Prediction and Prevention of Wildfires

2023-04-26

Authors:

Thenatchi Kamanthenu
IBM
tkamathenu@in.ibm.com

Sandeep Dayal
IBM
sanddaya@in.ibm.com

CONTENTS

FIGURES

TABLES

OVERVIEW

1.1 INTRODUCTION

Forests are lungs for the planet, it is not an exaggeration to say that without forests the planet cannot be sustained. Wildfires are one of the major hazards of global warming; they destroy forests and speed up the deforestation process.

Global Warming and Climate Change are at the top of all government agencies', business houses' and world forums' agendas. There is an interdependency between wildfire and climate change; climate change is causing more wildfires and wildfires are increasing carbon emissions. Although the exact quantities are difficult to calculate, scientists estimate that wildfires emitted about 8 billion tons of CO2 per year for the past 20 years[1] and estimate that wildfires make up 5 to 10 percent of annual global CO2 emissions each year.

Following are some key statistics related to wildfire from the past year:

- 60000+ Wildfire Incident reported (alone in US for the year 2022)
- 60+ Loss of life
- Spead across 7 Million Acres
- $2 Billion worth damages
- $55K – average suppress cost for a wildfire.

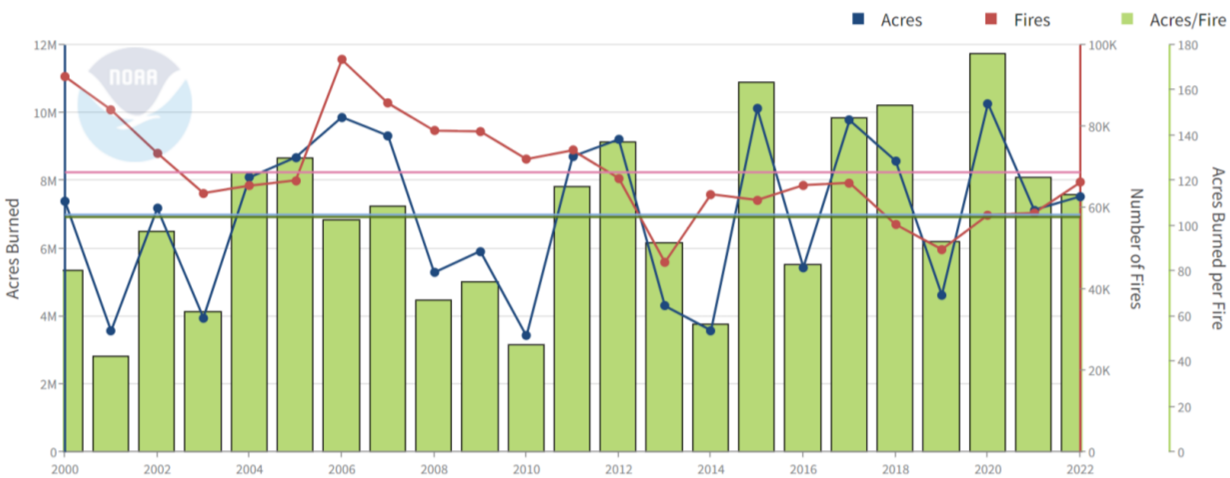

Figure 0-1: Wildfire statistics – US. Source: NOAA[2].

[1] *https://insideclimatenews.org/news/23082018/extreme-wildfires-climate-change-global-warming-air-pollution-fire-management-black-carbon-co2/*

[2] *https://www.ncei.noaa.gov/access/monitoring/wildfires/*

Wildfire causes are identified in two broader categories, Natural Causes and Human Errors. It is estimated that around 87%[3] of wildfires are caused by human errors, the remaining caused by natural events (mostly lightning and rare occurrences of volcano, meteor, coal-seam). The most common human error causes for wildfires are listed below in no particular order or sequence/magnitude:

- Burning debris
- Unattended campfires
- Cigarettes
- Power lines
- Fireworks
- Sparks from equipment
- Arson

In this paper we focus on wildfire caused by power lines since it is mostly technical failure and there are factors which can be controlled to reduce the occurences of such events.

