Phase 2 - Solution Definition and Design

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7. Project Title: Forest Ecosystem Management

8. Refined Problem Statement : Illegal logging and forest fires are two major factors degrading the forest ecosystem; approximately 90% of forest fires are caused by humans presence, emphasising the importance of appropriate mitigation. There are modules developed solely for animal ecosystem surveillance, but for better forest ecosystem balance, a multi-sensing approach for forest fire and illegal logging detection is required in a single viable architecture for agile enterprise and better forest ecosystem balance.

9. Product/Solution Specification - should include at least the following:

a. **All primary Inputs monitored or Data ingested**

Input Data Collected	**Sensor (Providing data)**	**Purpose**	**Collected Data Format**
Temperature, Humidity	DHT11	Fire Detection	Temperature, Humidity readings (Serial Data)
Smoke/gas Concentration	MQ135	Fire Detection	CO2 concentration in PPM (Serial Data)
Audio	ISD1820	Illegal Logging Detection	Recorded audio, .ogg format
Image	Arducam OV5642	Fire,Illegal Logging Detection	JPEG

b. **All primary outputs generated: Data, Control, Communication, etc**

Action	**Output Data Generated from server**	**Generated Format**
when illegal-logging detected (by the image classifying model)	Alert regarding the illegal logging generated along with the Location (refer 9.c part-2 to know how address is fetched)	Text alert displayed on an Android application, data stored in database.
when an increase in smoke/gas concentration detected	Alert regarding the forest fire generated along with the location	Text alert displayed on an application with CO2 concentration in PPM, data stored in database
When there is a suspicious sound detected (heavy machinery, vehicles) sound detected by the ML classifier.	Alert regarding the illegal logging generated with the location.	Audio/text alert generated On an application with GPS location.
When the image classifying model picks up a fire in the image.	Alert regarding the forest fire generated along with the location	Text alert generated with the reference image along with GPS location.

c. **All functions performed by the product or solution:**

Part-1 : Our first aim is to find the hotspots (Entries,exits,routes,roads) in the forest for placement of sensors in those particular areas or hotspots. For the Initial stage of the project we limit the target area to 4sq.km, later we can replicate the similar architecture multiple times to cover larger areas. Using Esri GIS we can find the hotspots in a forest area of 4sq.km . We Place the required sensors in the hotspots and through which primary data can be collected from those sensors.

Part-2 : Each module contains 3 primary sensors which are active in watch mode (refer 9.d for different operating modes), and one secondary sensor which is active in the Force mode. The Primary sensors are DHT11 (Temperature and humidity), ISD1820 (Audio recording module) and Arducam OV5642 (Day and night vision camera). MQ135 is the only secondary sensor to measure the co2 concentration in the surroundings.

We use data from DHT11, MQ135 and Arducam to detect the forest fires and data from ISD1820, Arducam to detect Illegal Logging, Note : We make use of camera to detect both forest fire and Illegal logging. To get a 360° coverage from the camera we attach a rotating gear (works with stepper motor).

All the above listed sensors along with the Zigbee module are embedded on an Arduino Mega board and the sensor data is logged here temporarily, and loaded into the Zigbee module (in a specific format).Through the established zigbee mesh network the data reaches the nearby base station. All the components are powered by a 12v battery(necessary regulators, buck converters used to step down voltage from its input (supply) to its output (load)), which in turn charges from the solar panel. The list of components and their specifications, cost, quantity are mentioned at the end of the document in a tabular format.

The data is logged once in every 15 minutes during watch mode and once in every 3 minutes during Force mode, Operating mode jumps from watch to force state. If the temperature reading crosses the pre-fixed (55°C, will be updated in future with help of literature survey) threshold value, it jumps from watch state to force state. (Note : Microcontroller compares the temperature value with threshold during the sensing and logging state). Also while installing the nodes in forest, a database is maintained for storing its location, and is retrieved back later while creating alerts using parameters of zigbee addressing structure (PAN ID, network address). Also, all the components are placed in a protective case which is water-proof.

