliability and precision of price updates.

From the perspective of the Software Engineering Code of Ethics (Principles 2.05 and 3.10), professionalism and fairness guide our internal collaboration. All design, testing, and implementation decisions are made collectively, with every team member's input evaluated and approved. We also maintain open communication with our supervisor and stakeholders regarding any identified risks, limitations, or ethical concerns during the development lifecycle.

Environmental and social sustainability represent additional ethical dimensions. In alignment with the ACM's imperative to promote sustainability and human well-being (Principle 1.1), PriceLink actively reduces environmental waste by replacing disposable paper and plastic price tags with e-ink displays. This design directly supports UN SDG 12 – Responsible Consumption and Production, reinforcing our project's commitment to both technological innovation and ecological responsibility.

Finally, as the Computer and Information Ethics section of the Stanford Encyclopedia of Philosophy highlights, we need to take into account the wider societal effects of digital systems. The roles and responsibilities of the workforce may change as remote pricing control systems are introduced. As a result, our project design will prioritize employee support over employee replacement, offering resources to increase productivity rather than duplication.

In conclusion, our project respects moral principles by safeguarding user privacy, guaranteeing system dependability, encouraging openness, encouraging collaboration, and supporting environmental sustainability. All phases of the Price Link system's development and implementation will be guided by these ideas.

2. Requirements

The essential system requirements, which are vital to the project, are explained in this section. These needs are separated into two groups: non-functional requirements, which specify how the system must operate with an emphasis on performance, quality, and security, and

functional requirements, which specify what the system must do.

2.1 Functional Requirements

These are the fundamental prerequisites for the Price Link application.

2.1.1 User Management

-The system needs to include an interface that enables the administrator to get login information and access the system.

-The administrator must be able to add, remove, and edit products.

- Customers must be able to view simply the quantity of products, their prices, and the store location through the system's interface.

2.1.2 Label and Product Management

-Functions for storing and updating the name, store location, category, and barcode of recently added products must be included in the admin panel.

-The interface of the system needs to be able to link product numbers in the database with label numbers.

-The system needs to include an interface that enables features like product removal and editing.

2.1.3 Price Changes and General Management

-Any product's pricing should be able to be changed by the system, either permanently or temporarily.

-The administrator should be able to change the prices of several goods or categories at once using the system.

- When price adjustments are made for a brief period of time, the system must to enable them to immediately return to the original price.

2.1.4 Monitoring and Reporting

-After every transaction, a dashboard on the central interface should show the current state ("Connected," "Update Received," "Disconnected," "Low Battery").

- Information about each transaction, including who carried it out, what it was, its prior status, and when it happened, should be entered into the database by the system.

2.2 Non-Functional Requirements

These specifications dictate the system's speed, effectiveness, and quality. These specifications are essential to the project.

2.2.1 Performance and Efficiency

-After being verified via the interface, operations including pricing adjustments, product additions, product deletions, and store location viewing must take place within five seconds.
- Labels in typical stores should have an average battery life of three years.

2.2.2 Reliability and Accuracy

-The previous state must be preserved in the event of a connection issue or interruption in specific operations.
-Errors must be shown to the administrator on the dashboard in the interface if more than three occur during actions, like pricing updates.
- 99% availability is required for the central administration server.

2.2.3 Usability

-Authorized staff must be able to easily utilize and comprehend the primary interface.
-Under normal circumstances, the e-ink label screen must be readily visible.

2.2.4 Security

-Only authorized workers with secure credentials may access the management interface and admin panel.
-Encryption (e.g., WPA2 or a similar standard) is required for wireless communication between the labels and the central server.

2.2.5 Sustainability and Limitations

-E-ink technology must be used by the system for shelf labels.
-The system needs to do away with paper labels in order to reduce waste.

3. References

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