An AI-Enhanced Smart Cart: Integrating RFID for Automated Billing with Gemini for Intelligent Product Recommendations

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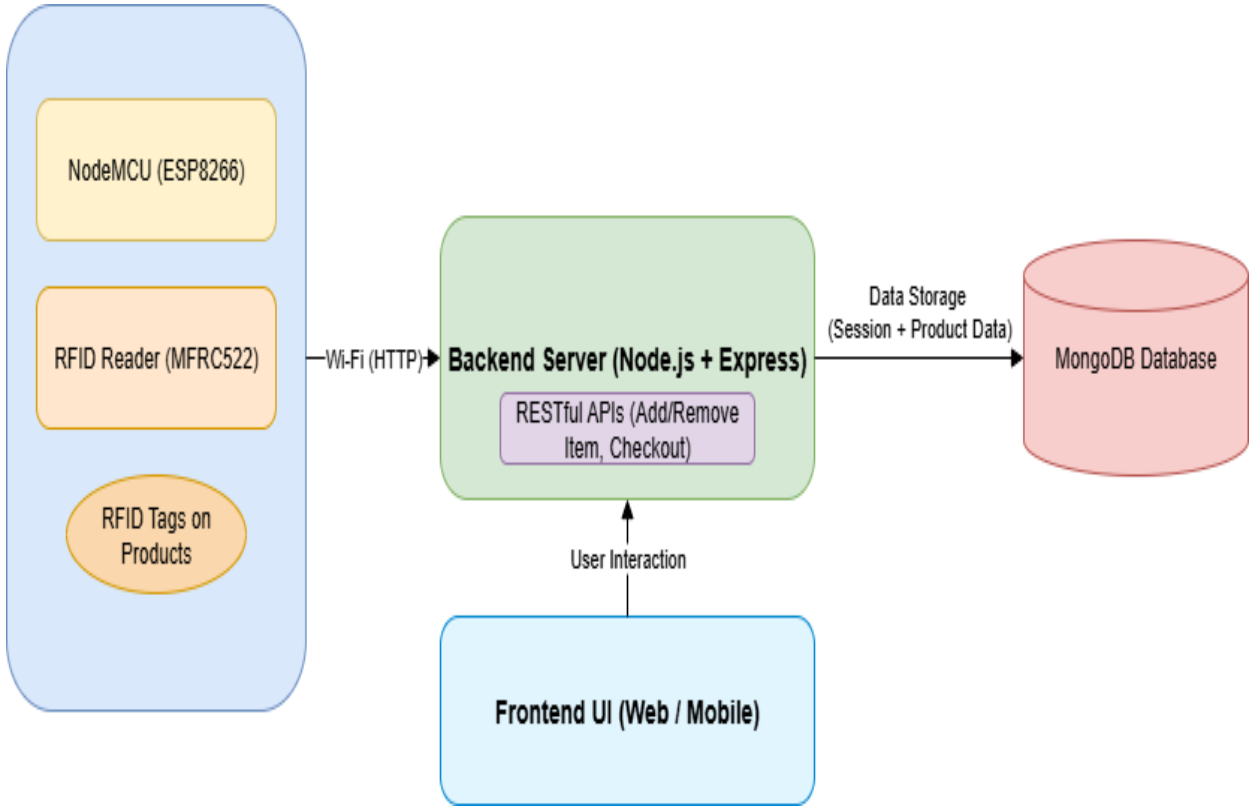
THE PROBLEM


Long checkout queues causing customer dissatisfaction
High staffing requirements
The Challenge in Modern Retail
Time-consuming billing process
Lack of personalized shopping assistance

