PaperTap: An NFC Driven E-paper Desk Dashboard

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***Abstract*—In a world of digital screens, the need for simple, distraction-free, and energy-efficient display solutions is growing. This project introduces an e-paper display system designed for low-interaction, static content presentation, such as calendars, weather, photos, and text. Through using the nature of ultra-low power consumption and high readability of e-paper technology, the display is updated by an ESP32 microcontroller and controlled with Near Field Communication (NFC) tags. The device allows users to change displayed content with a single tap with the NFC tags without requiring mobile applications. The system supports multiple modes, including photo display, live weather updates, calendar, and plain text. Designed with digital minimalism and sustainability in mind, the device operates mainly in deep sleep mode and uses NFC for both content control and ease of use. This makes it an accessible, low-power solution for users seeking a more focused, user-friendly, power-conserved alternative to traditional smart displays.**

I. Introduction / Background

In modern homes and offices, physical items such as calendars, photo frames, whiteboards, and noticeboards are common tools for organisation and expression. Although these items are often essentials and sentimental, they often cause cluttered spaces, particularly when placed together on desks or small surfaces. Additionally, they lack flexibility and are environmentally unsustainable due to frequent reprinting or manual updates.

With the growing popularity of smart homes, there has been an increased interest in digital dashboards and smart displays. These multifunctional devices can be used as calendars, photo frames, music controllers, smart home hubs, and even work with AI assistants. While powerful, such systems often exceed the basic needs of users who want to display static information like calendars, weather updates, or artwork. Moreover, they typically use LCD or OLED displays, which offer vibrant colour but suffer from high power consumption and cause eye strain due to constant light emission.

E-paper displays present a compelling alternative. Their reflective and paper-like screens provide high visibility under various lighting conditions and do not need backlighting. This reduces energy consumption and minimises distractions and eye strain, making them ideal for passive information displays. The bistable nature of e-paper display means that it only consumes power when updating content, allowing it to retain information forever without using energy.

Most smart display solutions still depend on cloud-based services or mobile applications for updates, requiring complex setups and constant internet connectivity. This introduces obstacles for users who seek simplicity, privacy, and local control. This leaves a gap for a minimal, energy-efficient, and user-friendly display without continuous digital interaction.

This project addresses that gap by introducing an e-paper display system that can be updated via Near-Field Communication (NFC). With a simple tap, users can update the display to show a variety of information, from calendar events and reminders to images and quotes. This can be achieved without a permanent internet connection or mobile app. Once configured, NFC tags can store and transfer the necessary data directly to the display. As living spaces become more compact and multifunctional products more desirable, this NFC-enabled e-paper solution offers a sustainable, space-saving, and minimal way to present information.

II. Related work

Make sure to cover existing work that is relevant, and cite the relevant references which should be listed in the References section at the end of the paper.

Existing products such as DAKboard [1], MagicMirror [2], and commercial smart hubs like the Amazon Echo Show [3] and Google Nest Hub [4] offer multifunctional digital dashboards. However, these devices typically use LCD or OLED screens and rely on cloud connectivity, mobile applications, or a continuous power supply. Although they offer rich features, they are often over-engineered for users who want to display static content like a calendar, image, or text.

Information display systems, especially those intended for long term use, often require displays to remain active and updated frequently. This makes the display screen one of the primary contributors to overall power consumption in devices [5]. To address this, e-paper has became a popular alternative for low-refresh-rate applications due to its reflective display technology, high readability, and ultra-low power consumption [6].

E-paper displays are bistable, meaning they only consume power when their content is updated. Once updated, the content remains visible without drawing any additional power. These characteristics make e-paper highly suitable for passive or static displays such as calendars, signs, or dashboards that do not require frequent updates.

NFC is a widely adopted short-range wireless communication technology, is suitable for localised and low-interaction applications. It allows for data transfer without needing internet connectivity or a battery on the receiving device.

Users can trigger a display update by tapping an NFC tag or smartphone to a receiver.

Battery-less NFC-powered e-paper displays have been commercially available for a while [7]. These usually use NFC to power and update small e-paper screens, and are generally deployed as electronic shelf labels or price tags in retail environments. The constraint of using NFC alone for both power and data transfer limits these displays' size and refresh capability. Therefore, most NFC-only e-paper solutions remain small and limited in resolution. For larger e-paper displays, external power is required to support the greater energy demands associated with full-screen updates.

This project combines the local nature of NFC communication with the power efficiency and readability of e-paper. It aims to create a user-friendly, adaptable, and energy-efficient display system for static content presentation.

III. Imagined or Existing Prototype Sketches/Drawings/Photos

A. Block Diagram

The electronic components of the design is constructed with a NFC module PN532 [8], a 7.2 inch e-paper display [9] and an e-paper ESP32 driver board [10]. These components are connected as shown in Figure 1. The ESP32 is the microcontroller that is the central processing unit. It manages communication with the NFC module and controlling updates to the e-paper display. It receives data via NFC through the PN532 module and subsequently processes and renders the content onto the e-paper screen.