Once the data reaches the nearby base station, the data is then transferred to the base station closest to the Central Surveillance System (CSS) using long range communication protocol 4G/LoRa (depending upon the location of the forest, if the forest is in cellular coverage area 4g can be used else we can go for LoRa) and later eventually to the CSS.

Part-3 :

Data from the base stations is uploaded to the cloud via the internet. Hence, the bandwidth requirements at the base station side should be large. When the raw data is uploaded, audio and image data is uploaded separately.

For the audio data in the cloud: Audio pre-processing takes place to clean-up unwanted noise, audio parameterization to settle for optimum variables and parameters for classification. Then the supervised audio classification algorithm which was trained from sampled audio files, classifies the input audio and if any suspicious activity is recorded, alerts the authorities.

For the video data in the cloud: Image pre-processing is done i.e conversion of BGR(blue green red) to HSV(hue saturation value) for better thresholding. Then thresholding is applied to mark out the points in the image that have fire. Detection and alerting the concerned authorities if necessary.

d. **Operating conditions within with the product or solution will operate**

There are 4 operating conditions :

1. **OFF State** : When Battery is drained out completely.
2. **Sleep State** : Whole time except Watch and force state
3. **Watch State** : Activates once for each 15 min from sleep state, this state is active for 1.5-2 mins and goes back to sleep if sensor values less than threshold else jump to force state.
4. **Force State** : Senses data for every 3 mins, Activates if sensor values greater than threshold, goes to watch state if sensor values goes back to less than threshold.

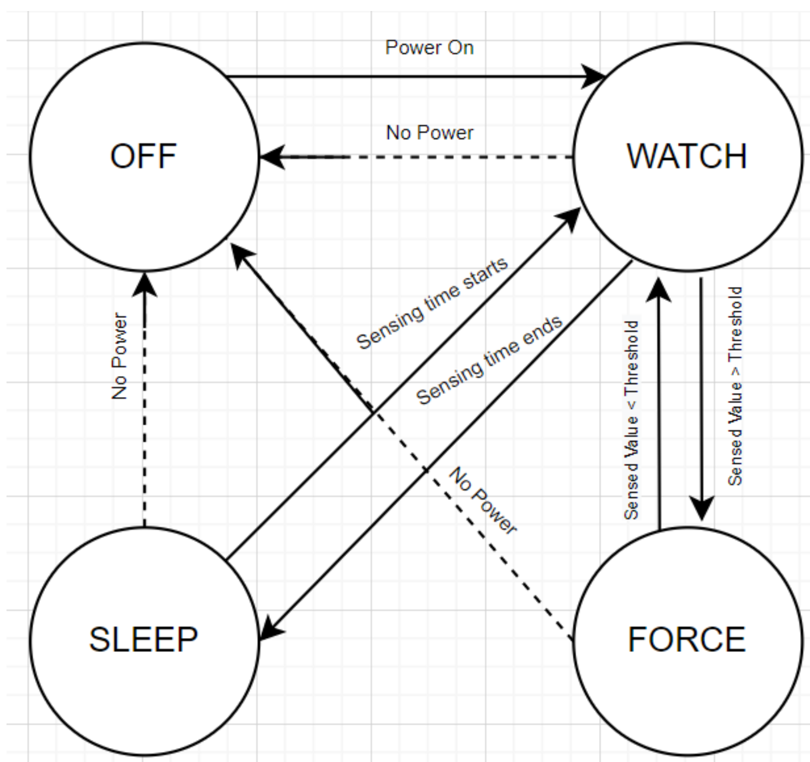

Fig.1 State Diagram of operating Modes

e. **Performance targets for this solution (You have to figure out how you define good performance for your own Product or solution)**

As of now we are providing solutions for a bounded area i.e 4sqkm (area of interest) as forests are dense and spread over a large area. We consider monitoring larger areas as our future challenge/goal to provide better/faster communication as bandwidth is one of the major concerns in forests. As of now there are modules that are deployed in forests for capturing the habitat of animals for ecosystem restoration whereas, we provide the multi sensing approach for ecosystem restoration i.e illegal logging and forest fire detection . The main targets that we want to achieve are extraction of the real time data from sensors,reliable data transfer and performing high accuracy ML models on audio,video data captured by sensors and finally sending important alerts to the forest department. Also the communication connection setup time must be in order of seconds and connection must have lower latency.

