

Based on the real-world problems discussed in Chapter ??, Chapter ?? aims to delve deeper into the existing products and solutions that can help address these issues. Specifically, it will also analyze some detailed use cases of the EPD (Electronic Paper Display) devices system, as outlined in Section ??.

0.1 Status survey

There are several e-paper display manufacturers that take advantage of EPD technology to provide solutions to multiple different businesses. This section will focus on four leading e-paper display providers: **E Ink**, **Seekink**, **Inkcase**, and **Pervasive Displays**.

E Ink is a leader in electronic paper (e-paper) display technology, co-founded in 1997 by MIT undergraduates and a professor from the MIT Media Lab. They offer a variety of e-paper display modules suited for diverse applications. Their products are used in several sectors, including reading and writing, education, business and office, mobile and wearables, retail, logistics and factories, healthcare, transportation, automotive, and innovative design. They also showcase customer-specific applications and provide optimized solutions and system integration for businesses. Although they have quality products and solutions aimed at a broad customer segment spread across various fields, E Ink focuses only on core e-paper technology with a few essential products such as eReaders, electronic shelf labels, and other low-power display needs. While beneficial for brand recognition and expertise in a specific area, this specialization can limit market reach and diversification compared to companies with a broader product range. Also, the manufacturing process for E Ink displays is complex and costly, which can lead to higher product prices, impacting competitiveness, especially in price-sensitive markets. That's why E Ink's specialized technology might not be as widely recognized or preferred by the average consumer in many specific regions, including Vietnam.

Seekink is recognized as a leading electronic paper display manufacturer with eight years of experience. Seekink operates its automatic manufacturing base, which is capable of mass production, and emphasizes a high level of customization to meet diverse needs across markets. However, Seekink is not widely recognized in Vietnam, primarily because their marketing and sales strategies are focused on large enterprises. This focus on big businesses typically involves offering high-priced, specialized products and services that might not cater to the broader consumer market or smaller businesses. This approach can limit their market presence and brand recognition among the general public and smaller enterprises.

InkCase is a product line from the Singapore-based consumer electronics de-

sign house Gajah. They specialize in offering protective cases for smartphones with added functionalities and are also involved in various innovative display solutions, including intelligent information display, healthcare, and tracking.

Pervasive Displays is a leading manufacturer in the electronic paper display industry, specializing in the design, manufacture, and marketing of e-paper displays. They have a manufacturing capacity of over 2 million pieces per week and are financially stable, being a part of the world's largest display company. Their products and services are tailored to industrial applications, with a focus on the design and manufacturing of ultra-low power displays, and are often ordered in large quantities by other major industrial clients.

With the assessments mentioned above, the features of the four e-paper display manufacturers can be summarized in the table ?? below.

Features	E Ink	Seekink	InkCase	Pervasive Displays
Prices	Contact sale	Contact sale	Not available	Contact sale
Client type	Business Commercial user	Business	Commercial user	Business Commercial user
Use case	Business Education Healthcare Logistics Transportation Automotive	Business Retail Education Transportation Healthcare IoT	Transportation Business	Logistic IoT Healthcare Education Business
Management System	✓	✓	✓	✓
Allow custom display	Customized for each customer	Customized for each customer	Not available	Customized for each customer
Connectivities	Bluetooth Internet Wired	Bluetooth Internet Wired	Bluetooth Internet	Not published
Other Products	Commercial e-paper electronic devices	E-paper display modules and devices	E-paper protective phone cases	E-paper display modules and devices
Available in Vietnam	×	×	×	×

Bảng 1: Comparison table of four EPD manufacturers in e-paper display solutions

Having learned from the survey of the above four systems and other real-life use cases, this project has concluded some objectives of building an EPD devices system, including designing and building EPD devices, as well as including some essential features fitting in multiple use cases.

First, take the advantage of the electrophoretic display technology in displaying information. With the unique characteristic of e-paper display, the EPD device

should be capable of displaying data for a long period of time without frequent refreshing. The device also need to be energy-saving and able to operate in reasonable time without recharging.

Second, manage EPD devices in a system via a central hub, which can be a cloud server, communicating with EPD devices and backend server using MQTT protocol and other wireless connectivities, or a local dock that is responsible for receiving data and displaying on EPD panels. Each solution's advantages and drawbacks are discussed in section ?? in chapter ??.

