**EcoDot**A community driven, open-source modular sensor ecosystem for environmental data

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**ABSTRACT**

The EcoDot is a community driven, open-source sensor designed to provide granular environmental data streams. Our team has shown that these sensors can be made cheaply with off-the-shelf, open-source hardware components that are intuitive to set up and use. Importantly, the EcoDot is a modular piece of equipment meaning it can be easily tailored to the needs of individuals and local communities. Furthermore, our team has demonstrated that the sensor is effective for collecting and disseminating information about its local environment in both stationary and mobile implementations. We believe that the focus on open-source technology will not only facilitate better environmental data collection, but also foster civic engagement with issues related to climate change and environmental stewardship.

**INTRODUCTION**

Climate change has emerged as one of the foremost problems facing our species in the 21st century. At the same time, technological advances in networking, machine learning and big data collection allow for unprecedented high resolution approaches to global problems. We believe that the most effective solutions to climate change will require a community oriented approach to environmental data, which will not only provide a better of understanding of climate change on both a global and local scale, but also foster civic engagement on issues related to environmental stewardship.

Overwhelming evidence points to the reality human-caused climate change[[1]](#footnote-1). Still, widespread public engagement with environmental issues remains a significant barrier to implementing effective solutions. A number of studies have found that the barriers to community engagement with climate change can be traced to cultural beliefs[[2]](#footnote-2), lack of correct information and barriers to technology, particularly in the developing world[[3]](#footnote-3).

Moreover, research has found that massive collections of data that can by analyzed by machines to reveal patterns and trends that would otherwise be invisible to human analysis (henceforth ‘big data’) is crucial to developing effective solutions to climate change[[4]](#footnote-4). Historically, big data analysis of climate change has relied on space-based assets to monitor climate trends on Earth[[5]](#footnote-5). These projects, such as the US Geological Survey’s LandSat, are capable of providing large amounts of data that cover the entire Earth, yet are less effective when it comes to prompting community engagement and providing real-time, granular data collection of climate variables on the ground.

In 2014, the United Nations launched the Big Data Climate Challenge as part of its Global Pulse program in an effort to leverage big data as a way to “strengthening resilience and mitigating emissions.”[[6]](#footnote-6) A number of innovative solutions emerged from the program[[7]](#footnote-7), such as the World Resource Institute’s Global Forest Watch[[8]](#footnote-8) monitoring system and the urban services monitoring project based in India[[9]](#footnote-9). Each of these projects focused on big data approaches to monitoring various aspects of climate change, implemented with specific use cases in mind. For all the strengths of these projects, many still relied on satellite data collection or were condemned to their own ‘environmental silo,’ so that their potential uses cases were limited.

EcoDot seeks to overcome these limitations by pursuing a more universal approach to climate-related big data collection and analysis that emphasizes system modularity, community engagement, and open-source development.

**EcoDot**

The EcoDot is a fully-modular, open-source technology tailored to collecting and disseminating information about its local environment. In this paper, we will discuss two potential implementations of the EcoDot that demonstrate its ability to be used as a mobile and stationary technology.

At its core, the EcoDot consists of a microprocessor and a modular array of environmental sensors tied to a GPS address. For this project, we are limiting our data collection to air pollutants, namely dust particulates, carbon dioxide and methane. The stationary implementation consists of a PVC ‘spike.’ The sensor array is amounted near the top of the spike in a 3D printed case (the CAD for the case has been developed by the EcoDot team and is freely available online at the EcoDot github repository[[10]](#footnote-10)). Power to the sensor array can be provided by a direct connection to the power grid or a small solar array, depending on the characteristics of the local environment. Data collected by the EcoDot is stored locally on an SD card.

The mobile implementation of the EcoDot is more or less the same, but instead of the sensor array being mounted on a spike, it is fixed to an air filter mask. Due to the size constraints of these masks, the number of sensors that can be fixed to the mobile EcoDot is limited, but the sensor array is still fully modular and can be tailored to the individual users’ needs.

As the EcoDot collects data from its environment, individuals are able to access the data and effectively turn the device ‘on’ to begin interfacing via a QR code placed on the sensor array housing. The data is then transmitted to a user’s internet connected device via Bluetooth radio. This data can then be stored on an individual’s phone or other internet connected device to be pushed to a cloud platform where it is stored for analysis. This aspect of the EcoDot drives community engagement—anyone with access to an internet-QR reader is able to interact with the mobile or stationary EcoDot implementations and assist in collecting and disseminating the environmental data constantly being collected by the sensor array.

The EcoDot is more than just a mere sensor array, however: It is hardware base that facilitates the creation of a community driven data ecosystem. The effectiveness of the EcoDot depends on large-scale adoption, insofar as the value of a network increases proportionally to the number of nodes (in this case, EcoDots) in the system[[11]](#footnote-11). As previously mentioned, the goal of the EcoDot is to provide granular data about the local environment, so widespread distribution of the EcoDot in dense urban areas will be key.