Data from the base stations is uploaded to the cloud via the internet. Hence, the bandwidth requirements at the base station side should be large since both audio and video are bandwidth hungry. Both audio and video data are separated and computed separately in the detection phase. The latency between the base station and cloud should be minimal.

For the audio and image data in the cloud: Supervised Machine Learning is used for classification of audio data, the dataset required for training the model should be labeled for better accuracy. The accuracy for the classification model should be high. It should be well above 90-95%. Also the speed of the classification should be optimum. Effective classification algorithms should be chosen for efficient classification.

For image data, the Python OpenCV module is used for detection of fire in images data. Here, the computational requirement is minimal compared to audio classification. Nevertheless, the accuracy of detection should be high. Once the algorithm detects any suspicious activity either be it in audio or video data, the alert generation and alert communication should be within seconds if not in minutes.

As we are working with real time data the whole process should not take more than a couple of minutes as the requirement of action from the concerned authorities should be immediate otherwise there will be havoc.

10. Architecture block diagram and high level description. This should say what off the shelf components you plan to use (HW or SW and indicate on the diagram), and which components you will develop yourself (please indicate). Should also state how you will integrate everything together and what external communication links you will need to use, if any.

Architecture block diagram mainly contains 3 parts, these are indicated as 3 square boxes in fig 2.

1st block, Indicates the target area size (4 sq.km), and also we use GIS to find the hotspots in the forest for the placement of sensor nodes.

In the 2nd block, all the required hardware components, their connections are shown. DHT11,ISD1820,OV5642 are primary sensors, always on during Watch Mode and MQ135 sensor is a secondary sensor which starts working only if the control signal is given by the processor (during Force Mode). All these sensors are embedded on an Arduino based microcontroller where some basic processing is done and the data is temporarily logged and pushed into the Zigbee module.

The sensing takes place once in every 15 mins in the normal conditions (watch state), but if any suspicious activities are encountered the sampling rate is increased and sensing takes place once in every 3 mins (Force state). All the sensors used in architecture have both active modes and stand-by modes, therefore very minimal power is required during in-active state(sleep state). Also sensor selection was based on cost, accuracy and power requirements for our application, all of these can work on batteries for years. To power all the components a 12v battery is used and the battery is constantly charged using a Solar panel.Each component has different operational voltage levels, we use regulators and buck converters to provide the required supply.

Once the data is pushed in the zigbee mesh network, it reaches the nearby base-station, from base-station the data is sent to the base-station nearest to the CSS, thus we can use long range wireless communication protocols 4G or LoRa depending upon the location on forest.

<u>3rd Block :</u> The data is received at CSS, and sent to the cloud for processing (run ML models) As a result, the CSS's bandwidth requirements should be high. When uploading raw data, audio and image data are uploaded separately.

For cloud audio data, we use the following procedure: Pre-processing of audio is done to remove unwanted noise, and audio parameterization is done to find the best variables and parameters for classification. The supervised audio classification algorithm, which was trained on sampled audio files, then classifies the input audio and alerts the authorities if any suspicious activity is detected.

Image pre-processing, i.e. conversion of BGR to HSV for better thresholding, is done for video data in the cloud. Then thresholding is used to highlight the areas of the image that contain fire. Detection and, if necessary, notification of the appropriate authorities.