Third, implement the EPD device system in some initial use cases to test the performance and effectiveness of the system in solving real-life problems. The initial use cases include name tags for students, employees, and clients; price tags in mini-markets and logistics services; and room and other signages.

Finally, implement security in the system and enhance user experience.

0.2 Functional Overview

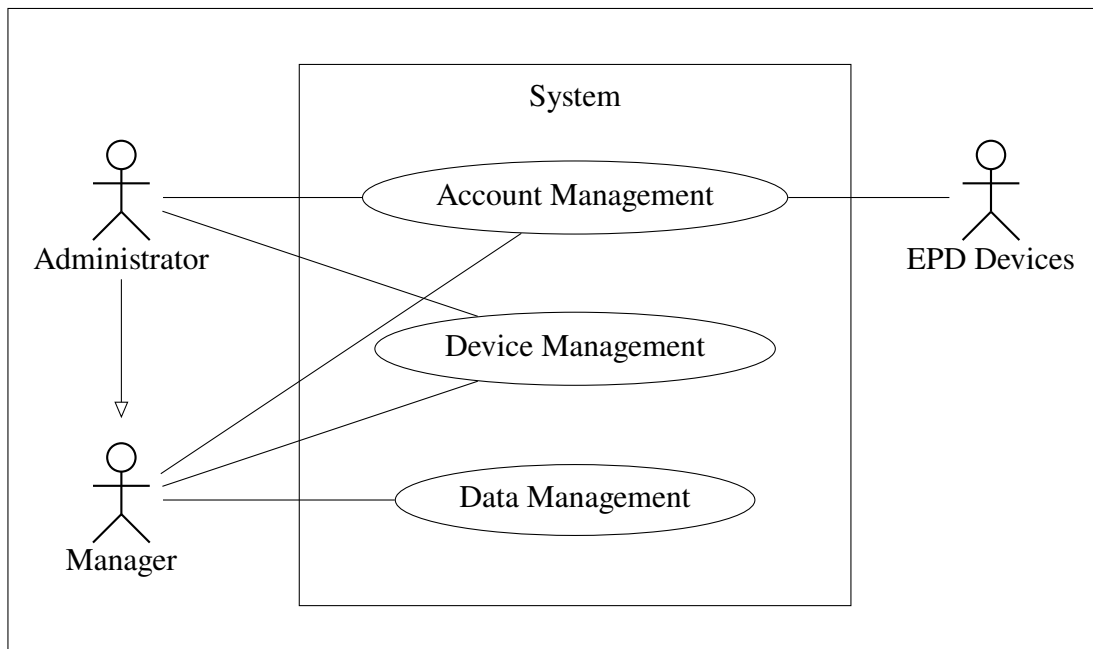
0.2.1 General use case diagram

The general use case diagram of the EPD devices system is illustrated in Figure ?. As per the diagram, the system involves three main actors: The Manager, The Administrator, and the EPD devices. The Manager can manage EPD devices, data, and their accounts. The Administrator inherits the functions of the Manager and can also manage and test the devices more advanced. On the other hand, the EPD devices act as end-users, receiving and displaying data on the screen. They also interact with the system via the MQTT protocol.

