BreatheSync

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Scope:

Brief Summary:

We are designing a Continuous Positive Airway Pressure (CPAP) device aimed at rehabilitating the phenomenon of sleep apnea. Sleep apnea, a disorder characterized by interruptions in breathing during sleep, can lead to various health complications, including cardiovascular issues and reduced cognitive function. The primary need for this system arises from the discomfort and inefficiencies observed in traditional CPAP machines. These machines, while effective, operate on a continuous airflow mechanism, often causing discomfort to users. Our design aims to provide relief to sleep apnea patients, ensuring that when a person is not breathing during sleep, we start pumping in air into the nostrils. The primary objectives for these are i) Rehabilitate sleep apnea by providing air only when a patient stops breathing. Design a power-efficient device that operates based on continuous monitoring. Ensure maximum comfort by accommodating various sleep postures and body types. The main design challenge we are addressing is the continuous and often unnecessary airflow of traditional CPAP. machines. This is not causing discomfort but also results in power inefficiencies. Our solution aims to make the CPAP device more responsive, supplying air based on real-time needs.

Operational Requirements:

	Requirements	Justification
1.	Detect breathing irregularities during sleep	Timely detection is crucial for immediate intervention, preventing prolonged apneas which can have severe health repercussions.
2.	Deliver air pressure to correct the irregularities during breath through a mask or a hose	This selective delivery enhances patient comfort by eliminating the discomfort of continuous airflow, improving therapy adherence.
3.	Emergency notification Alarming sound on device	If there is any irregularity with the patient's breathing pattern or the device itself the patient should be notified using an alarm on the mask or the hose
4	Collect data of breathing pattern during sleep	Can adapt to a patient's unique breathing pattern overtime creating a specialized treatment for each patient
5.	Connect to the Wi-Fi	Allows for connectivity to database
6.	Send acquired sensor data to patient’s mobile application using Wi-Fi	Creates a visual system for the patient explaining the sleep report of the acquired data
7.	Low power consumption and portable	As we are using a selective delivery system, it is easy to conserve energy. Additionally, we are trying to make the device portable such that the device should not need an AC power supply (i.e., trying to remove AC supply and trying to add DC supply)
8.	Store data in an SD card (if possible)	This may be useful as a backup whenever there's network connectivity issues
9.	Make the device as comfortable as possible for the patient to wear	Create the best patient experience when providing effective treatment

Functional Requirements:

	Requirements	Justification
1.	A sensor or a group of sensors to detect if the patient has breathing irregularities or not	Timely detection is crucial for immediate intervention, preventing prolonged apneas which can have severe health repercussions.
2.	Actuator that is used to take air from the environment and exert pressurized air into patients nostrils	This selective delivery enhances patient comfort by eliminating the discomfort of continuous airflow, improving therapy adherence.
3.	A nose piece and a pipe	These are needed to send pressurized air from out actuator to the nostrils of the patient.
4.	Microcontroller unit with SD card	MCU is needed to analyze sensor data and to act as the brain for our system. This will help us detect when our selective air pressure delivery is needed. SD card to store backup data
4	Wi-Fi module (in build or external)	Integrating the Wi-Fi module will help us transfer data easily from our device to the mobile device. (Some microcontrollers come with inbuilt Wi-Fi module)
5	On device alarm system (Buzzer or a vibrating device)	This is used for alarming the patient if any irregularities in breath are observed or if the device has any issues.
5.	Power supply with 8 hours backup	As we are trying to remove the Wall socket connection to our device, we are adding the battery network to the device. So that patient can carry it even if he's traveling.
6.	Mobile application	A mobile application with option to view sleep irregularities in the form of reports, with an additional option to export data as pdf.
7.	Switches and buttons	Used to turn the machine on, off,
8.	LED (GREEN RED)	To indicate the following states: Powered on and ready to use Powered on and all the required components are not initialized properly