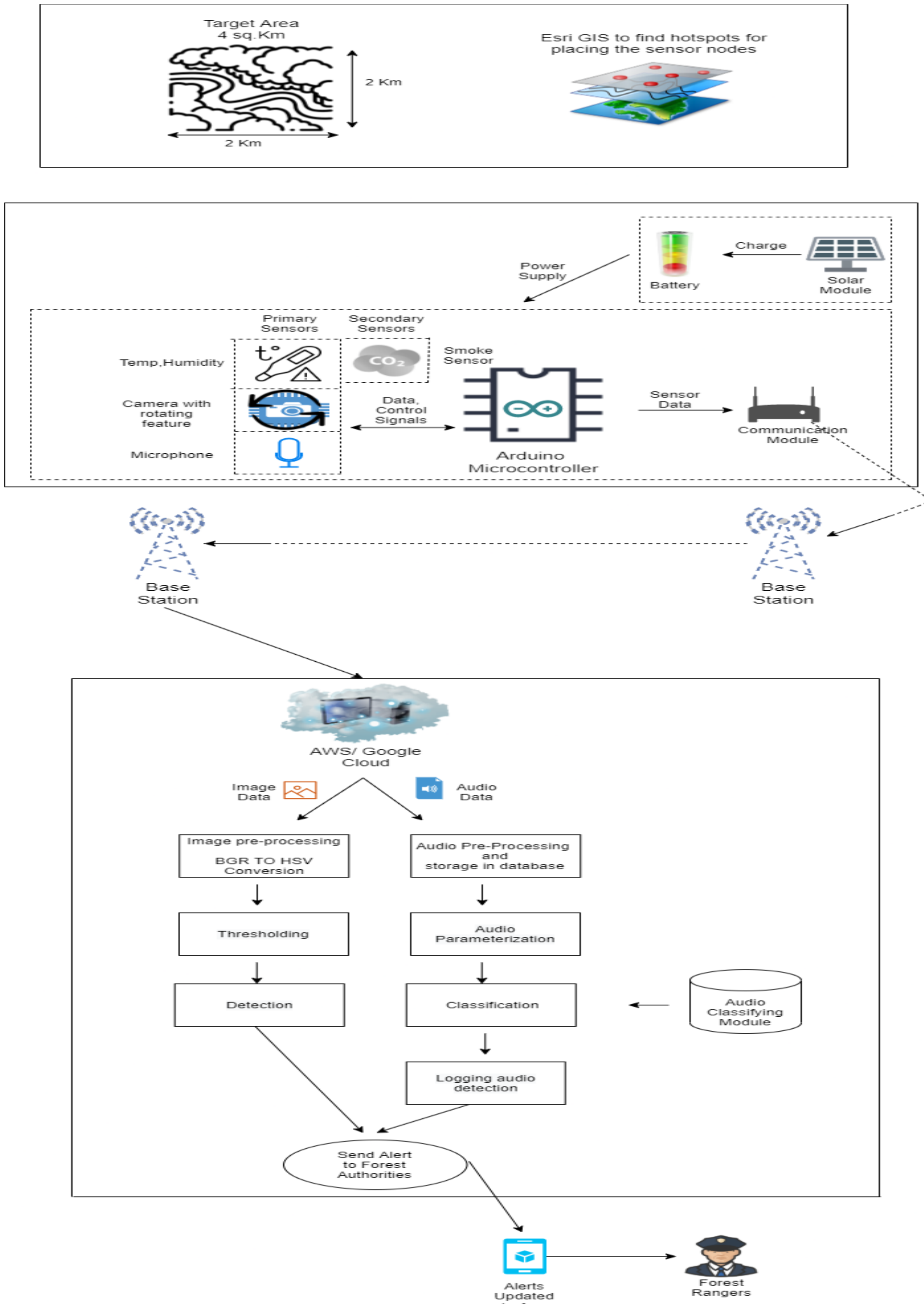

Fig 2. Overall Architecture of Forest ecosystem management system

11. Validation Plan - How will you check that your solution or product works like you have specified it? What resources will you need to do the test or validation?

To validate the selected sensors, datasheets were looked up. All components have both active and stand-by mode, therefore suitable for our battery powered application, all the hardware works fine for years on battery and accuracy provided is adequate for the application. The sensors work fine individually, the exact test parameters such as voltage range/current values/output waveforms etc, will be verified after building the prototype. Following the construction of the prototype, we will conduct preliminary testing. If any errors or flaws are discovered, we will modify it and retest it. Once the prototype is up and running, we can move on to the next step. Then we will conduct periodic testing and check if the system is reliable, then we will proceed to initial deployment. Following the initial deployment, we can conduct periodic field testing to ensure that the system is functioning properly.

When all of the results match the theoretical values that we expect, we can conclude that the system is working properly.