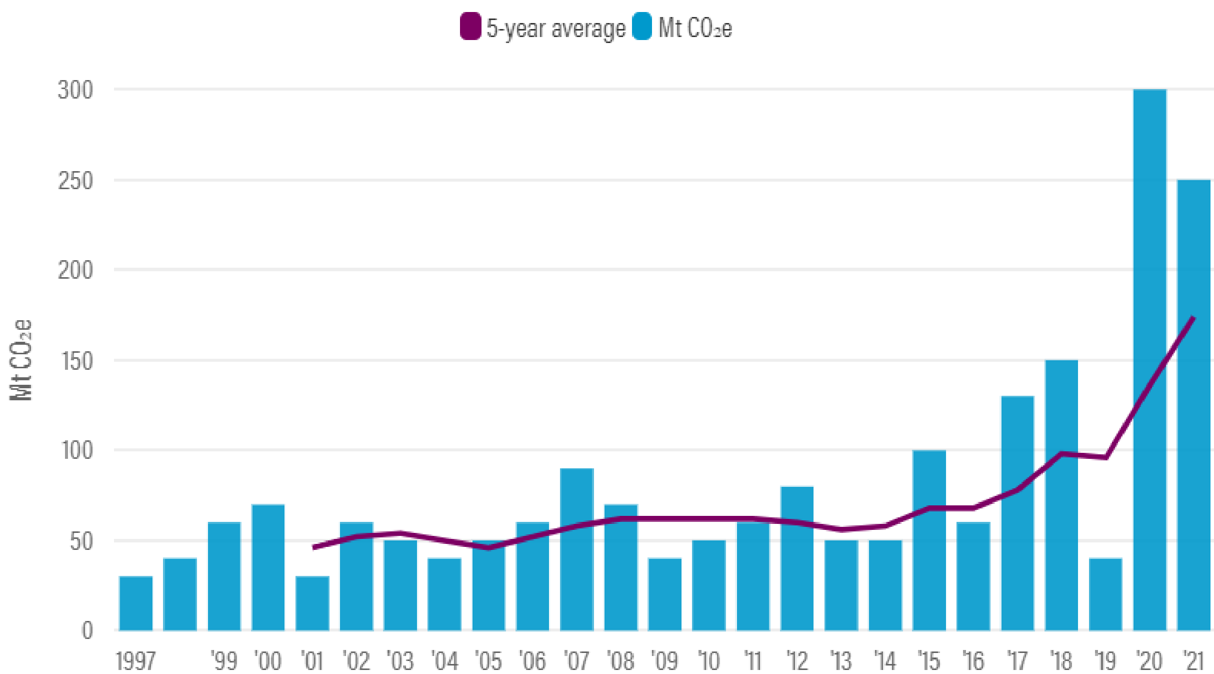

Figure 0-2: Carbon emissions from wildfire, continental U.S. Source: World Resources Institute[4].

Beside damages, wildfire impacts long-term and short-term sustainability goals such as air quality, wild-life habitat, flooding. It also reduces solar energy generation due to a thick cloud of smoke.

[3] *https://www.nifc.gov/fire-information/fire-prevention-education-mitigation/wildfire-investigation*
[4] *https://www.wri.org/insights/wildfire-forest-carbon-stewardship*

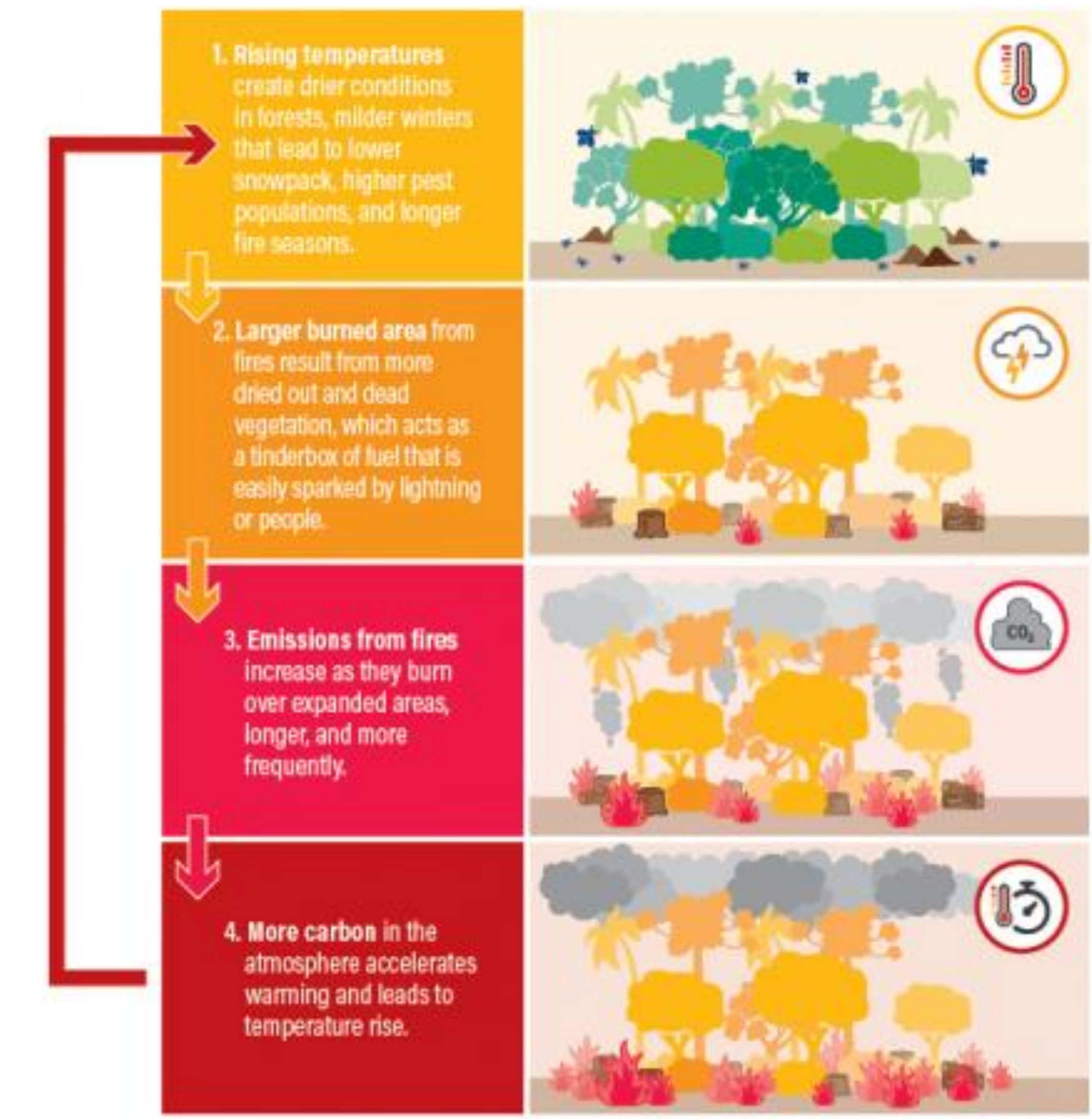

Figure 0-3: Wildfire – Climate feedback loop published in World Resources Institute [5].