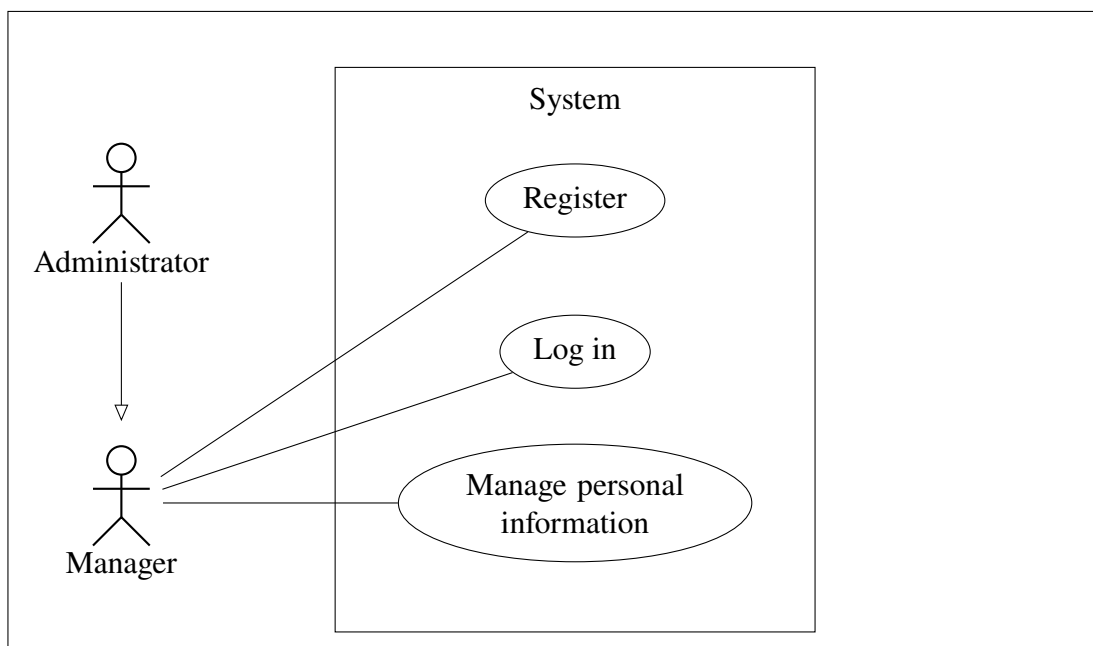
0.2.2 Detailed use case diagram

a, Detailed use case of User's Account Management function

Figure ?? below describes the detailed use case diagram of the User's Account Management function, including the Manager and Administrator. Users can create a new account, log in, and modify personal information.



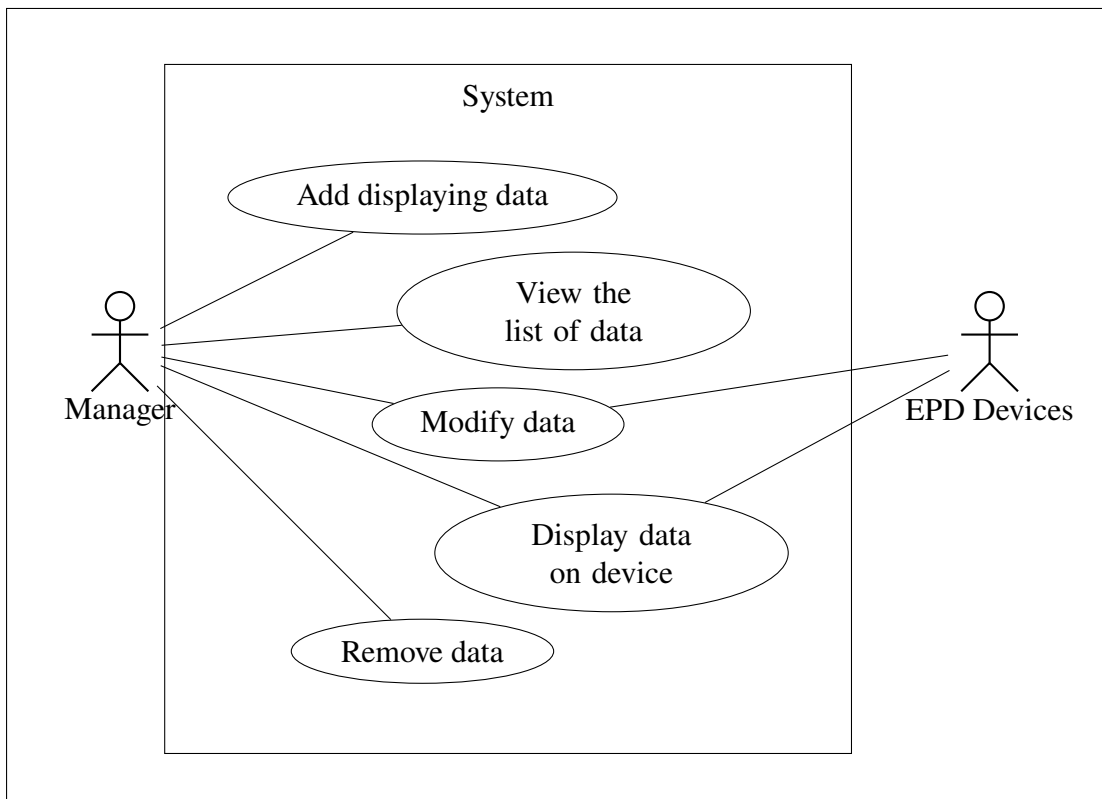
Hình 0.1: General use case diagram of the EPD devices system