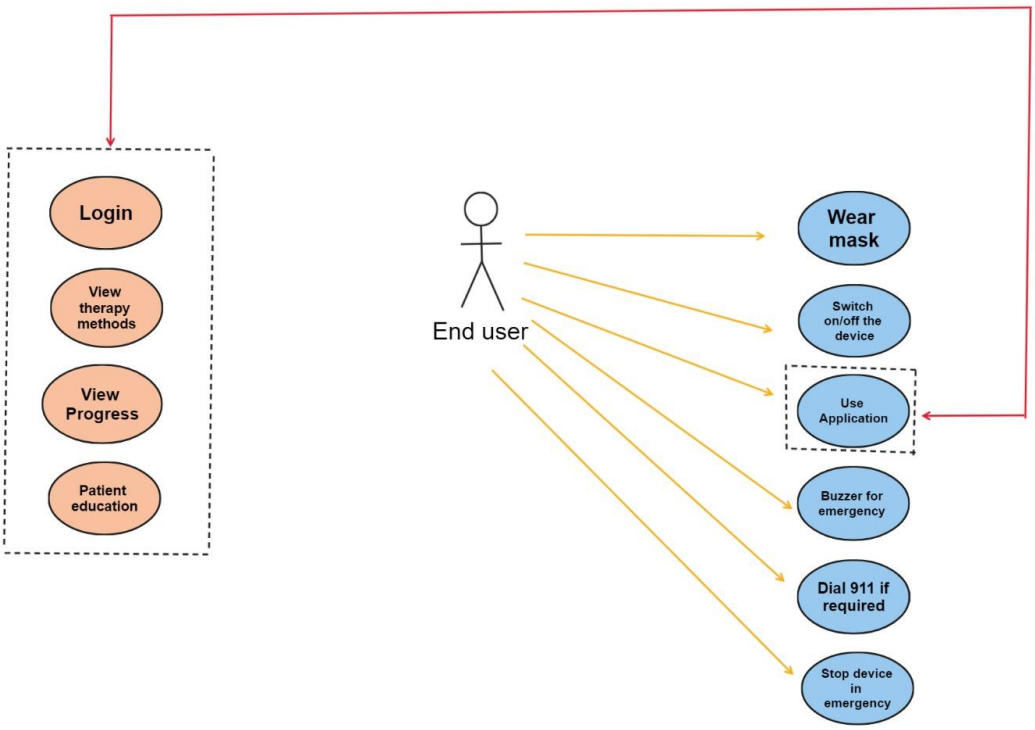
Performance Metrics:

1	Required Operating Airflow	6- 14 cmH2O
2	Battery Life	10-12 hours
3	Weight of Device	750g-1000g
4	Noise level	28 dBA-35dBA
5	Device Size	150mm x 80mm x 40mm

System Overview:

Our system is designed to proactively detect and address breathing irregularities that occur during sleep, a challenge often faced by individuals with sleep apnea. At the heart of our design are advanced sensors, diligently monitoring breathing patterns to identify any deviations from the norm. Working in tandem with these sensors is a precision-engineered actuator, ready to deliver the necessary corrective air pressure through a user-friendly nose piece and pipe. This intricate princess is overseen by a state-of-the-art microcontroller, which also boasts Wi-Fi capabilities. This wireless feature not only ensures seamless data transmission to a dedicated mobile application but also provides users and healthcare professionals with real-time insights into breathing patterns. For added safety, we have integrated an on-device alarm, which is triggered during emergency situations, offering an added layer of security. Our commitment to comprehensive data collection is evident, with the device equipped to store data on an SD card, if needed, and the capability to replay this data directly to a patient's mobile application. Prioritizing user experience, we have crafted the device to be lightweight and portable, ensuring it is easy to use and transport. It is design also emphasizes quiet operation, ensuring users are not disturbed by noise. With a robust battery life of 10-12 hours, users can rest assured of uninterrupted support throughout their sleep cycle. The device is not only efficient but also exceptionally user-friendly, positioning it as a comprehensive solution for sleep apnea patients.