Both EcoDot implementations rely on less than $100 USD of components, although this cost could be significantly lowered by mass production of the components in readymade EcoDot kits. By using readily available, off-the-shelf components that can be acquired or printed cheaply, the barrier to community adoption is significantly lowered. We anticipate the first users of the EcoDot to be educators and maker spaces, although the system is optimized for mass adoption.

**Pollution in Beijing as a Potential Use Case**

Air pollution in Beijing from industrial activities has long been a recognized problem. Of particular concern are PM 2.5 pollutants (particulates that measure less than 2.5 micrometers in diameter). These pollutants are particularly dangerous because they can easily bypass many filtration devices, enter the lungs and cause a number of potentially fatal diseases. Both the Chinese government and US embassy in Beijing publish hourly measurements of PM 2.5 levels, although these measurements have historically been prone to discrepancies. The reason for this is that these measurements are taken on opposite sides of Beijing—the US embassy measures in eastern Beijing near the heavily trafficked Third Ring Road, while the Beijing governments are taken in the Western Xicheng district.[[12]](#footnote-12)

The discrepancy when it comes to measuring pollutants in Beijing points to one of the fundamental problems in understanding how pollutants contribute to climate change at a local level. Beijing is a city of an estimated 25 million people spread out over 16,000 kilometers, and the levels of pollution have been shown to vary drastically over large urban centers. Two primary sources of PM 2.5 measurements are inadequate to capture the complexity of pollution patterns in large cities, thus limiting the government’s ability to keep their citizens safe during days with high pollution levels.

The benefits of the mobile and stationary implementations of the EcoDot in this scenario can be easily seen. For example, a Chinese citizen traveling through the city with an EcoDot mask would be able to track their movement through the city using GPS sensors on the mask, which would simultaneously be taking particulate readings. This user would then be able to track their exposure to particulate readings over time in local contexts, upload this data to a publicly available database, which could then be used by others to understand pollution levels in various neighborhoods in real time. In the stationary implementation, if EcoDot ‘spikes’ are deployed on a block by block basis throughout the city, anyone would be able to interact with the spike to collect the data and publish it to the cloud. This would create a granular map of pollution levels, while also encouraging community engagement with one of the largest environmental issues faced by Beijing residents. This map could then be accessed by anyone with an internet connected device in order to understand pollution patterns in the city and avoid heavily polluted areas.

**FUTURE DEVELOPMENT**

**Delay Tolerant Networking as a Model for Data Transfer**

One of the largest obstacles during the initial adoption phase of the EcoDot is coverage. The value of EcoDot is proportional to the number of deployed devices. Barring any government-backed mass deployment schemas, natural adoption will mean large sections of urban centers will initially be lacking data from the EcoDots. To address this dilemma, we will be leveraging delay tolerant networking protocols to facilitate data transfer between remote locations.

Delay tolerant networking (henceforth ‘DTN’) is a networking protocol originally pioneered in the late 1980s for space-based applications. The basic idea is the ability to route information packets between two points that lack constant connectivity. This requires bundling the information into self-contained packets that are routed opportunistically between nodes in the network as they become available. DTN has been successfully deployed to route information on an interplanetary scale between satellites, as well as deployed on Earth for everything from tracking animals in the wild to delivering internet connectivity to remote populations of reindeer herders. The latter case will provide an illustrative example for how DTN could be used to create a robust network of EcoDots.

Each year, reindeer herders near the North Pole gather to mark their reindeer before dispersing to a number of villages within the Arctic Circle. These villages are usually several miles from the nearest power grid and lack even the most basic internet connection. This makes accomplishing even the most mundane tasks, such as checking a bank account, incredibly difficult. In 2010, a team of Scottish researchers traveled to the Arctic to test a DTN protocol called the Bundle Protocol (BP) as a way to connect these remote villagers to internet. Their experiment required setting up a solar-powered internet router at each village (each of which are separated by dozens of kilometers) which was used to store data from the villager’s individual internet connected devices in self-contained data bundles. The Scottish researchers would then fly from village to village in a helicopter, where they would download the data on the solar routers, before flying to a main internet link in a major city, effectively establishing a highly delayed internetwork.

During the initial phases of EcoDot adoption, a similar schema could be used to route data from point to point in an urban center. Stationary implementations of the EcoDot could be used to store environmental data locally on the ‘spike.’ When a user with a mobile EcoDot implementation (such as the smart mask) would interface with the stationary devices, they would effectively be acting as a data mule, ferrying the environmental data from spike to spike until they had access to an internet connection to push this data to the cloud.