Statistics indicate that wildfire alone has severe impact on decarbonization[6] [7] and it is difficult to detect and control the fire.

The best chance to stop and avoid damage is at the initial stages. Due to wilderness and vast areas, it is difficult to prevent wildfire; therefore, prediction is the best chance to avoid the severe impact.

[5] *https://www.wri.org/insights/6-graphics-explain-climate-feedback-loop-fueling-us-fires*
[6] *https://www.ncei.noaa.gov/news/national-climate-202206*
[7] *https://insideclimatenews.org/news/23082018/extreme-wildfires-climate-change-global-warming-air-pollution-fire-management-black-carbon-co2/*

2 CURRENT LANDSCAPE

The following are a few approaches currently being used to predict wildfire.

2.1 NASA IMAGINARY USING SATELITE[8] [9]

NASA has two different types of satellite systems to help track wildfires: polar orbiters and geostationary platforms. Polar orbiters like NASA's Terra and Aqua satellites and NASA-NOAA's Suomi NPP satellite provide detailed views of fires and smoke globally up to twice a day.

2.2 NOAA'S CLIMATE PREDICTION[10] [11]

NOAA's Climate Prediction Center offers a range of subseasonal and seasonal forecasts and long-lead outlooks that preview temperature and precipitation trends. These can establish conditions conducive for enhanced fire risk.

2.3 AIR PATROLS[12]

Air patrols, consisting of a pilot and trained aerial observers, fly predetermined routes over remote areas during periods of high fire danger, or following lightning activity. Commercial and recreational pilots also report wildfires.

2.4 INFRARED TECHNOLOGY[13]

The Government agencies use both ground personnel and aircraft with thermal imaging technology to assist in fire operations. Thermal imaging can be utilized for detecting hot pot and areas of residual fire on larger fires during mop up, boundary establishment, fire mapping and fire progression.

2.5 FIRE LOOKOUT TOWERS[14]

One way fires are detected is by lookout Towers. These are situated at a location with extensive visibility and have associated structures manned by a lookout observer whose prime purpose is to locate and report wildfires. This is the conventional way.

8 *https://www.nasa.gov/mission_pages/fires/main/missions/index.html*
9 *https://appliedsciences.nasa.gov/join-mission/training/english/arset-techniques-wildfire-detection-and-monitoring*
10 *https://www.noaa.gov/noaa-wildfire/fire-weather-tools*
11 *https://www.nesdis.noaa.gov/our-environment/dust-ash-fire/fire*
12 *https://www.enr.gov.nt.ca/en/services/wildfire-operations/detecting-wildfire*
13 *https://en.wikipedia.org/wiki/Infrared_photography*
14 *https://en.wikipedia.org/wiki/Fire_lookout_tower*

2.6 PREDICTIVE SERVICES[15]

Predictive Services was developed to provide decision support information needed to be more proactive in anticipating significant fire activity and determining resource allocation needs. Predictive Services consist of three primary functions: fire weather, fire danger/fuels, and intelligence/resource status information. Predictive Service staff units are located at the National Interagency Coordination Center (NICC) and the Geographic Area Coordination Centers (GACCs) across the country.

Table 2-1 below lists multiple AI/ML models[16] that are available or being developed for predicting wildfire accurately.

Data	Data Type	Sources
Fire History	Shape file	Fire and Resource Assessment Program (FRAP), CAL Fire, United States Forest (MSDA Project, Service region, Bureau of Land Management and National Park Service.
Weather	Censor data (CSV file)	Climate Data Online (CDO) and Local Climatology Data (LCD).
Vegetation	Remote-sensing satellite data	Landsat 8 satellite using Google Earth Engine (GEE).
Powerline	Sensor Data	Acquired through multiple sources/sensors.
Terrain	DEM file	United States Geological Service (USGS).
Satellite	Images/Blobs	Satellite data is also critical for observing and monitoring smoke from fires. This information helps firefighting efforts from the air and enables better air quality forecasts. It can monitor the concentration of greenhouse gases in the atmosphere, such as aerosols, water vapor, carbon monoxide (CO), carbon dioxide (CO2) and methane.

Table 2-1: AI/ML models[17] that are available or being developed for predicting wildfire accurately.

[15] *https://www.predictiveservices.nifc.gov/predictive.htm*
[16] *https://www.mdpi.com/2073-4433/12/1/109/htm*
[17] *https://www.mdpi.com/2073-4433/12/1/109/htm*

3 PROPOSED SOLUTION

There are many efforts underway to predict and prevent wildfires as described in the previous section; however, here we outline an approach that uses a combination of multiple available technologies. We are utilizing technologies such as the Internet of Things (IoT) and UAVs (Unmanned Aerial Vehicles).

1. UAV Based Surveillance: UAVs/Drones are becoming increasingly more useful and new use cases are being identified. One of the more popular UAV uses is survellience.[18] [19] UAVs have a wider range of access to and from difficult terrain and location to well connected geographical locations.
2. UAV/Drones do not require any prior installation and eliminate the costs associated with it. Additionally, it can be equipped with a spectrum of sensors which can capture most of the environmental inputs.
3. Drones, unlike IoT devices, do not require to be fixed to a geographic location. The data collected by UAV based sensors and cameras are suitable for different kinds of analysis. The recordings of the thermal sensors can be analyzed from the point of view of fire presence on the area, surface distribution of soil temperature, plant temperature, and presence of fire condition on the given territory.
4. The investment into drone powered solutions is solid and advisable due to the fact that drones are cheap, and the prices of the necessary drones show a decreasing tendency.
5. There is a potential challenge regarding legal requirements for using drones/UAVs at fire sites; however, this challenge can be overcome by working with respective agencies[20] that provide regulations in this area. Each country follows different legal requirements and regulatory standards[21] to seek approval[22]. Widespread usage / bulk deployment of UAVs can pose additional legal challenges which need to be explored before applying a solution. There is no single rule or guideline available, hence there is a need for further analysis and exploration of the legal framework for each juridisction[23].

