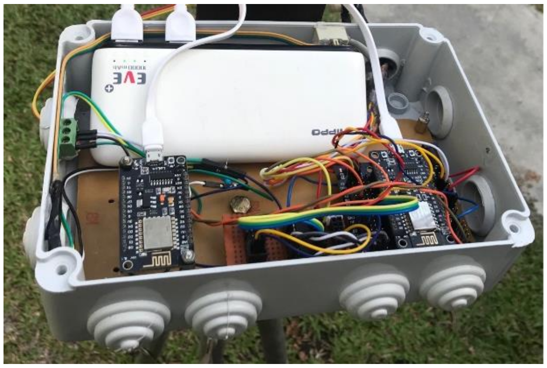
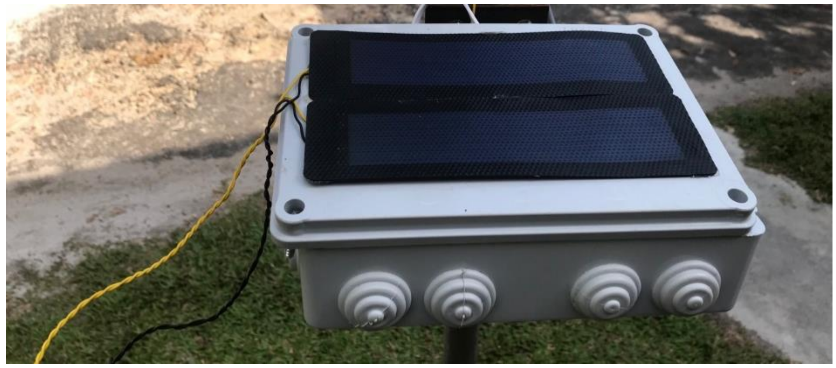



MONITORING FOREST FIRE: GAS DETECTION SENSOR PHASE ONE

EXPERIMENTATION RESULT

Nanis Sakti Ningrum

December 2018

KOPERNIK

MONITORING FOREST FIRE: GAS DETECTION SENSOR PHASE ONE

Every year slash-and-burn agricultural practices in Sumatra and Kalimantan result in severe regional air pollution. In 2015, approximately 2.6 million hectares of forest were burnt, resulting in one of the worst haze crises in decades[1]. In Kalimantan, combating forest fires is especially difficult due to the extensive presence of peatland. Introducing a reliable fire monitoring system could assist the government and other stakeholders to respond effectively in containing fires, thus minimizing the impact of haze.

One alternative to satellite data fire monitoring is the use of gas sensors, which detect fires through the measurement of gases and particulate matter. In this experiment we tested the functionality of a gas detection sensor built by the University of Palangkaraya, Central Kalimantan, measuring:

- The levels of Particulate Matter (PM_{10}), Carbon Dioxide (CO_2), and Carbon Monoxide (CO);
- The number of fire events detected by the sensor (indicated by elevated levels of gases and particulate matter) as well as by satellites; and
- Whether the information was successfully transmitted to the designated users, which, in this experiment, were researchers from the University of Palangkaraya.

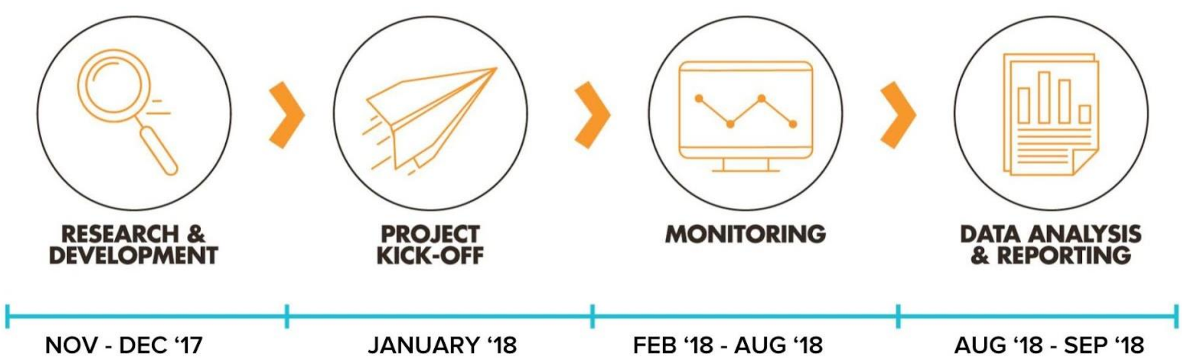
The results from four and a half days of measurements showed a three to seven-fold increase in CO, CO_2 and PM_{10} levels on a day when three fire events occurred in areas that were located between 38 and 84 kilometers from the sensor. Given this distance we concluded that the sensor was likely detecting smoke carried on the wind since no fire events occurred within the sensor detection range (which is within 10 kilometers). While in this experiment it was not possible to conclude whether the system is able to detect the actual number of fires in the immediate locality, the system was successful in transmitting SMS alerts when the gas and particulate levels surpassed the trigger levels.