Hình 0.2: Detailed use case of User's Account Management function

b, Detailed use case of Data Management function

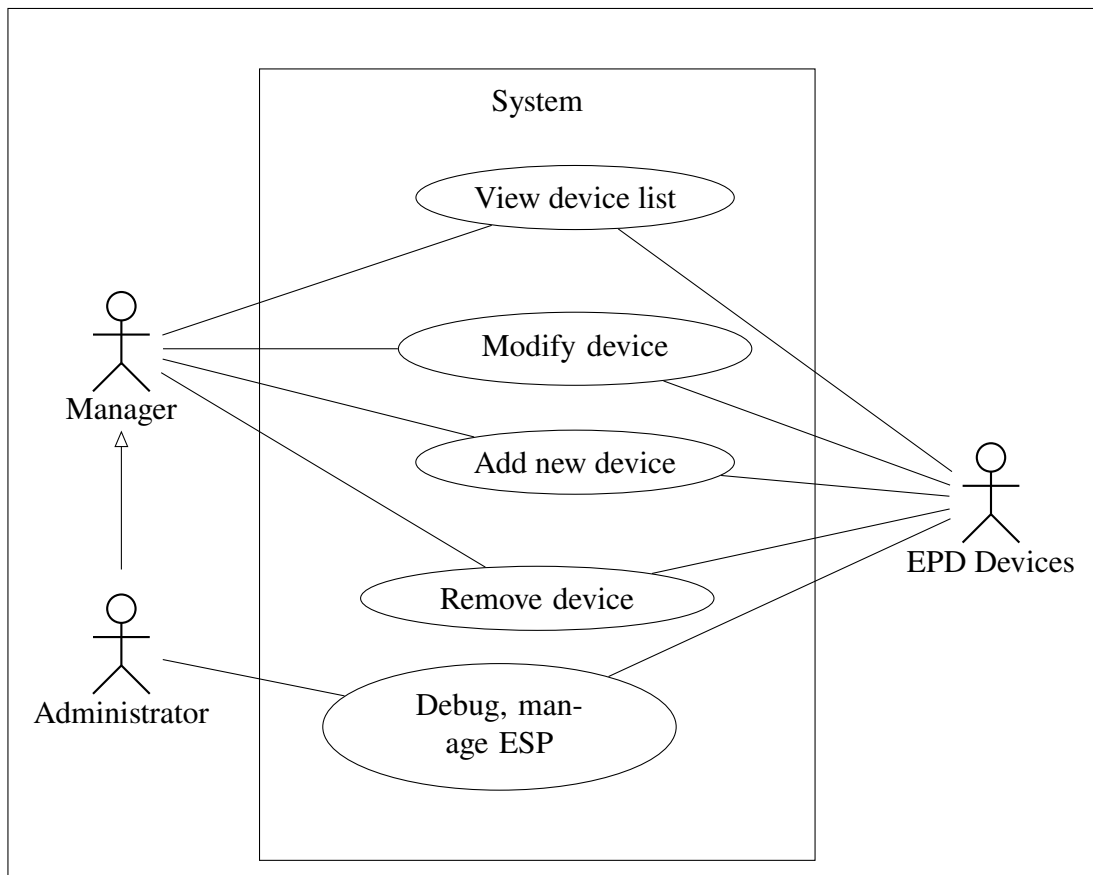
A detailed use case diagram of the Data Management function of the Manager is displayed in figure ??. This function enables the Manager to view, add, modify, remove data, and choose whether or not to display it on the EPD devices.



Hình 0.3: Detailed use case of Data Management function

c, Detailed use case of Device Management function

Figure ?? illustrates the use case diagram of the Device Management function, showing two actors participating in the system. This function enables the Manager to view, add, modify, or remove device information. The Administrator, inheriting the functions of the Manager, can also debug the device after connecting it to the computer via a USB port.