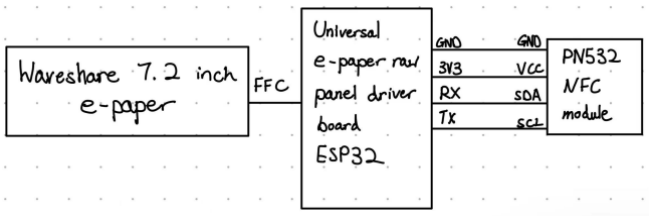

Figure 1 Block diagram

B. Enclosure

The components are enclosed in a 3D printed frame, as shown in Figure 2 and Figure 3. At the front of the frame, a clear acrylic sheet is there to protect the e-paper display and allowing the users to write on the surface, similar to a whiteboard. This acrylic sheet can be easily removed and reinserted through a slot at the top of the frame, allowing for easy cleaning. A white frame surrounds the e-paper display, both improving the aesthetics by covering the edge of the e-paper display and providing structural support. It also helps to align and secure the middle plate using six standoffs, thereby protecting the e-paper display. The middle plate has holders for mounting the ESP32 board and PN532 module. The back plate is attached to secure all components and cover the wiring. Similar to the acrylic sheet, the back plate can be removed through a top slot. Additionally, there is a hole on the side of the frame is there for a power cable.

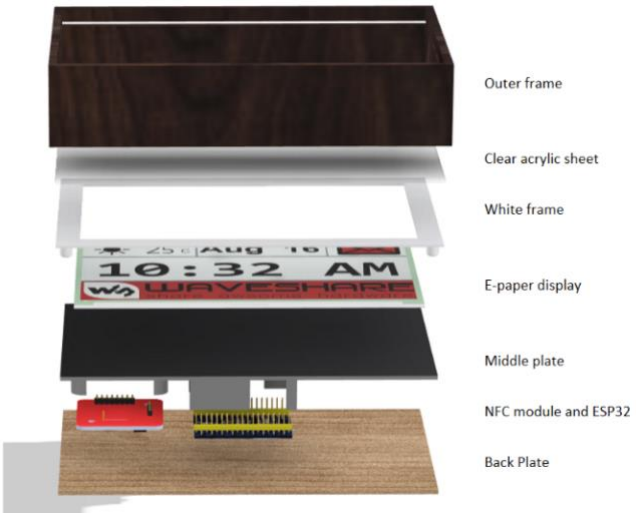

Figure 2 Exploded view of the device. Models for e-paper display, NFC module and ESP32 sourced from online [11], [12], [13].

Figure 3 Front (left) and back (right) view of the device

C. Functionality

The device should display the following information:

- Photos
- Time and weather
- Calendar
- Text

Display updates are triggered through NFC tags, enabling users to change the display with a simple tap.

In photo mode, low-resolution images can be stored directly on the NFC tag, for small file sizes, or uploaded to a cloud service, with the image URL in the tag. Upon reading the tag, the device retrieves and displays the corresponding image.

In time and weather mode, tapping the NFC tag initiates the Wi-Fi-enabled ESP32 to fetch and display the current time along with weather data and forecasts using the OpenWeather API [14].

In calendar mode, the device displays a monthly calendar layout. Users can annotate this calendar directly by writing on the acrylic sheet overlaying the e-paper display.

In text mode, any text stored on the NFC tag is shown on the display. This could include reminders, to-do lists, inspirational quotes, messages from loved ones, desk nameplates, Wi-Fi credentials, and more.

Once the API configuration is complete and the ESP32 is connected to Wi-Fi, the only user setup required is the configuration of the NFC tags. After this initial setup, all interactions with the device can be performed simply by tapping the NFC tags. The device will be in deep sleep mode

unless it is triggered by NFC tags or is on Time and Weather mode.

D. Future alteration

For fully local photo mode, adding an SD card module should be considered. This allows all the photos can be stored into the SD card without the need to storing them on cloud. If a large amount of photos is stored, an NFC tag could be set up to trigger a random photo display.

IV. Responsible innovation

In a world filled with digital distractions, where countless photos are taken only to be forgotten in a phone's storage, this device minimises digital interaction and simplifies the setup process. By utilising NFC technology, users can change the display content with a simple tap, making it accessible even to those with little technical experience.

The system is designed to operate without cloud services or companion applications, unless users want to display high-resolution images, which need to be stored online. It could become an open-source project, and offers flexibility for customisation and adaptation by the broader maker community.

The e-paper display reduces distraction by not emitting light and provides a more natural, paper-like viewing experience. Additionally, because content updates are triggered via NFC tags, users do not need to interact with their phones or other digital devices, reducing the likelihood of being drawn into additional screen time. Due to the ultra-low power consumption of the e-paper display, and that Wi-Fi connectivity and API usage are only required in the time and weather mode, the device can operate in a deep sleep mode during idle periods. This significantly reduces the power consumption and makes it ideal for low-maintenance, energy-efficient applications.

V. Author bio(s) / experiences

I am a PhD student in UCL CASA's Connected Environment lab. My research is about people counting with computer vision and machine learning while preserving privacy.

I have a background in electronics, built through my studies in A-level Electronics, a BEng in Electrical and Electronic Engineering from the University of Bath and an MSc in Connected Environment from UCL.

I'm experienced in designing and building circuits and PCBs, both by hand and using tools like Cadence and Autodesk software. I'm also proficient with microcontrollers such as Arduino and Raspberry Pi, and programming in C++ and Python, enabling me to prototype sensor-based systems quickly. Since 2018, I've been self-learning 3D modelling and printing using Autodesk Fusion and Blender, which I now use to create custom enclosures and mounts for my sensor designs. These skills are utilised in my PhD work, where electronics, coding, and 3D printing are essential to developing and deploying my sensor systems. Outside of research, I enjoy making functional and creative 3D-printed objects; from repairing electronics to designing tools and game-inspired items.

VI. Acknowledgements

None.

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