Special points of interest:

- Forest fires in Kalimantan are difficult to combat.
- Gas sensors can be used to detect forest fires in their early stages.

Content

TIMELINE



[1] *Indonesia's Fire and Haze crisis. The World Bank. 25 November 2015*

CONTEXT

Forest fires in Sumatra and Kalimantan are seasonal events resulting from the local practice of land clearance, known as slash-and-burn, where fire is set to any vegetation growing on land to clear it for new planting. In 2015 the worst fire events in decades occurred, with approximately 2.6 million hectares of forests burnt leading to economic losses in excess of US$16 billion[2]. The fires also caused widespread toxic haze and smog, affecting 69 million people across the Southeast Asia region[3]. Combating the forest fires in Kalimantan during this time was extremely difficult due to the extensive existence of peatland in this region. Peat soil contains a high carbon content, and when dried it can easily set on fire and continue to smolder for weeks or even months. Fire prevention and early detection are critical to avoid this catastrophe from reoccurring.

Current forest fire monitoring systems such as the government-owned SiPongi or Global Forest Watch Fires (GFW Fires), developed by the World Research Institute, use satellites to map the location of fires. GFW Fires combines near real-time satellite data from NASA, satellite imagery, maps data, weather conditions, and air quality data to track fire activities, while SiPongi gathers hotspot data from satellites to locate fires. The drawbacks of these monitoring systems include visual obstruction by clouds, false hotspot detection from other heating phenomena, and a delay in information supply due to the satellites' orbiting periods.

A recently developed fire monitoring technique uses a Wireless Sensor Network (WSN)[4], consisting of a network of low-cost sensors for sensing temperature, gases and particulate matter which communicate information wirelessly. This technology can be used as a real-time monitoring system for forest fires, and can potentially provide information that a fire has started much earlier than satellite-based monitoring systems.

Kopernik partnered with Mr Rony Teguh and his team of researchers from *The Laboratory of System Sciences and Informatics* at the University of Palangkaraya, to build a gas detection sensor and test it in Central Kalimantan. Based on the WSN principle, the system is intended to detect any increased level of Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Particulate Matter (PM_{10}) beyond a baseline level and transmit this information as an SMS alert. In the future, this information could be sent to relevant stakeholders such as fire patrols, local government, environmental organisations, and the researchers, in order to assist in containing and managing forest fires.

[2] *Indonesia's Fire and Haze crisis. The World Bank. 25 November 2015*
[3] *Indonesian forest fires exposed 69 million people to killer haze. Channel News Asia. 16 November 2016*
[4] *Wireless Sensor Network for Forest Fire Detection. Hariyawan et al. Telkomnika 10.12928. September 2013*

HYPOTHESIS

We hypothesized that the gas detection sensor can:

- Detect forest fires through the measurement of CO, CO_2 gases and PM_{10} levels, and;
- Provide alerts to designated users.

METHODOLOGY

The Palangkaraya team built a sensor system using the Arduino's Wido IoT (Internet of Thing) microcontroller board and three different types of sensors: gas sensors (CO_2 and CO), a dust sensor (PM_{10}) and environmental sensors (temperature, relative humidity and wind direction). The system was powered by a solar charged battery and was equipped with GPRS (General Packet of Radio Service) connection to allow remote data collection and monitoring via Ubidots web platform. The sensor collected and transmitted data every five minutes. Figure 1 illustrates the sensor system and Figure 2 shows a picture of the final product.

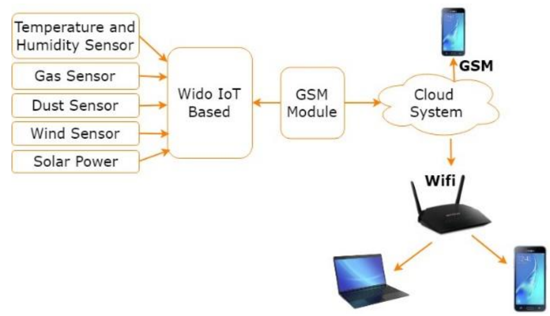


Figure 1. Diagram illustrating the gas sensor system

The sensor was equipped with a mechanism to send SMS alerts automatically to designated users, in this case these were researchers from the University of Palangkaraya, as soon as CO_2, CO, and PM_{10} levels exceeded a certain level. During the initial installation period there was no specific dataset available to establish baseline CO_2, CO, and PM_{10} levels under "no-fire" conditions. Given this limitation the national air quality index[5] for CO, PM_{10} concentrations and a typical CO_2 concentration in outdoor air[6] were used as trigger levels for the alert system. These trigger levels were 5 ppm for CO, 50 µg/m^3 for PM_{10}, and 300 ppm for CO_2.