Hình 0.4: Detailed use case of Device Management function

0.2.3 Business process

The system comprises several business processes, with the most prominent ones being the process of adding data and displaying it on EPD devices and the process of adding EPD devices to the system. Each flow showcases how the system communicates with the device via USB and the MQTT protocol and how the device receives and processes data.

a, "Creating new device" flow

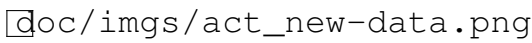
Figure ?? below shows the business process when the Manager creates and registers a new device to the system. This process requires the users to connect the EPD device to the computer via a USB port, choose from the list of connected devices, and then fill in the required information before submitting it to the system. Upon receipt of the submitted data, the system sends a data write request to the device via Serial Port. The EPD device then connects to the Internet with the received information and connects to the MQTT Broker before publishing its connection status to the system.

 doc/imgs/act_new-device.png

Hình 0.5: "Creating new device" business flow

b, "Creating and displaying new data" flow

The following describes the business process when users add new data to the system, as depicted in Figure ???. Firstly, the user selects the type of data they want to display. Afterward, they add the corresponding detailed information based on the chosen data type. Users can also decide whether or not to allow display on the EPD device. If they choose to do so, the system will provide a list of devices connected to the MQTT Broker for the user to choose from. The user will then provide additional information about how to display the data on the selected device. Once all the necessary information has been provided, the system will send MQTT messages through the MQTT Broker. The selected device will receive and display the data and send the status back to the system via the MQTT protocol.

doc/imgs/act_new-data.png

Hình 0.6: "Creating and displaying new data" business flow

0.3 Functional description

ID	Name
UC01	Create new device
UC02	Modify device information
UC03	Remove device
UC04	Add new data
UC05	Modify data information
UC06	Remove data
UC07	Create account
UC08	Sign in

Bảng 2: List of use cases

0.3.1 Description of use case "Create new device"

ID	UC01	Name	Create new device
Actor	Manager, System, EPD device		
Pre-condition	The user logs into the system as a Manager. To create a new device and edit device information in case the device is not connected to the Internet, users need to connect the device to the computer via a USB port.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Select "New Device" function
	2	System	Retrieve and display the list of devices connected via USB

Main scenario (success)	No.	Executed by	Action
	3	Manager	Choose a device from the list
	4	System	Connect to the device via Serial Port
	5	System	Display the interface to enter device information
	6	Manager	Fill in the device information (<i>described below</i> *)
	7	Manager	Send a request to create a new device
	8	System	Store device information at the server and transmit data to the connected device
	8.1	System	Store device information at the server
	8.2	System	Transmit data to the EPD device
	8.2.1	Connected EPD device	Process the received information
	8.2.2	Connected EPD device	Connect to the Internet and MQTT Broker
	8.2.3	Connected EPD device	Send status information to the server
	8.2.4	System	Receive and edit information of the new device
	9	System	Notify successful device creation
Extensions	No.	Executed by	Action
	4a.	System	Error message: Unable to connect to the device
	8.1a	System	Error message: Need to enter all required fields of the device if the Manager misses any
	8.2.2a	System	If no update response is received from the device, save the device information
Post-condition	The system store new device information in database		

0.3.2 Description of use case "Modify device information"

ID	UC02	Name	Modify device information
Actor	Manager, System, EPD device		
Pre-condition	The user logs into the system as a Manager, and the device is registered in the system. To modify a device not connected to the Internet, users need to connect the device to the computer via a USB port.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Access Dashboard, select Device
	2	System	Retrieve and display the list of registered devices
	3	Manager	Choose a device from the list and select Edit
	4	System	Check the status of the device
	4.1	System	If the device is not connected to the system, display a message asking the user to connect the device via USB
	4.2	Manager	Connect the device via USB and choose from the list of connected devices
	5	System	Display the interface to enter device information (described below *)
	6	Manager	Fill in and send a request to change device information
	7	System	Save the new updated information
	7.1	System	If the device is connected via USB, transmit data to the connected EPD device
	7.2	System	If the device is connected to the MQTT server, send a request to change information on the device via the MQTT protocol
	8	Connected EPD device	Process the received information
	8.1	Connected EPD device	If the device is connected via USB, connect to the Internet and MQTT Broker
	9	Connected EPD device	Send status information to the server
	10	System	Receive and edit information of the new device
	11	System	Notify successful device information change
Extensions	No.	Executed by	Action
	4.2a.	System	Error message: Unable to connect to the device
	7a.	System	Error message: Need to enter all required fields of the device if Manager misses any

Extensions	No.	Executed by	Action
	10a.	System	If no update response is received from the device, save the device information
Post-condition	The system store new device updated information in database		