[18] *https://www.mdpi.com/2504-446X/5/1/15*
[19] *https://par.nsf.gov/servlets/purl/10133280*
[20] *https://uas.nifc.gov/*
[21] *Regulation of unmanned aerial vehicles - Wikipedia*
[22] *Drone Laws & Regulations: Do You Need a License to Fly? (businessinsider.com)*
[23] *https://en.wikipedia.org/wiki/Drones_in_wildfire_management*

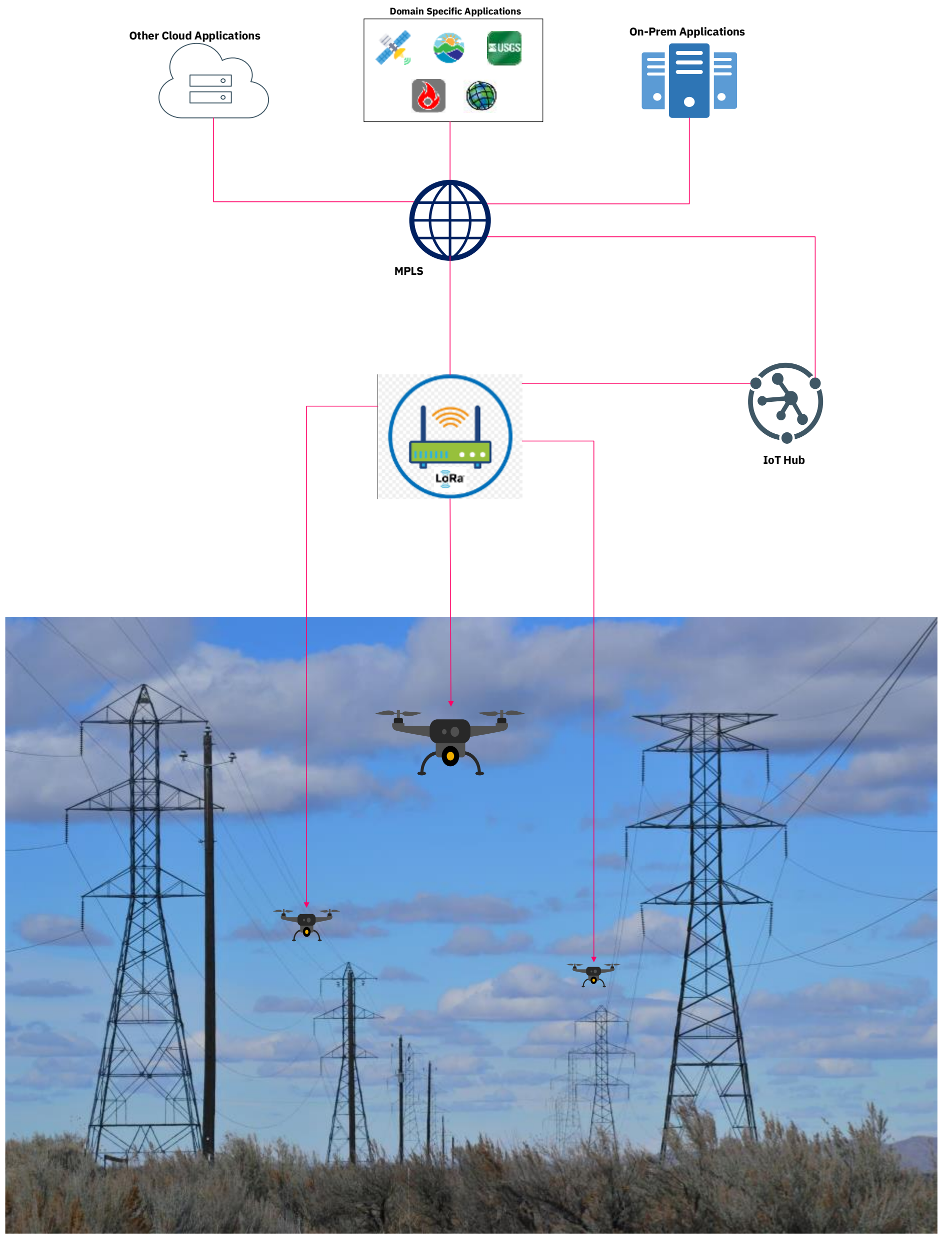

Figure 3-1: UAV-based power line and forest surveillance.

6. IOT Mesh Device Network: The use of IoT device networks has not yet become a standard solution in general practice, as it was expected initially. Within this solution also, IoT Device Mesh is used only for limited and identified high risk area(s), where drone deployment is difficult due to infrastructural challenges. IoT Device Mesh implementation and Maintenance is costly compared to the UAV based approach. However IoT Devices can collect more sensor data than UAVs.

LoRa based sensor nodes transmit the data to an IoT gateway. The collected sensor data then gets integrated with other source systems to produce intelligent insights. However, in the case of the forest survellience, the decision needs to be performed on an immediate basis for avoiding widespread fire in the forest.

The solution uses LoRa[24] and edge gateway node for monitoring the environmental parameter of a forest. IoT edge gateway is based on edge computing where it is capable of performing analytics at the gateway node. This gateway node after, providing the analytics, transmits the valid information to the cloud server(s). LoRA Networks are used for UAVs as well as IoT device implementation. Widely used technical specifications [25] are available.