SYSTEM ARCHITECTURE

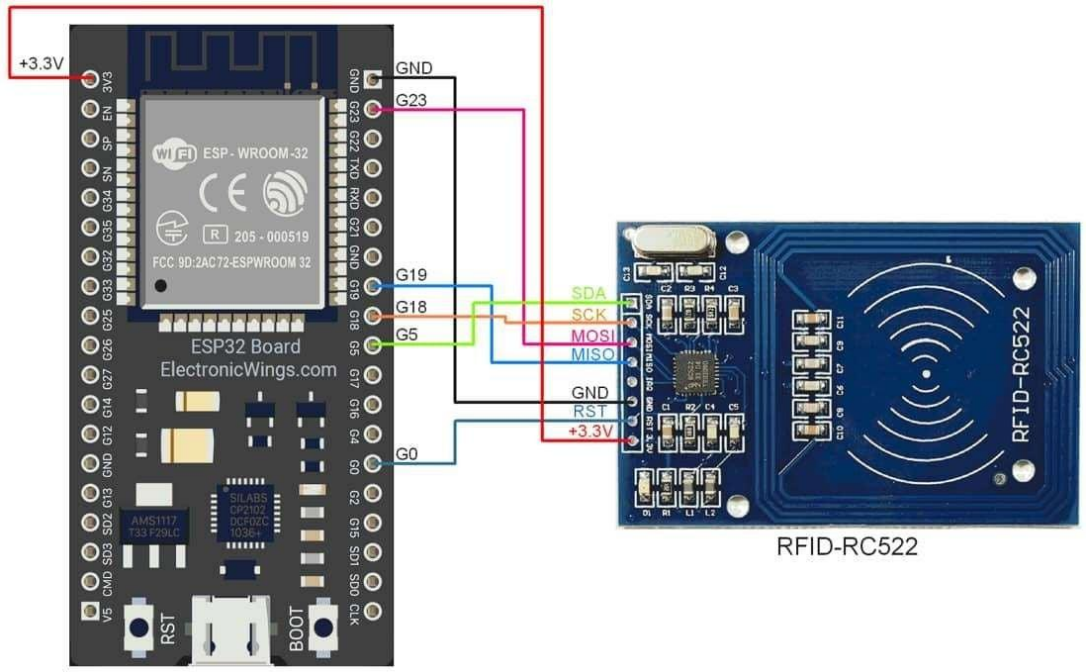
- **Hardware Layer (Cart)**
  - NodeMCU microcontroller
  - MFRC522 RFID reader (13.56 MHz)
  - Portable power supply
- **Backend Server**
  - Node.js + Express.js
  - MongoDB database
  - Google Gemini API integration
- **Frontend Interface**
  - React.js web application
  - Real-time cart updates