Figure 2. The final product

The testing of the sensor system occurred in Pulang Pisau district, a high-risk fire location in Central Kalimantan, and the Government's forest monitoring system SiPongi was used to determine the location of fires in this region. In this experiment we measured:

- The levels of PM_{10}, CO_2, and CO;
- The number of fire events detected by the sensor (indicated by elevated levels of gases and particulate matter) and by satellites; and
- Whether the information was successfully transmitted to designated users.

[5] National air quality index. Environmental Impact Management Agency regulation KEP- 107/KABAPEDAL/11/1997
[6] Allowable level of CO_2 concentration. ASHRAE. Accessed at 2018

FINDINGS

The production of the gas detection sensor was completed in June 2018 after a few months' delay in procuring components. As a result, we were forced to reduce the installation period from six months down to two months (July until August 2018). In addition the researchers also required extra time to undertake sensor calibration and debugging, and as a result data obtained before the 25th of August was invalid. The small time window for data collection was exacerbated by multiple GPRS connection failures, meaning data could not be retrieved continuously. Subsequently it was only possible to obtain measurement results for a period of four and half days, consisting of the following time periods**:**

- 25 August 2018 (for 10 hours); and
- 28 - 31 August 2018 (4 days).

Hotspots from Satellite Data

Based on data from SiPongi we found that the majority of fires occurred in West Kalimantan, with 1,902 hotspots recorded in August 2018. Central Kalimantan ranked second after West Kalimantan, with 400 hotspots detected in the same month. Out of these 400 hotspots, 50 percent of the incidents were situated in Kotawaringin Barat and Timur regency, 13 percent were in the Pulang Pisau regency and the remainder were spread around nine other districts[7]. Using SiPongi we were also able to locate fires (hotspots) on the days when valid measurements from the sensors were obtained. Figure 3 below shows the hotspot distribution map in the vicinity of the sensor for the 25, 28, 29, 30 and 31 August 2018.

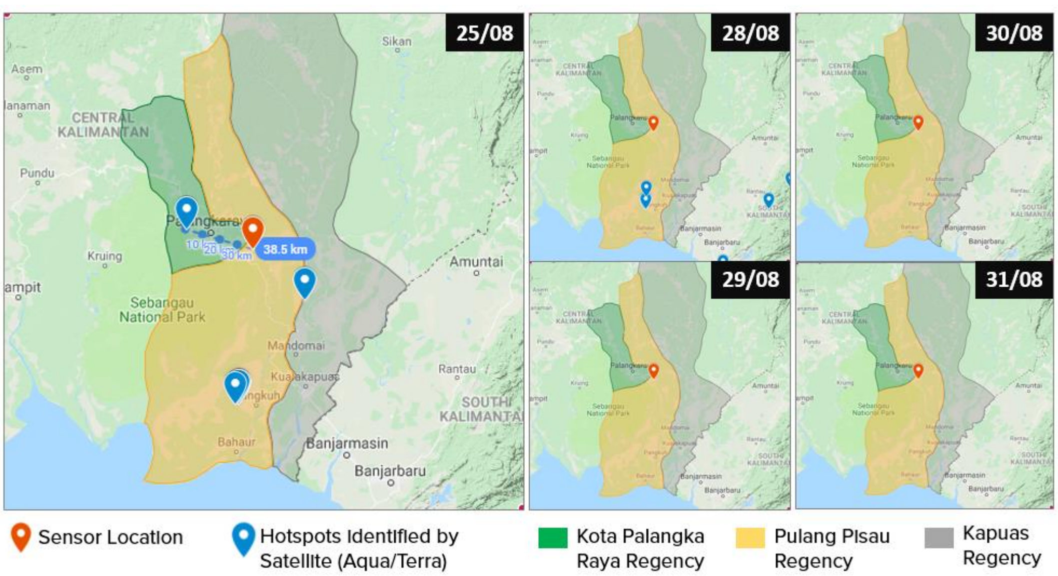


Figure 3. Hotspots distribution map obtained from the Government forest monitoring system (SiPongi)

[7] *Matrix of Hotspot TERRA/AQUA (LAPAN) for 2018. Forest Fires Monitoring System (SiPongi) managed by the Ministry of Environment and Forestry. 2018*

On 25 August it was found that there were three fire events the Pulang Pisau, Kota Palangka Raya and Kapuas Regencies. The distance between these fire and the sensor location was 84, 38 and 40 kilometers respectively, all of which were greater than the sensor's 10 kilometer range. On the 28th of August, there were fires in Pulang Pisau districts, however, they were a long way from the sensor location (84 km). From 29 to 31 August there were no fires detected within a 200 kilometer radius of the sensor location.