Importantly, this would also solve another major barrier to adoption of the EcoDot, which is limited internet access in developing countries. India, for instance, has some of the most polluted cities in the world, yet internet penetration in the country is relatively low (despite being the second largest smart phone market in the world). This means that even Indians without access to internet could participate in the EcoDot network by using their phones to store data from stationary EcoDots and use DTN protocols to pass this data from phone to phone or EcoDot to EcoDot until it is finally routed to someone with a reliable internet connection, who can push that sensor data to the cloud.

**Blockchain Implementations for Verified Data Collection and Network Gamification**

In the last few years, a relatively new technology called the blockchain has found a number of industry applications. The blockchain is essentially a distributed ledger used to record happenings on a network in a publicly accessible way. The distributed consensus that is baked into blockchain technology has two important implications for the EcoDot, insofar as it encourages adoption through gamification as well as providing security for the data being collected in the network.

Initially, the adoption of the EcoDot will depend on the goodwill of community members who are interested in improving their community by collecting and distributing local environmental data. However the rate of EcoDot adoption could be rapidly accelerated by gamifying the system through the blockchain by developing a digital asset native to the EcoDot network. Known as cryptocurrencies or tokens in common parlance, these digital assets would incentivize individuals to adopt mobile or stationary implementations of the EcoDot by rewarding data collection, storage or transfer (in the case of DTN protocol deployment). For example, an individual who sets up a stationary EcoDot in their home could be rewarded based on the amount of environmental data their sensors collect—this data could then be sold to interested parties in enterprise or government and the users rewarded with micropayments in the EcoDot digital asset.

Most importantly, however, the blockchain would add a much-needed level of security to data collection in the EcoDot system. As a community driven approach to creating a so-called smart city, the EcoDot inherently encourages a vast network of independent nodes, each of which represents a potential vulnerability in the ecosystem. The value of the EcoDot network is the integrity of the data, so the ability for malicious actors to pump false data into the network would significantly reduce its worth and adoption. Since the blockchain requires cryptographic consensus between two parties each providing signing a given ‘block’ of data with their private keys, this method of data verification could be deployed to ensure that the data from a given spike is accurate. Furthermore, the immutability of the blockchain ensures that any data collected on the EcoDot network is publicly available and unchangeable for as long as the network exists.

**Geocaching for Remote Environmental Sensing**

The final future development of the EcoDot system is moving the data network from densely populated urban areas to more remote geographic locations. Climate change is not limited to cities and the ability to collect, store, and transfer environmental data in remote locales is crucial to the success of the EcoDot. In the United States, a vast network of trails crisscross our national parks and receive millions of visitors each year. Stationary EcoDots could be strategically placed throughout the national parks and along hiking trails that would be capable of storing data for long periods of time. Visitors to these stationary EcoDots could then interface with the device, collect its data, store it locally on their internet connected device and then push that data to the cloud once they re-established an internet connection by leveraging delay tolerant networking protocols.

Importantly, these EcoDots need not only exist along well-trafficked trails. The US also has a robust geo-caching community which are essentially scavenger hunters seeking out objects in obscure locations. The most well-known geocaching example is perhaps Pokemon Go, but the community existed far before the popular app. By taking advantage of the millions of geocachers in the US, EcoDots could also be placed in remote areas and visits to these stationary data storage devices would be inherently incentivized through the goals of the geocaching community.

1. <https://climate.nasa.gov/causes/> [↑](#footnote-ref-1)
2. <https://climateaccess.org/resource/individual-understandings-perceptions-and-engagement-climate-change-insights-depth-studies> [↑](#footnote-ref-2)
3. <https://www.researchgate.net/publication/23966336_Adaptation_to_Climate_Change_in_Developing_Countries> [↑](#footnote-ref-3)
4. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4174912/> [↑](#footnote-ref-4)
5. <http://www.pnas.org/content/113/39/10729.full> [↑](#footnote-ref-5)
6. <http://www.unglobalpulse.org/big-data-climate-challenge-2014> [↑](#footnote-ref-6)
7. <http://www.unglobalpulse.org/big-data-climate-challenge-winners-show-UN-how-data-can-drive-climate-action> [↑](#footnote-ref-7)
8. <http://www.globalforestwatch.org/> [↑](#footnote-ref-8)
9. [http://surat.ursms.net/cms/home.aspx#](http://surat.ursms.net/cms/home.aspx) [↑](#footnote-ref-9)
10. <http://www.github.com/hackbuild> [↑](#footnote-ref-10)
11. <https://en.wikipedia.org/wiki/Metcalfe%27s_law> [↑](#footnote-ref-11)
12. <https://blogs.wsj.com/chinarealtime/2012/01/23/comparing-pollution-data-beijing-vs-u-s-embassy-on-pm2-5/> [↑](#footnote-ref-12)