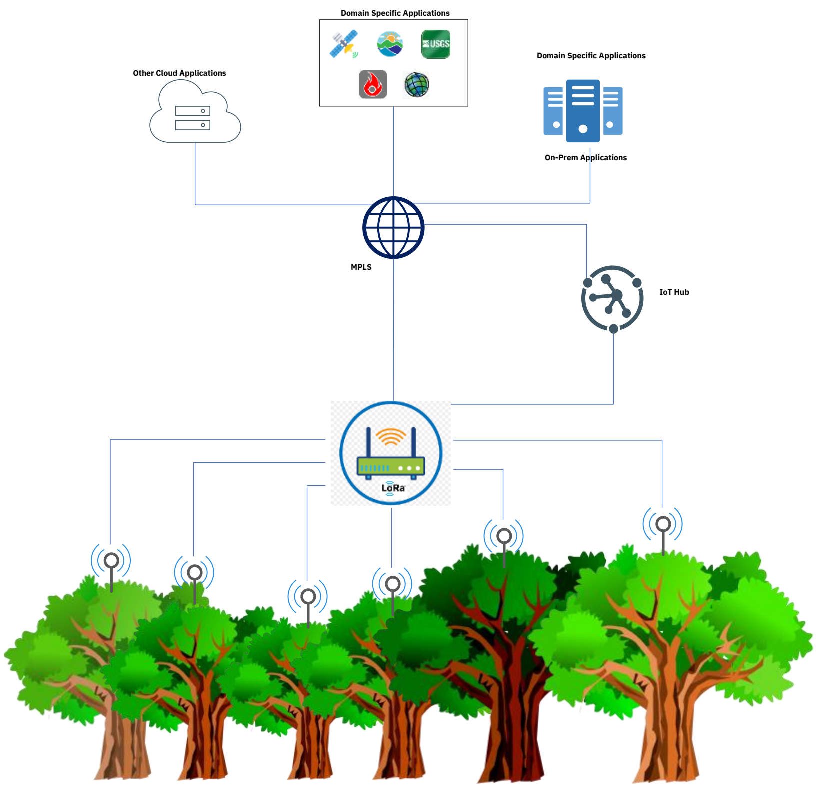

Figure 3-2: IoT Device mesh-based transmission line and forest surveillance.

4 Potential Challenges

4.1 Business Challenges

- IoT Device Mesh Implementation and Maintenance is costly and business cases need to be developed, however wildfire related claims are even costlier.

[24] *https://www.mdpi.com/2079-9292/9/3/531*
[25] *https://ieeexplore.ieee.org/abstract/document/9530545*

- The 10-year regulatory strategy will require new investments in collaborative capacity, both within the Forest Service and other Federal agencies and for Tribes, States, partners, and communities.
- Adopting regulatory standards and legislative needs poses challenges especially regarding the use of Drone implementation.
- Co-ordination across the Government would require consistent effort to seek just the right time for approvals.
- No single entity can accomplish the work alone to achieve the collective impact that our forest and communities need. We must build a multijurisdictional coalition to work across land management. This includes work across Federal, Tribal, State, local, and private lands. Partnerships, including those beyond existing contracts and agreements, will help identify barriers to success and ways to overcome them.
- Over the last 10 years, the number of agency permanent employees dedicated to fire suppression has significantly increased, while the number of employees in other fields has decreased: we need to rebuild skills and workforce capacity to accomplish fuels and forest health treatments and fully engage with communities at the necessary pace and scale.

4.2 Technical Challenges

- Low band networks such as LowRaWan or 6LoWPaN network's data transfer capacity in depth forest areas is a challenge. Equivalently, solutions can leverage Mesh, 4G and future networks of Wi-Sun, 5G etc., but the anticipated implementation cost could be higher for the longer forest area to cover.
- Implementing Security components is a challenge due to the ongoing adoption of technologies such as 5G, Edge and IoT.
- Implementing DLR (Dynamic Line Ratings) is costly and not all utilities are looking for that. The solution leverages DLR inputs and without that it can't achieve desirable accuracy.
- It is crucial to know wildfire hazards due to natural factors. When planning regular operations and thinking of how to prevent a wildfire from happening, foresters should consider current and upcoming weather conditions and their danger to forests.
- Monitoring is primarily concerned with detecting active fires and estimating burnt areas. Satellite instruments have increased the use of earth observation data. Despite the increased availability of satellite data, this is not fully used operationally. For early warning purposes, continuous forest surveillance data assessment and its resilience has always been a challenge.
- There is limited research on fire management in the country to assess burning patterns and trends for input into fire management, etc.

5 SOLUTION INSIGHT

- Collection of data from various sources upfront (e.g.: Satellite, Govt Agencies, Tribals, etc.) will help with a strong foundation for the solution.
- Use of Data Simulator for IoT Devices during development and testing phase helped in solution development.
- Device Health Dashboard is critical for IoT sensor-based solutions. It helps to avoid many unknowns and debugging with sensors.
- Establishing Networking Framework is the key to success for the solution.
- Designing IoT resilience and Disaster Solutions especially around networking approaches (Eg: Alternatives around Cellular) is a must for a successful working solution.
- Clear definition of RACI (Responsible, Accountable, Consulted, Informed) particularly working with various parties.
- Focus on building fire safety messages and techniques upfront to avoid major disasters while applying prevention techniques.

5.1 SOLUTION CONCEPTUAL VIEW

This section outlines key building blocks / components for the solution with an enterprise view. This section describes the solution holistically with all components included (Primary and Support).

