From Crowdsourcing to Crowdsharing: The Smart Environmental Sensing Web of EPA

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***Abstract*—This article describes how the Environmental Protection Administration (EPA) under the Executive Yuan of Taiwan (R.O.C.) leverages its Smart Environmental Sensing Web comprising crowdsourcing and crowdsharing built on its existing Internet of Things (IoT) based environmental monitoring system to make the public care more about the quality of their living environment, and create positive feedback loops of information flows. Furthermore, we use data visualization technology and location-based services to design graphical dashboards and interactive maps to enable users to access real-time local environmental sensing information at any time. Taiwan EPA will also continue to maintain the concept of open, transparent and innovative applications to serve society with public, diversified, and convenient information services.**

Keywords- Citizen as Sensor; Crowdsourcing; Internet of Things; Location-Based Service; Social Networks; $PM_{2.5}$.

I. INTRODUCTION

This article describes how Taiwan EPA leverages its Smart Environmental Sensing Web comprising crowdsourcing and crowdsharing [1] built on its existing IoT-based environmental monitoring system. This Smart Environmental Sensing Web includes continually expanding Micro Environmental Sensors, an environmental quality sensor networking platform, an Environmental Info Push application for smart phones, and an i-Environment website. Combining environmental sensing data from different sources through common transmission protocols and Open Geospatial Consortium (OGC) Standards, we used data visualization technology and location-based services to design graphical dashboards and interactive maps enabling users to access real-time local environmental information at any time, while also adding a convenient notification function that sends alerts when needed.

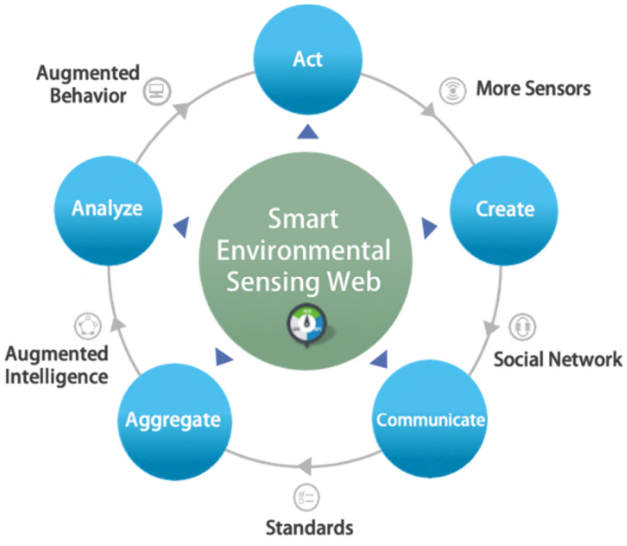

Figure 1. The Conceptual Cycle of Smart Environmental Sensing Web

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We also encourage the deployment of sensors, Open Data and crowdsharing to maximize the benefits of the Smart Environmental Sensing Web. Users can not only freely use these Open Data on environmental quality to design their own innovative value-added services and explore environmental issues, but also they can make use of the existing platform to share their personal feelings regarding the environment and publish these on the community website. Users may also use community links to stimulate other people's concern about the quality of living environment to create positive feedback cycle of data flows (in Figure 1).

II. METHODS

A. Data enrichment— Crowdsourcing

In addition to collecting and disseminating the various types of environmental monitoring information generated by Taiwan EPA, the Smart Environmental Sensing Network will also incorporate data from Micro Environmental Sensors operated by local governments, educational institutions, enterprises, and individuals. These Micro Environmental Sensors (list in TABLE I.), inspired by the Maker Movement, are designed to operate as a network of sensors managed by the public and experts. The sensors will continuously monitor air pollutants ($PM_{2.5}$), temperature, and humidity, and upload their real-time sensing data via wifi to an open or self-built IoT platforms. The platform provides Application Programming Interfaces (APIs) for Open Data to aid the development of display interfaces and application services for these types of environmental information. Currently, the number of micro-sensors has reached 2,100 units, which are mainly distributed in Taiwan's densely populated metropolitan areas, as well as at public primary schools in several counties and cities.

TABLE I. DIFFERENT SOURCES OF ENVIRONMENTAL SENSING NETWORK

Deployment	Number of Devices	Sensors	Trans-mission	Device Provider
Airbox Taipei City	155	$PM_{2.5}$, Temperature, Humidity	Wifi	Edimax
Airbox New Taipei City	298			
Airbox Taichung City	232			
Airbox Tainan City	214			
Airbox Kaohsiung City	242			
AirBox (other)	621			
LASS	97	$PM_{2.5}$, Temperature, Humidity	Wifi	Open Community
MAPS	83	$PM_{2.5}$, Temperature, Humidity	Wifi or LoRa	IIS-NRL of Academia SInica
EPA Monitoring Site	76	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2	ADSL	EPA or Local Goverment
EPA Industrial Parks	33	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO, NO_2, NO_X, THC	ADSL	
Local Government Monitoring Site	26	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2	ADSL	
EPA Large-scale Enterprises	70	O_3, $PM_{2.5}$, PM_{10}, SO_2, NO_2	ADSL	
EPA Mobile	20	$PM_{2.5}$, Temperature, Humidity	Bluetooth	
EPA Fix	200	$PM_{2.5}$, PM_1, O_3, NO_2, CO, Temperature, Humidity, Noise	Wifi	