HARDWARE IMPLEMENTATION

Cart-Mounted Module

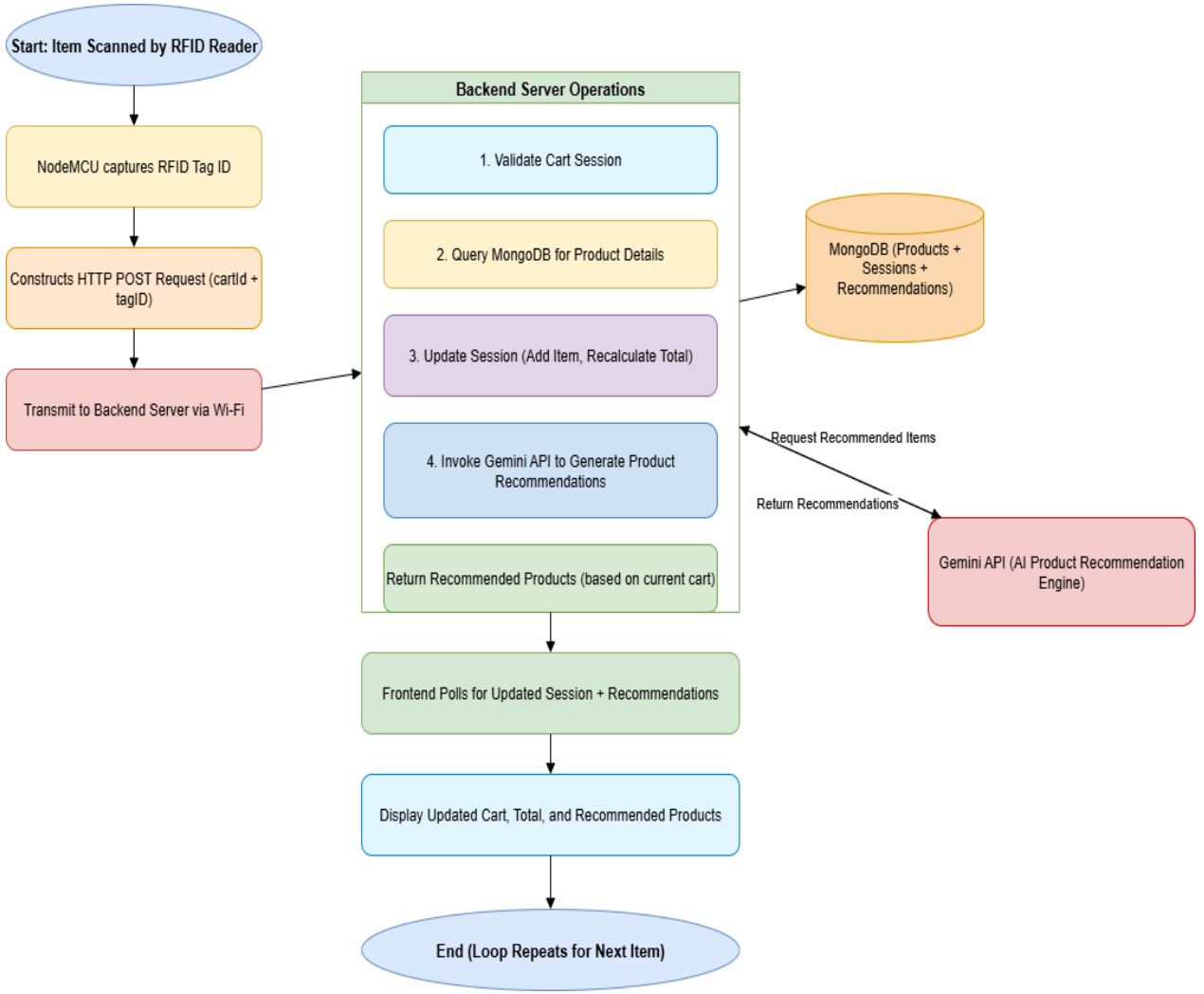
- **Microcontroller:** ESP32 (Wi-Fi enabled)
- **RFID Reader:** MFRC522 via SPI protocol
- **Connections:**
  - SDA→GPIO5
  - SCK→GPIO18
  - MOSI→GPIO23
  - MISO→GPIO19
  - RST→GPIO0
- **Power:** USB power bank
- **Communication:** Wi-Fi for real-time data transmission



RFID-RC522

OPERATIONAL WORKFLOW

- **Item Registration Process:**
  - RFID tag detected by reader
  - ESP32 sends tag ID via HTTP POST
  - Backend queries MongoDB for item details
  - Session updated, bill recalculated
  - Frontend displays updated cart
- **AI Recommendation Process:**
  - User clicks "Get Recommendations"
  - Cart contents sent to backend
  - Gemini API generates contextual suggestions
  - Recommendations displayed to user



AI INTEGRATION

Google Gemini API for Smart Recommendations

Prompt Engineering Example:

"Based on a shopping cart containing: Notebook, Milk, Eggs. What are three complementary products you would recommend? Provide the product name and a brief, helpful description."