This solution is a comprehensive approach for prevention through early detection of wildfire. It uses combined approaches for statutory IoT Devices and Mobile UAVs for data acquisition and then it utilizes the sensory data to produce an early warning.

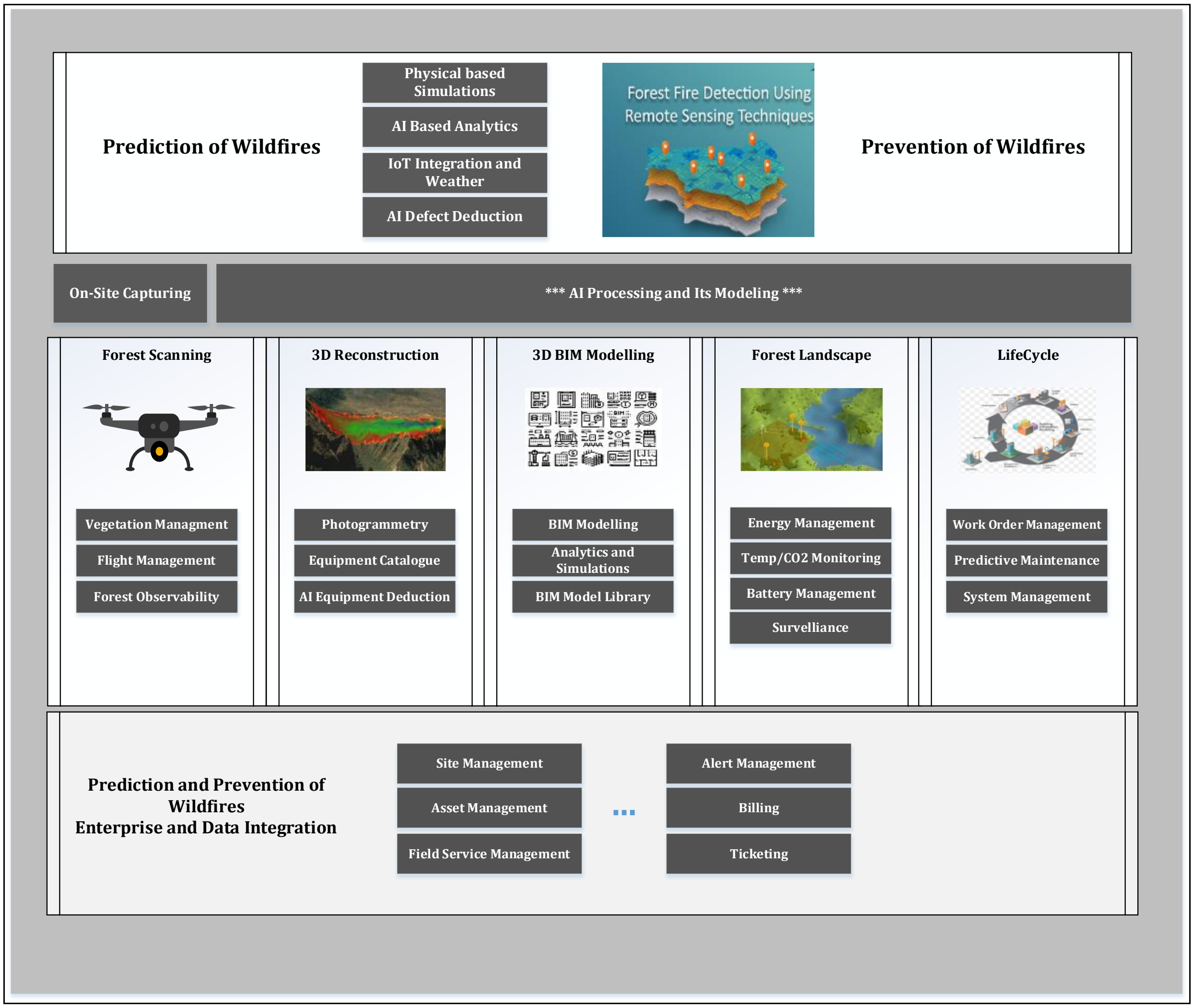

Figure 5-1: Solution view - Enterprise conceptual (indicative).

The key building blocks for wildfire prediction and prevention solution include:

Forest Scanning: UAVs follow guided flight paths to capture high-resolution images of the forest's high risk spots. Installed sensors collect related data that is processed at the cloud-based processing applications/algorithms.

3D Reconstruction: The solution uses 2D drone images to reconstruct a 3D realistic model of the tower. We use information from photogrammetry services, equipment catalogs, and intelligent equipment detection using AI to enrich the realistic model.

3D BIM Modeling: The realistic reconstruction is converted automatically into an initial 3D BIM model and further improved using BIM model libraries. These models allow engineers to perform highly accurate design enhancements (e.g., add an antenna, dish, or Remote Radio Unit (RRU) equipment from a BIM library) and perform different types of physical simulations (e.g., EMF-Electromagnetic Field and structural stability) through the digital twin application.

Forest Landscape: The ability to manage IoT/edge devices, like HVAC, batteries, and energy consumption.

Lifecycle management: Ongoing lifecycle support of the built tower through its continuous monitoring and predictive maintenance capabilities.