Uses Cases:


Login
View therapy methods
View Progress
Patient education
End user
Wear mask
Switch on/off the device
Use Application
Buzzer for emergency
Dial 911 if required
Stop device in emergency

Potential failures:

1. Battery Failure: Low battery or weak battery. (Device tries to contact family members or the person to charge or change the battery based on the requirement

2. Motor failure: Can lead to the device not delivering sufficient air pressure

3. Hose Leakage: Can lead to insufficient air pressure

4. Loose mask or mask sealing issues: can reduce the effectiveness of the device

5. Short-circuit: Can lead to damage in the device and either the device or the component may need to be replaced

6. Charging issue: Device may not charge due to some component error. Try to replace the faulty component or the device

7. sensor malfunction: Inaccurate readings leading to inefficient therapy

8. Data corruption or data transfer errors: May lead to inaccurate data storage and transmission, resulting in faulty treatment

9. Connectivity issues: Device may face issues connecting to wi-fi and can cause delays in transmitting or receiving data

10. Human errors: Failure to replace used and exhausted components like the therapy medicine, masks, filters etc.

11. Incorrect setup: Failure to setup the device correctly can lead to inaccurate treatment

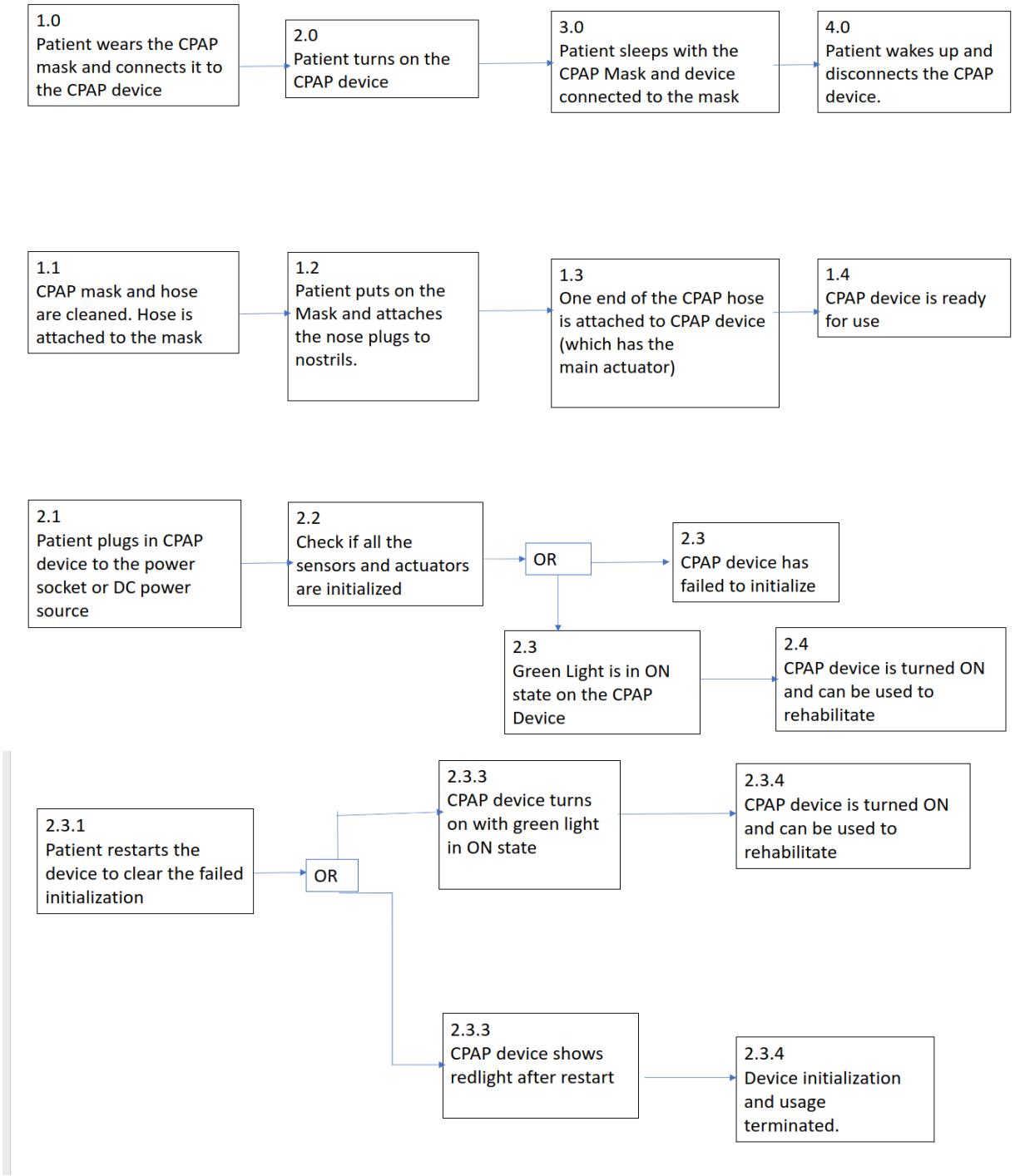
12. False alarm: Device can sometimes detect and dial emergency service inaccurately without the actual need to dial