Data from pm25.lass-net.org [2] and EPA

In order to increase the density of the environmental sensing network, Taiwan EPA encourages citizens to join the network by installing personal air sensors in their living environment, such as AirBox and Location Aware Sensing System (LASS), which monitors air quality that people actually breathe. Since 2016, Taiwan EPA has also continued to develop new sensors that can transmit real-time data to the Smart Environmental Sensing Web via other modes of transmission, such as Bluetooth, Wifi, or Long range (LoRa) [3]. Since LoRa technology has advantages of low power consumption and long range capability, Taiwan EPA has begun deploying these sensors in a certain industrial park.

The Environmental Info Push App provides the public with environmental information that is updated every minute. Internet access is all it takes for people to know the air quality near their home or the place they plan to visit, so they may take appropriate measures to protect their health.

B. Technique of implementation

Through the Open Platform for Environmental Resources [4], Taiwan EPA compiles real-time monitoring information to create i-Environment [5], a thematic interactive map browsing platform, and the Environmental Info Push app to serve the people's demand for this type of information.

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Figure 2. i-Environment Webpage (2016)

Based on governmental open data, "i-Environment" is the first government website designed for the Hybrid Web. It is developed using data visualization technology, which helps present reports, statistics, quantitative figures, and other information in a visual manner. An interface with dashboards and interactive maps provides location-based services that allow users to easily browse and search the environmental information they need (see Figure 2). In addition to these convenient information services, the sensor network also provides air quality alerts to the public, along with suggestions for appropriate activities under the various circumstances reminding users of immediately responding to discomfort and risks from environmental pollution, and to maintain their best health.

III. CURRENT PRACTICES—CROWDSHARING

To raise the public's environmental awareness and call attention for sources of air pollution in people's immediate living environment, Taiwan EPA has monitored the Mazu Goddess Tour, a month-long procession of a sea goddess touring Taiwan, greeted by the way by of celebrations involving massive fireworks that push up $PM_{2.5}$ values into the hundreds or even above 1,000 since 2016.

Firstly, in the spirit of crowdsourcing, EPA launched AirPhoto, a function of Environmental Info Push app through which people can share a photo stamping real-time air quality data on it, and share the photo on the map as well as on one's own Facebook Wall. Thus, through crowdsourcing and crowdsharing, the public is engaged as "citizen sensors" and made more aware of environmental issues.

Secondly, in response to the development era of Internet of Things, Taiwan EPA has developed Bluetooth transmission modules that can be deployed around temples and those places where celebrations were held to monitor the environmental conditions on the ground. After the dynamic data was measured and uploaded, it can be immediately seen on mobile phones with the app and also uploaded to the IoT cloud platform of Taiwan EPA (see Figure 3.).

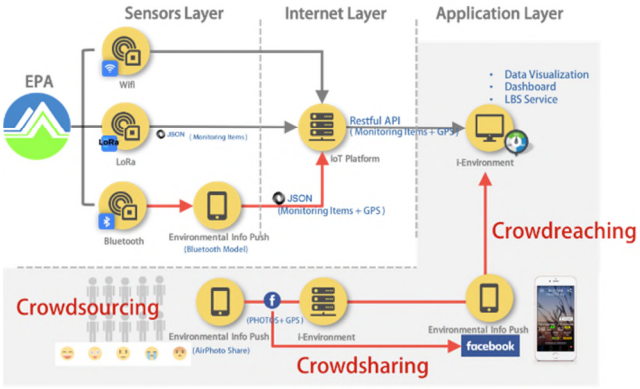

Figure 3. New Structure of Environmental Sensing Web of EPA（2017）

During events, people can view real-time information on the i-Environment website, including real-time air quality monitoring values, photos shared through the AirPhoto, as well as statistical charts and data. In addition, the public can use trend maps that compute spatial changes in combination with real-time sensor information and interactive features of maps on the i-Environment website (see Figure 4).

Figure 4. New Web design of Environmental Sensing Web of EPA（2017）

IV. CONCLUSION

In light of the worldwide positive acclaim of Open Data, Taiwan EPA will continue to maintain the concept of open, transparent and innovative applications [6] to serve society with public, diversified, and convenient information services to facilitate people's decision-making that involves environmental aspects. Taiwan EPA furthermore hopes that the Smart Environmental Sensing Web along with the relative apps will encourage crowdsourcing and crowdsharing to make the public more concerned about the quality of their living environment, and create positive feedback loops of information flows.

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