5.2 Solution Detailed View (Logical)

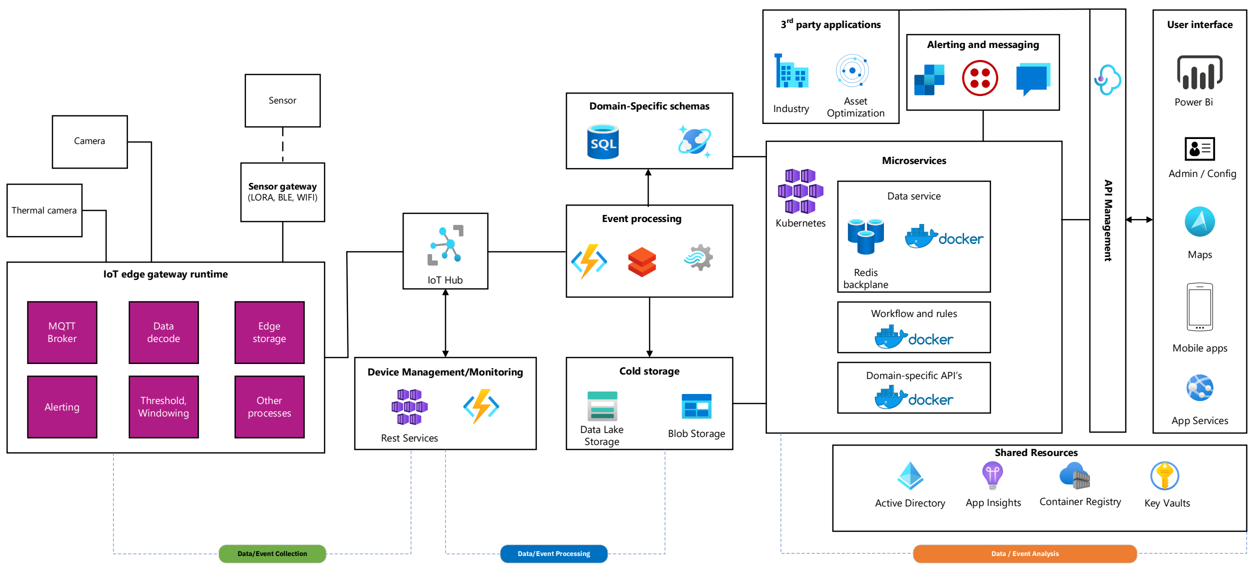

Figure 5-2: Solution View – Logical (Indicative).

Wildfires can be predicted and prevented using available connectivity technologies, following are two approaches:

- UAV based Prediction : The first approach by which forest fires are detected is through imaging. This can be accomplished with fixed cameras, satellites, or drones and it allows authorities to get a bird's eye view of the fire, pinpoint its exact location, and get its contour.
- IoT Device Mesh: The second approach that is our review focus, involves the use of sensors that can detect environmental data such as heat, humidity, gases,and so on. These sensors, which can be placed strategically throughout the forest, will send an alert to authorities if they detect a fire.

5.3 Environmental Measurements

One of the best ways to detect a forest fire early is to use sensors. IoT Devices / Sensors are used to collect the following measurements.

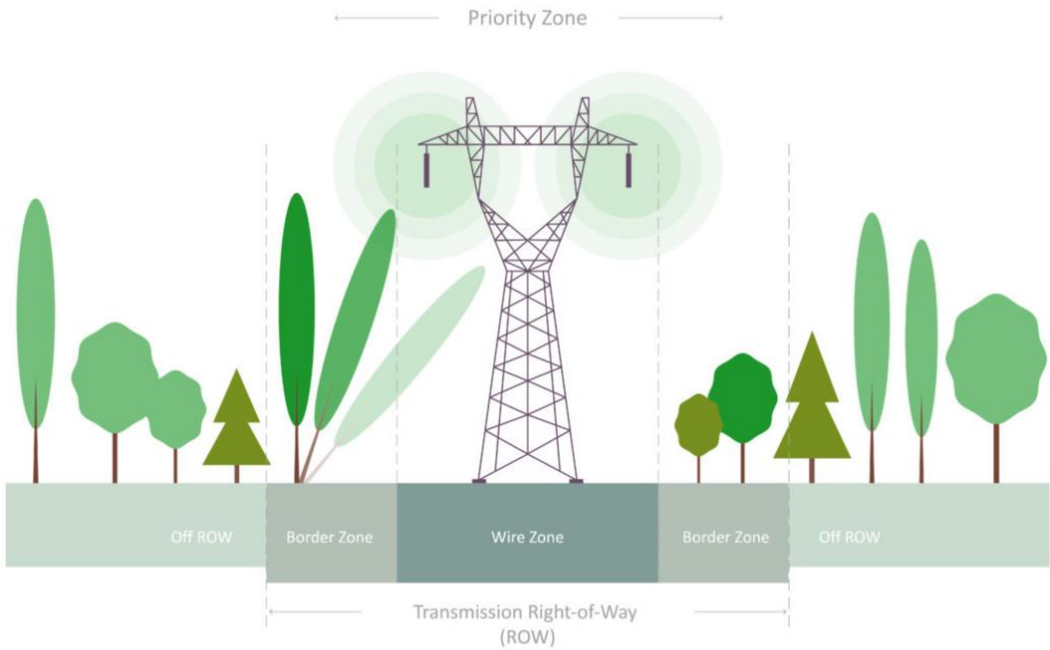

Figure 5-3: Vegetation management. Source: IBM.

Temperature - Temperature sensors are the most commonly used type of sensor for Forest fire detection. They can be used to detect hot spots, which are areas where the temperature is significantly higher than the surrounding area.

Moisture - Moisture sensors can also be used to detect forest fires. When the air is very dry, it can help to spread a fire. By measuring the moisture, firefighters can get an idea of how dry the conditions are and whether or not a fire is likely to spread.

CO/CO2/Smoke - CO and CO2 sensors can be used to detect the presence of smoke, which is a major indicator of a fire.

Light - Light sensors can also be used to detect fires. When there is a lot of smoke, the light levels will be lower than normal.