To validate an Audio classifier, the model data is split into training data and test data into optimal percentage called cross-validation which checks the accuracy of the classifier. Cross-validation is primarily used in applied machine learning to estimate the skill of a machine learning model on unseen data. That is, to use a limited sample in order to estimate how the model is expected to perform in general when used to make predictions on data not used during the training of the model.

To validate the image detection, we can use sample data to test our algorithm. Since the algorithm should detect fire both in the day and in the night, we should use optimum threshold value to find the pixels with fire. Using trial and error methods to find the optimum threshold value holds-up well. For the detection and alerting phase, we should make sure that no false alarms are sent. We should double check with output data from the smoke detector to validate whether there is a real fire or is it just a false alarm. If possible we can also alert the authorities with the picture of the fire.

12. Your feedback about this hackathon:

This Hackathon has been a very exciting and interesting one.This Hackathon helped us in brainstorming for new creative ideas and approaches. The Hackathon has most certainly introduced us to a very exciting yet important problem to work on. Developing an integrated ML and IoT model for forest ecosystem management seems very important in today's modern world. This hackathon has provided us to fuse the latest technologies towards conserving our mother nature.

13. Your feedback on the technical mentor

a. **Mentor name**: Arjun Dinesh

b. **Feedback**: Arjun Dinesh sir is very helpful in our idea phase. He helped us in turning our indefinite idea into a strong cohesive one. He helped us in choosing the optimal sensors and softwares for our project. He also held regular meetings which were very helpful and productive.He helped us in refining our problem statement into a very effective one so that we have a very clear idea on how to approach and proceed.

14. Your feedback on the business mentor

a. **Mentor name**: Rahul Nair

b. **Feedback**: Rahul Nair sir helped us in building our understanding on how a business works and provided great insights on building a strong business model for our project. He helped us on how our project can be marketed as a product.

15. Cost for equipment (for 4sq.km)

S.NO	ITEM	COST (Rupees)	Power supply	QUANTITY	ESTIMATED TOTAL
1.	DHT11	115	DC 3.3-5V Current supply Measuring:1 mA Stand-by: 45 uA	20	2300
2.	MQ135	140	DC 2.5-5V Current supply 150mA	20	2800
3.	ISD1820	169	DC 3V Stand-by:0.5 uA	20	3380
4.	Arducam OV5642	2000	DC 3.3/5V	20	40,000
5.	Arduino Mega	1200	DC 6-12V	20	24,000
6.	zigbee	1949	DC 2.1-3.6V Transmit current:33mA Receive current : 28mA	20	39,000
7.	Cloud services access	--	--	1	Depends on plan and company
8.	Solar Panel	1500	50 watt, 12V	20	30,000
9.	Battery	650	12V,1.3Ah	20	13,000
	Total Cost	--	--	--	1,54,000

16.PHASE-I REVIEWS:

Review-1: The idea of monitoring forest fires seems ok in outer forests. But, deploying and maintaining microphones and cameras in remote forest areas to catch poachers seems not to be much practical.

Addressing the review:

We first find the hotspot regions using ESRI GIS and place sensors majorly in those required areas so we can control most of the illegal entries to the forest. At present,we are considering 4sq.km of forest area.

Review-2: This team is not clear if they want to stop illegal tree falls or prevent forest fire. Both the cases are useful for the environment. The team may need to redefine their business goals and see how they bring this solution as a product.

Addressing the review:

As specified in our problem statement, there are modules developed exclusively for forest fire detection, or for the detection of illegal-logging. So our main objective is to develop a multi-sensing, multi-purpose module for detection of aforementioned i.e,Forest fire detection and Illegal logging challenges in a single viable architecture for agile enterprise and better forest ecosystem balance.

Review-3: The only concern is network connectivity in the forest.

Addressing the review:

We replaced wifi with Zigbee for short range communication, As we are using zigbee mesh topology we can transfer sensor data even though one of the nodes is dead in path as each node is connected to every other node in mesh topology connectivity problem can be solved to the maximum and bandwidth is also major concern in forests so we are implementing communication module with zigbee which can replace wifi module. For base-station to base-station we are going for long range communication protocol 4G if the forest area is in cellular coverage area else LoRa can be used.