0.3.3 Description of use case "Remove a device"

ID	UC03	Name	Remove a device
Actor	Manager, System, EPD device		
Pre-condition	The user logs into the system as a Manager, and the device is registered in the system.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Access the Dashboard, select Device
	2	System	Retrieve and display the list of registered devices
	3	Manager	Choose a device from the list and select Delete
	4	System	Display a warning asking the user to confirm deletion
	5	Manager	Confirm deletion of data
	6	System	Check the display status of the device
	6.1	System	If the device is not displaying data, remove the device from the system
	6.2	System	If the device is displaying data, send a request to delete data on the device via MQTT
	6.2.1	EPD Device	Process the received information, delete the displaying data information
	6.2.3	System	Remove device display information from the data
	7	System	Notify successful remove
Extensions	No.	Executed by	Action
	6a.	System	End the use case if the user confirms not to delete the device
	6.2.3a	System	Error message: Unable to delete the device if an error occurs during deletion
Post-condition	No		

0.3.4 Description of use case "Add new data"

ID	UC04	Name	Add new data
Actor	Manager, System, EPD device		
Pre-condition	The user logs into the system as a Manager.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Select "New Data" function
	2	System	Display the interface to choose data type to add
	3	Manager	Choose the type of data from the list
	4	System	Display the interface to enter data information
	5	Manager	Fill in the data information (<i>described below **</i>)
	5.1	System	If the user chooses to display on a device, show the interface to select device and design
	5.2	Manager	Choose device to display, and choose the design
	6	Manager	Send a request to create new data
	7	System	Save new data information on the server
	7.1	System	If the user chooses to display data, transmit data to the connected EPD device
	7.2	EPD Device	Process the received information
	7.3	EPD Device	Display the data
	7.4	EPD Device	Send status information to the server
	7.5	System	Receive and update data information
	8	System	Notify successful creation of the data
Extensions	No.	Executed by	Action
	4a	System	Error: Need to enter all required fields of the device if the Manager misses any
	5.1a	System	If there are no active devices, notify users and finish the use case
	7.1a	System	Error: Can't write data to the device
Post-condition	The system store new data in database		

0.3.5 Description of use case "Modify data information"

ID	UC05	Name	Modify data information
Actor	Manager, System, EPD device		
Pre-condition	The user logs into the system as a Manager, and the data is stored in the system.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Access Dashboard, select Data
	2	System	Retrieve and display the list of data
	3	Manager	Choose a data from the list and select Edit
	4	System	Display the interface to enter data information
	5	Manager	Fill in the data information (<i>described below **</i>)
	5.1	System	If the user chooses to display on a device, show the interface to select device and design
	5.2	Manager	Choose device to display, and choose the design
	6	Manager	Send a request to update data
	7	System	Save the updated data on the server
	7.1	System	If the user chooses to display data, transmit data to the connected EPD device
	7.2	EPD Device	Process the received information
	7.3	EPD Device	Display the data
	7.4	EPD Device	Send status information to the server
	7.5	System	Receive and update data information
	8	System	Notify successful update
Extensions	No.	Executed by	Action
	4a	System	Error: Need to enter all required fields of the device if the Manager misses any
	5.1a	System	If there are no active devices, notify users and finish the use case
	7.1a	System	Error: Can't write data to the device
Post-condition	The system store new updated data in database		

0.3.6 Description of use case "Remove data"

ID	UC06	Name	Remove data
Actor	Manager, System, EPD device		
Pre-condition	The user logs into the system as a Manager, and the data is stored in the system.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Access Dashboard, select Data
	2	System	Retrieve and display the list of data
	3	Manager	Choose a data from the list and select Delete
	4	System	Display a warning asking the user to confirm deletion
	5	Manager	Confirm deletion of data
	6	System	Check the display status of the data
	6.1	System	If the data is being displayed, send a request to delete data on the device via MQTT
	6.2	EPD Device	Process the received information, delete the displaying data information
	6.3	System	Remove data information on the device
	7	System	Remove the data from the system
	8	System	Notify successful remove
Extensions	No.	Executed by	Action
	6a	System	End the use case if the user confirms not to delete the data
	7a	System	Error message: Unable to delete the device if an error occurs during deletion
Post-condition	No		

0.3.7 Description of use case "Create account"

ID	UC07	Name	Create account
Actor	Manager, System		
Pre-condition	No		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Go to the sign-up page
	2	System	Display the interface to fill user information