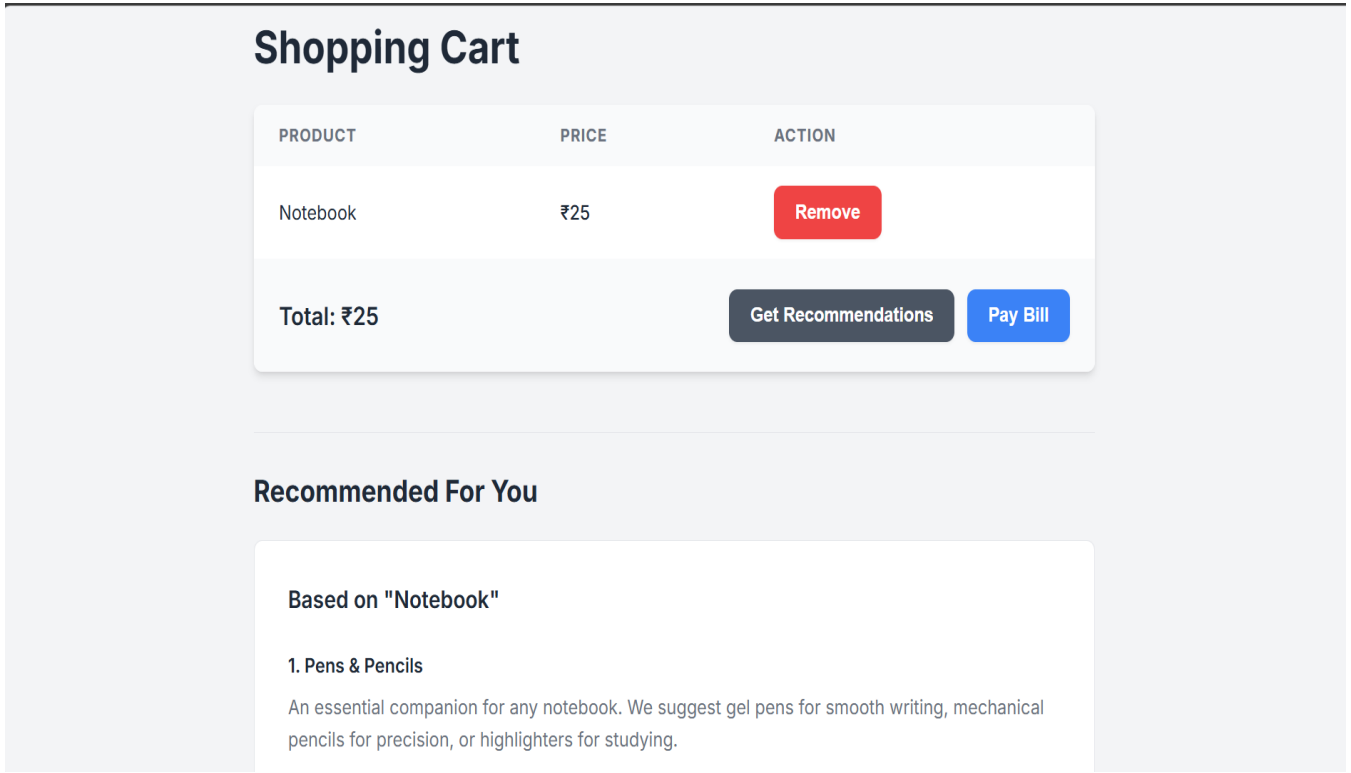
Advantages over Traditional Systems:

- Contextually aware, creative suggestions
- No historical data required
- Natural language responses
- Personalized shopping experience

USER INTERFACE DEMO

- Real-time item display with prices
- Automatic total calculation
- One-click item removal
- AI-powered recommendation button
- Checkout initiation ("Pay Bill")

Example: Cart with "Notebook" → Gemini suggests "Pens & Pencils" with helpful description



LIMITATIONS & CHALLENGES

- **RFID Range:** Limited to 3-5 cm (requires deliberate placement)
- **Item Removal:** Manual removal via interface (no auto-detection)
- **Power:** Limited battery life with continuous operation
- **Scalability:** Tested with single cart only
- **Security:** HTTP (not HTTPS), no device authentication
- **Connectivity:** Requires stable Wi-Fi, no offline queuing

Conclusion

- We successfully designed and implemented an intelligent Smart Cart system.
- The seamless integration of an ESP32 with a modern web stack (Node.js, React) and a Generative AI (Gemini) is our key contribution.
- This provides a viable, low-cost blueprint for the next generation of interactive smart retail technology.

Thank You