Measurement from the Sensor

From 28-31 August, we found the CO_2, CO and PM_{10} levels measured by the sensor to be consistently lower than the measurements from 25 August. This finding supports the satellite data in figure 2, which shows that there were no hotspots or fires detected in the sensor's vicinity during this period. We calculated the average gases and particulate level from 28-31 August and assigned this 4 day period as the "no-fire" baseline level for:

- CO_2 , the baseline level is **289 ppm**
- CO, the baseline level is **0.26 ppm**
- PM_{10}, the baseline level is **12 µ.gram/m³**

These CO_2, CO and PM_{10} baseline levels were then compared to the levels detected on the 25 August, when there were two fire events 38 km and 40 km from the sensor. Figure 4 below shows the comparison plot for each measurement.

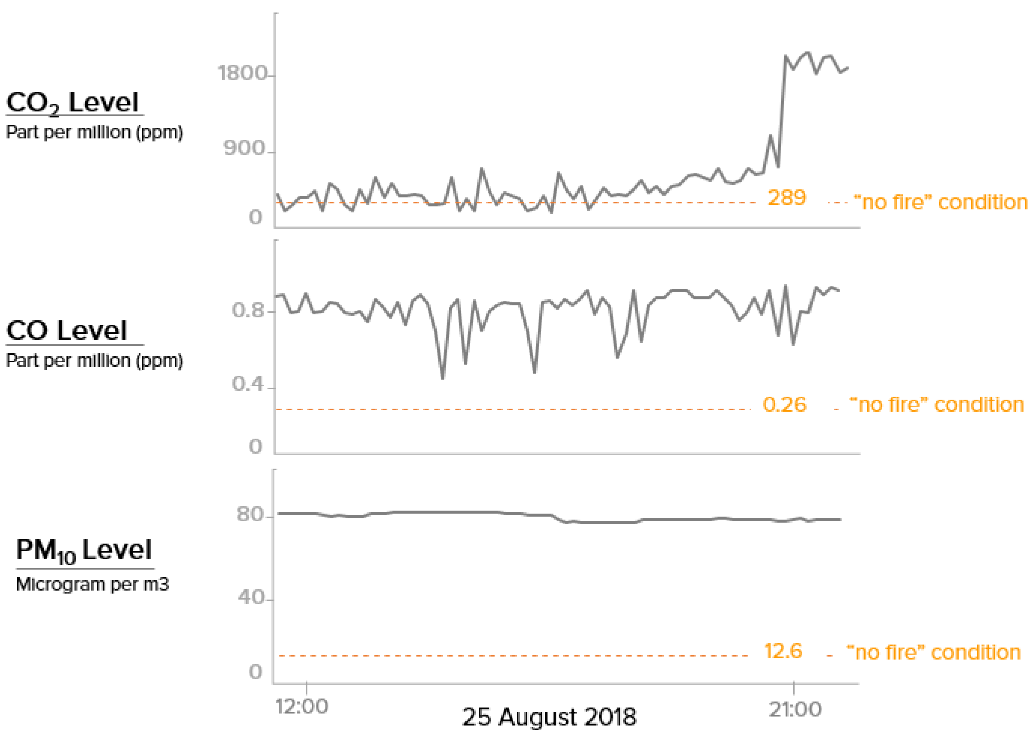


Figure 4. Gases and particulate measurement on 25 August versus level during "no fire" condition

Figure 4 shows that the CO level and PM_{10} level were consistently higher, three-fold and six-fold respectively, than the “no-fire” baseline condition. We believe this is due to the fact that the sensor detected the smoke produced by the fires in Kota Palangka Raya (38 kilometers away) or Kapuas Regency (40 kilometers away). Although the distance of these fires is greater than the sensor range (10 kilometer), gases and particulate matter can be transported by wind.