Main scenario (success)	No.	Executed by	Action
	3	Manager	Fill in the user information (<i>described below ***</i>)
	4	Manager	Send a request to create new account
	5	System	Save new user information on the server
	6	System	Notify successful creation of the user, and direct to log-in page
Extensions	No		
Post-condition	No		

0.3.8 Description of use case "Sign in"

ID	UC08	Name	Sign in
Actor	Manager, System		
Pre-condition	The user have stored account.		
Main scenario (success)	No.	Executed by	Action
	1	Manager	Go to the sign-in page
	2	System	Display the interface to fill user email and password
	3	Manager	Fill in the user credentials
	4	Manager	Send a request to check account
	5	System	Notify successful log-in, and redirect to dashboard page
Extensions	No.	Executed by	Action
	5a	System	Error: User's credentials are incorrect
Post-condition	No		

(*) The input data of the device:

No.	Name	Description	Required
1	Name	Name of the device	✓
2	SSID	Name of the network the device connects to	✓
3	Password	Password of the network the device connects to	✓

(**) The input data of data:

No.	Name	Description	Required
1	Type	Type of the data	✓
2	Name	Name of the data	✓
3	Email	Email data, depend on data type	×
4	Student ID	Student ID data, depend on data type	×
5	Class	Class of the student, depend on data type	×
6	Employee ID	Employee ID data, depend on data type	×
7	Department	Department of employee, depend on data type	×
8	Category	Category of product, depend on data type	×
9	Price	Price of product, depend on data type	×
10	Address	Address data, depend on data type	×
11	Purpose	Room's purpose, depend on data type	×
12	Manager	Room's manager, depend on data type	×
13	Status	Room's status, depend on data type	×
14	Active	Display on device status	✓
15	Font Style	Display main font style	Yes, if <i>Active</i> is true
16	Theme	Display schema	Yes, if <i>Active</i> is true
17	Device	Device to display	Yes, if <i>Active</i> is true

(***) The input data of the account:

No.	Name	Description	Required
1	Name	Name	✓
2	Email	Email	✓
3	Password	Password	✓

0.4 Non-functional requirement

Given the system's unique nature, where a user has to manage a vast array of data across numerous devices in an open environment, system security is a top priority when facilitating communication between devices. Additionally, the system requires transparency and user-friendliness for new users, including those with physical impairments. Moreover, to operate reliably in large enterprise environments with numerous devices, users, and data, the system also demands high fault tolerance, ease of inspection, upgrades, and maintenance.

0.4.1 Security

Containing sensitive user and business data, the system needs to ensure privacy and security among EPD devices and servers. The system also requires authenticated and authorized services so that only users with specific permissions are allowed to access particular services. Moreover, it is also crucial to protect the sys-

tem from outside attacks by implementing secure connections between services using TLS/SSL protocol. The details of this problem and its implemented solution are discussed in chapter ??.

0.4.2 Performance

With the characteristic of having to update in real time, the system also requires multiple performance criteria. First, the EPD devices should process data in a reasonable time and maintain a stable connection with the server in the event of receiving requests. The EPD device also needs long-lasting battery life and sufficient resources to store and handle data. On the other hand, the system also needs to manage many EPD devices and users efficiently, especially in big businesses. Chapter ?? will also provide a clear view of the performance evaluation process and various techniques used to improve both EPD devices and the server's overall quality.

0.4.3 User Experience

UX/UI is also one of the most essential requirements of the system. The web interface needs to be user-friendly, with a consistent layout and color scheme across different pages. Additionally, the interface should support responsive design, making it adaptable to various screen sizes on different devices. Moreover, information in the system needs to be delivered to the users efficiently and clearly, making it easy to understand for all ages.

About the EPD devices, the display needs to have a clear and simple layout, ensuring the data is well-organized and easy to view, especially in complicated use cases. The e-paper screen also needs to refresh clearly and does not show any remaining black pixels after the refresh.

Both the website and the EPD devices should follow a minimalistic design, only showing the users what they want to show. The color, layout, and design patterns should be consistent among devices and pages, overall enhancing user experience and brand recognition.

0.4.4 Flexibility and Scalability

The system is still in the development and expansion phase, so it needs to be designed for easy modification and upgrading to suit new requirements as they arise. Changes or additions to features or devices should also not affect the system's operation. The system also needs to be fault-tolerance provide detailed logs in the event of errors and have backup storage in an emergency. All logic failures must not cause the system to stop running, and the system should have handling strategies

for all of them and a notification system to indicate the error to the users.