Sound - Sound sensors can be used to detect the sound of a fire. This can be helpful in determining the location of a fire.

Wind Speed - Wind speed sensors can be used to determine the rate at which a fire is spreading. The faster the wind is blowing, the faster a fire will spread.

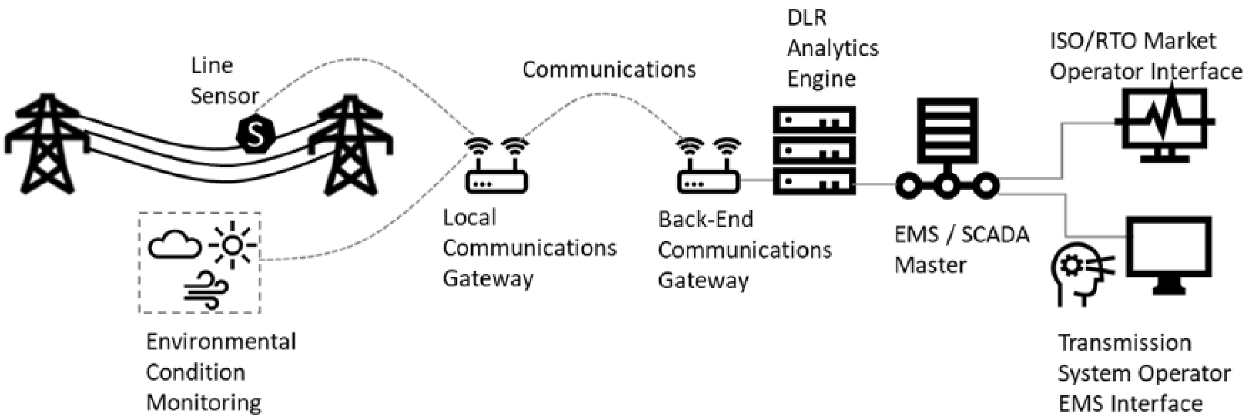

Figure 5-4: DLR - Dynamic line ratings conceptual representation. Source: DoE.

5.3.1 DLR[26]

DLR refers to the active varying of presumed thermal capacity for overhead power lines in response to environmental and weather conditions. This is done continually in real time, based on changes in ambient temperature, solar irradiation, wind speed and wind direction. All Power Lines data listed below can be acquired through DLR to predict / identify presence of wildfire.

5.3.2 Power Lines

Line Sag (Clearance from the Ground / Vegatation) – Line Sag indicates a fire event as sag increases exponentially under wildfire event.

Clearance – Ground Clearance measurement is handy to understand the proximity of transmission lines and ground/vegetation.

Vibration - Vibration data can be used to identify a wide variety of phenomenon, from transient effects to nondestructive damage identification. For high voltage transmission applications, vibration transducers could be used to identify the following events:

- Tampering of towers
- Heavy construction equipment near towers (possible sign of encroachment)
- Avian nesting activity
- Lightning strikes
- Tilt indicating tower damage
- Detect damage in polymer or ceramic insulators (requires separate excitation)
- Detect some forms of foundation damage (requires separate excitation).

[26] *https://www.energy.gov/oe/articles/dynamic-line-rating-report-congress-june-2019*

Radiation - Thermal radiation is the transfer of heat energy from a hotter object or gas to another object or gas through empty space. It occurs without an intervening medium because the energy is transferred by electromagnetic waves. In the event of a wildfire, energy is transmitted from the fire to the bare overhead conductors by radiation at a rate that depends mainly on the difference between the flame fire and the conductor temperature. Measuring Radioation Factor will be useful indicator of presence of Fire within Transmission Lines.

Voltage – Voltage fluctuations can cause fire as voltage fluctuation damages insulators and overall health of Transmission Lines.

6 OUTLOOK

The current solution can have the following enhancement(s) with subsequent releases:

- Satellite Imaginary Processing: Current solution uses sensor data and UAV acquired data; however, in the future the solution can be enhanced to use Satellite Imaginary in addition to current data.
- Additional Work-Flow: Current solution notifies various agencies and organizations on wildfire risk identified, in subsequent enhancement, other work-flows can be added to the solution such as confirming the presence of fire and calling fire departments.
- Additional Sensors: Subsequent enhancements can include a variety of sensors which can make predictions more accurate, also more area can be covered.
- Robotics Process Automation: Instead of using DLR sensors to get Transmission Line related data-sets, in the future these details can be acquired through Robotics input like PLI – Power Line Inspection Robot. This solution can be enhanced to receive real-time inputs from PLI. This enhancement can also include additional sensor data that is relevant to the use.
- Blockchain-Based Calibration (Recertification): Most of the sensors used in the solution require re-calibration yearly. In the next release the recalibration can be done using blockchain to avoid the manual calibration process.

7 CONCLUSION

Wildfire Incidents are on the rise, and they are responsible for huge losses in terms of human life and precious environmental damages. Wildfire and Climate changes are having circulatory impact, climate changes increase wildfires and vice versa. There are many efforts underway to have better control of wildfires so that the devastating effects can be minimized, if not eliminated. Predicting is the best way to prevent wildfire. This paper outlines solutions which potentially can be deployed as a proof of concept/Minimal Viable Product and then further, expanded for broader use.

8 ACKNOWLEDGEMENTS

The views expressed in the *IIC Journal of Innovation* are the contributing authors' views and do not necessarily represent the views of their respective employers nor those of the Industry IoT Consortium.

© 2023 The Industry IoT Consortium logo is a registered trademark of Object Management Group®. Other logos, products and company names referenced in this publication are property of their respective companies.

➢ Return to *IIC Journal of Innovation landing page* for more articles and past editions.