We found that CO_2 levels exceeded the baseline 62 percent of the time, with a sudden spike in the evening to 2000 ppm. This is seven times the baseline level, however, a similar increase in CO or PM_{10} levels was not observed. This suggests that this sharp increase of CO_2 was likely not caused by fires, but instead could indicate the beginning of a peatland fire in the region. Unfortunately no other data was available to investigate and corroborate this finding.

Number of Fires and the Alerts

The increased levels of gases and particulate matter on 25 August successfully triggered a series of alerts from the sensor system. At this time, the trigger level for each parameter was still defined by the national air quality index values, as specified in the methodology. The CO_2 levels exceeded the trigger value (300 ppm) 30 percent of the time, resulting in a total of 29 SMS alerts. The PM_{10} level exceeded the trigger value (50 µg/m^3) 77 percent of the time, triggering 77 alerts, while the CO level never exceeded 5 ppm and thus no additional alerts were issued. Figure 5 below illustrates the SMS text message alert, which says: “Warning, PM_{10} level is reaching the threshold”.

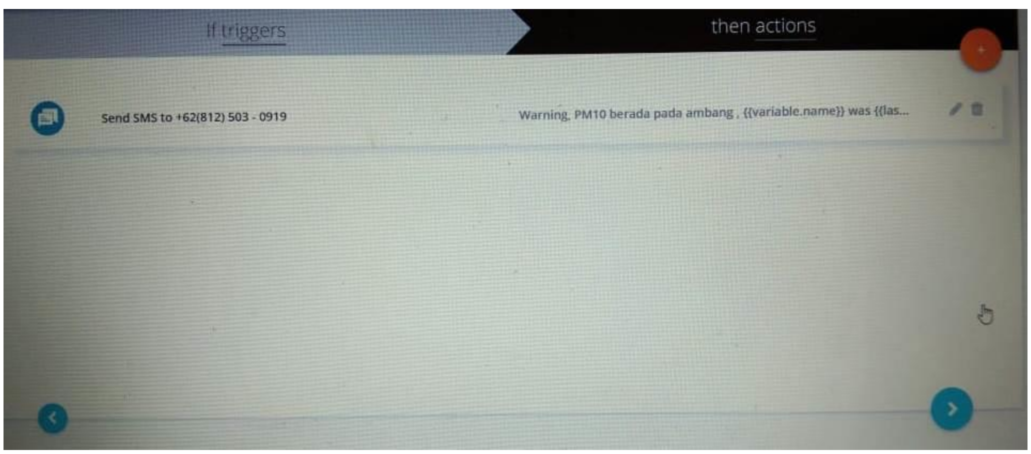


Figure 5. The SMS text message sent to designated users

CONCLUSION

Technical difficulties in sensor validation and failed GPRS connection resulted in invalid and untransmitted data for most of the sensor installation period. During the period of four and a half days in which valid data was collected the sensor was successful in measuring the desired parameters. The results showed increased levels of CO, CO_2 and PM_{10} when fires were detected by the satellite (25 August) and a lower levels on the days when no fires were detected by the satellite (28-31 August).

The fire events detected by satellites on 25 August were located well beyond the sensors 10 kilometer range. Thus it is likely the sensor detected smoke transported by the wind, and not the immediate nearby emission from the flames itself. As a result we were unable to use this information to justify the number of fires successfully detected by the sensor, or to determine the location of these fires. This study remains inconclusive regarding whether the sensor can detect fires and we could not prove or disprove the first hypothesis due to a lack of data.

The system was successful in providing alert information to designated users with 29 SMS text alerts for increased CO_2 levels and 77 alerts for increased PM_{10} levels issued. These alerts occurred immediately after the gases and particulate level surpassed the appointed value, thus proving our second hypothesis.

TESTIMONIAL:

We are happy to collaborate with Kopernik to build a system to detect gas and some particles in the peatland area of Central Kalimantan. This is the starting point of developing tools that are useful for the communities that are prone to become victims of forest fires and smoke disasters. This collaboration will become one of the many contributions in science and community service

- Rony Teguh, Founder of the Laboratory of System Sciences and Informatics, Palangkaraya University

RECOMMENDATION

Based on the result of this experiment, Kopernik recommends:

- Further testing the functionality of the gas detection sensor using controlled fire events at several distances within the 10 kilometer radius for the sensor, and to extend the measurement period under natural conditions (at a high fire risk location) to at least four months;
- Counteracting the failed GPRS connection by using an offline data logger;
- Complimenting the wireless network system with at least two more gas detection sensors in order to provide cross verification and locate the fire more accurately; and
- That Kopernik, in collaboration with other organization or government, should integrate the gas detection sensor into the existing forest fire monitoring platforms based on satellite data.