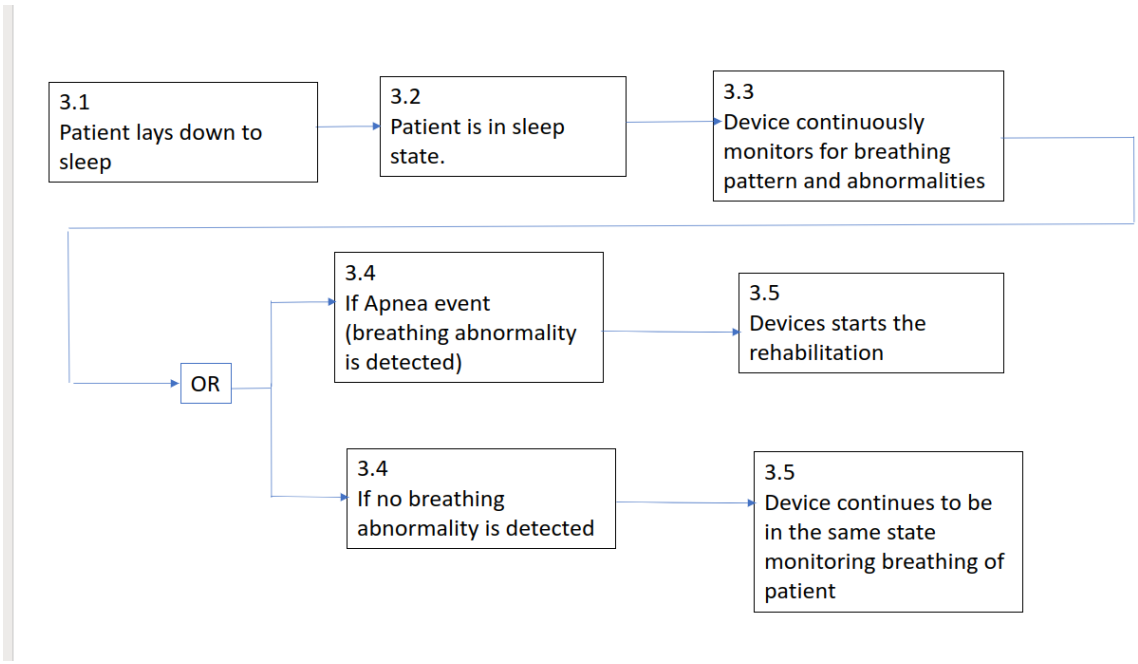
13. Does not dial emergency service in time or when required: it is possible that the device may fail to detect and call emergency service when required

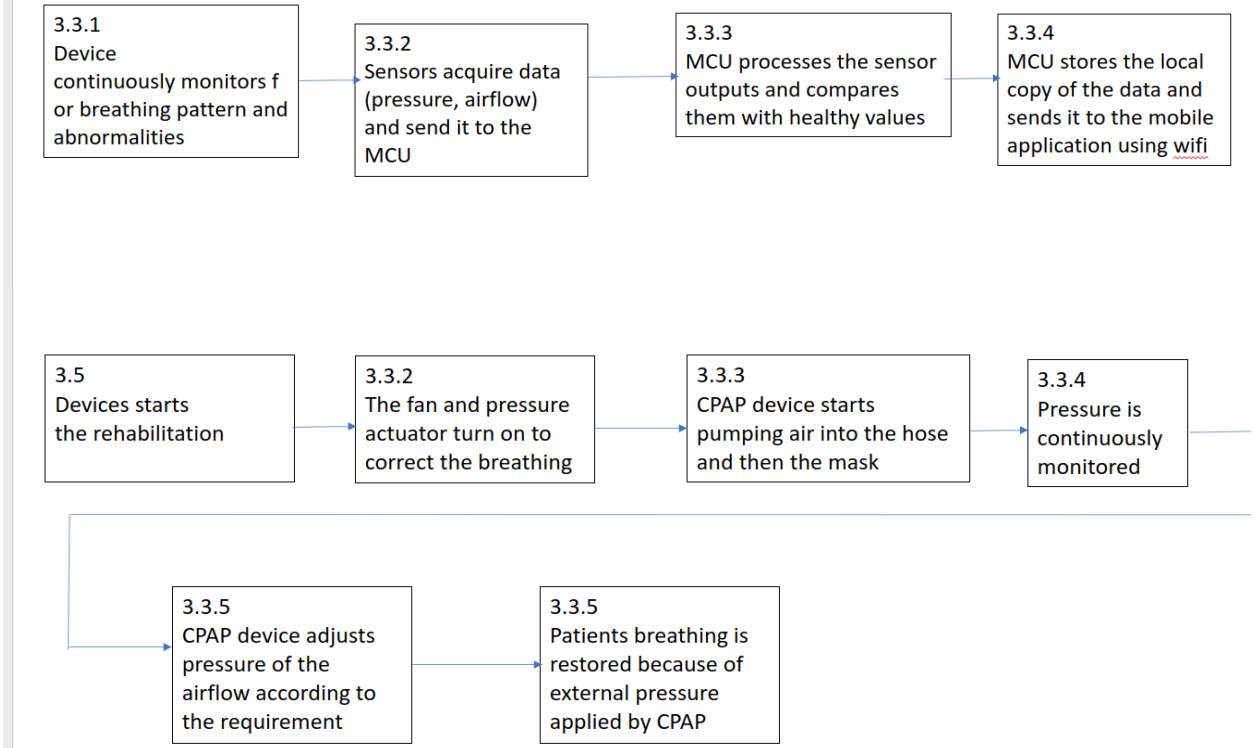
14. Server failure: The server storing the data may be inaccessible, which may result in data transfer delays

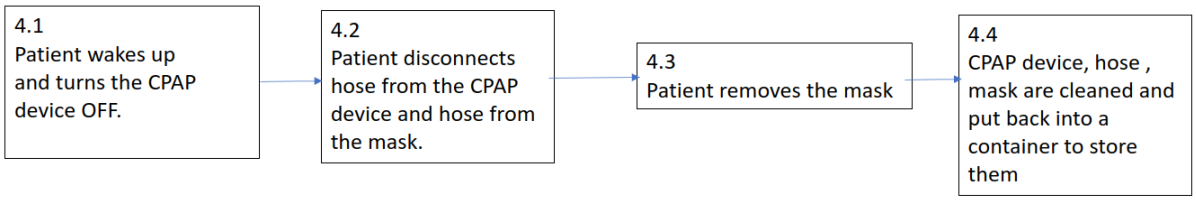
15. Devices overheat: The device may get overheated if not stored in a safe, cool, dry place, causing the device to not work properly

Functional Flow diagrams:




3.1
Patient lays down to sleep
3.2
Patient is in sleep state.
3.3
Device continuously monitors for breathing pattern and abnormalities
OR
3.4
If Apnea event (breathing abnormality is detected)
3.5
Devices starts the rehabilitation
3.4
If no breathing abnormality is detected
3.5
Device continues to be in the same state monitoring breathing of patient


3.3.1
Device continuously monitors f or breathing pattern and abnormalities
3.3.2
Sensors acquire data (pressure, airflow) and send it to the MCU
3.3.3
MCU processes the sensor outputs and compares them with healthy values
3.3.4
MCU stores the local copy of the data and sends it to the mobile application using wifi
3.5
Devices starts the rehabilitation
3.3.2
The fan and pressure actuator turn on to correct the breathing
3.3.3
CPAP device starts pumping air into the hose and then the mask
3.3.4
Pressure is continuously monitored
3.3.5
CPAP device adjusts pressure of the airflow according to the requirement
3.3.5
Patients breathing is restored because of external pressure applied by CPAP


4.1
Patient wakes up and turns the CPAP device OFF.
4.2
Patient disconnects hose from the CPAP device and hose from the mask.
4.3
Patient removes the mask
4.4
CPAP device, hose , mask are cleaned and put back into a container to store them