Collecting Smart City IoT Data to Generate Actionable Insights

A Technical Paper prepared for SCTE•ISBE by

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1. Abstract

Data is the new oil driving the digital world. There is a massive amount of data being generated as more and more cities around the world roll out smart city applications and deploy IoT sensors. Managing, analyzing and correlating data from multiple sources can help cities in many ways, including lowering operational costs, creating environmental sustainability, increasing citizen engagement, enhancing healthcare, improving public safety and providing an overall improvement in the quality of life for its citizens.

Spectrum is engaged in a smart city proof of concept (POC) in St. Petersburg, FL, in collaboration with the University of South Florida St. Petersburg campus, US Ignite and the St. Petersburg Innovation District. Several IoT sensors and use cases involving pedestrian safety, video analytics, edge computing and smart street light management are currently being tested.

This paper discusses the uses cases and several types of sensor data collected in the St. Petersburg POC project. Details include the collection, storage, visualization and analysis of IoT sensor data.

2. Introduction

Data-driven decisions are made more than ever before in every domain today. Cities can also benefit from IoT sensor data to draw insights that can improve the quality of life of its citizens, allow cities to make better decisions on infrastructure planning and can help lower operating costs by efficiently using resources to deliver services to its citizens. In this paper, we share some examples of smart city use cases, technology and the methodology used to collect and analyze a broad array of IoT data from the proof of concept project implementation at the city of St. Petersburg, FL in collaboration with US Ignite, the St. Petersburg Innovation District, the University of South Florida St. Petersburg and Spectrum Enterprise.

2.1. Data and the smart city

Data is ultimately what makes a city smart. But it not just the collection of data through the deployment of sensor technology, it's also the ability to analyze and use the data in near real time to make informed decisions. When it comes to data, privacy is, of course, very important, especially if the data collected has personal information (PI). Such data should be handled as per the agreement with the city, and it must also meet regulatory compliance.

2.2. Why do we need smarter cities?

As cities around the world grow at an unprecedented rate, it is putting a strain on the environment and on cities' resources and services such as water, electricity, parking, waste management and many more. The gap between demand and supply of city resources is growing, affecting the quality of life of citizens. One way to close this gap is to use a city's limited resources more efficiently by deploying smart city applications. A forecast from the International Data Corporation (IDC) Worldwide Smart Cities Spending Guide shows global spending on smart cities initiatives will total nearly $124 billion this year, an increase of 18.9% over 2019.[1]

3. Proof of concept setup

In the POC deployed in St. Petersburg, FL, we are using several IoT sensors, edge computing, computer vision, wired and wireless connectivity, cloud services for data storage, analysis and visualization to help the city improve pedestrian safety, lower energy costs for street lights and improve citizen engagement and safety.

3.1. Connectivity architecture

In this POC, we have installed four smart light poles. Each light pole has dual connectivity. Fiber as a primary and 4G LTE as a secondary connectivity to backhaul the data to the cloud from all the sensors.

3.2. Hardware setup

The fiber switch inside the light pole has multiple Power over Ethernet (PoE) ports providing power and data connectivity to a camera, WiFi, emergency button, digital banner, weather and air quality station as shown in Figure 1.

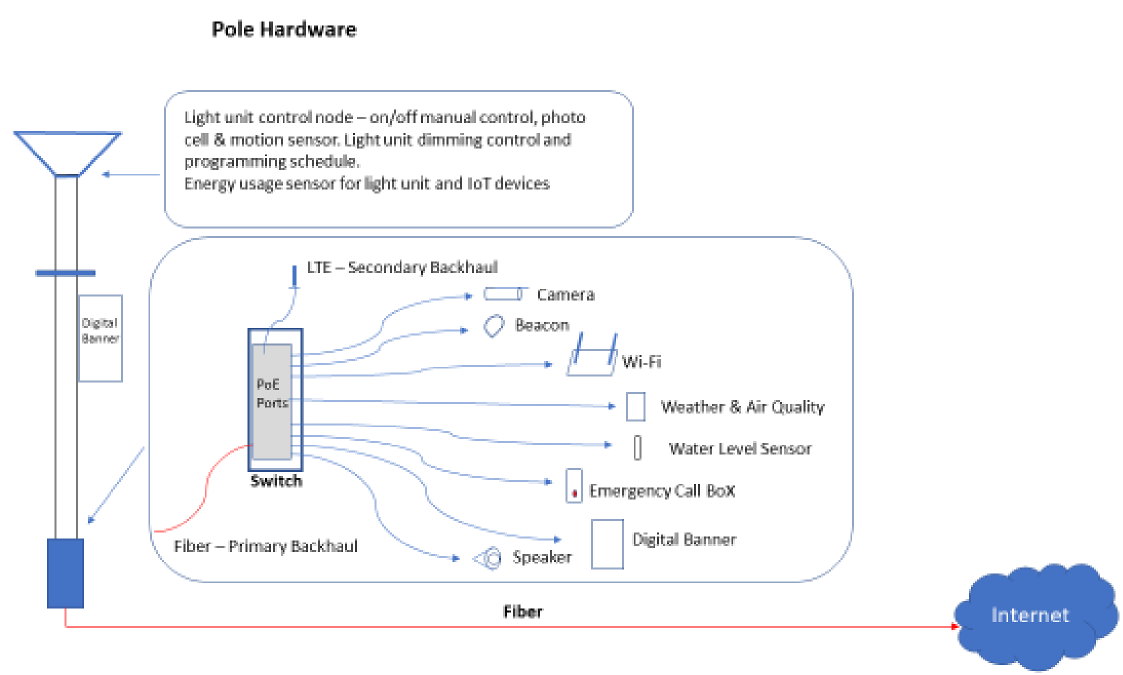


Figure 1 – Hardware Setup

3.3. Smart light controller

The smart light pole uses energy-efficient LED lightbulbs. The smart light can be controlled via an easy-to-use user interface which provides a broad range of capabilities and functionality. The light can be remotely operated to activate at certain hours. Schedules for events can be set up or the light can automatically turn on when the photocell measures the ambient light level below a certain threshold.

Additionally, the light allows for integrated notification capabilities to provide updates or alerts to the operator when issues occur, delivering the city with a more efficient overall operating model.

3.4. Camera

Each smart light pole is fitted with a camera that can be used for a variety of use cases including situational awareness and public safety. The camera has several alert features, e.g., guard zone, virtual fence, loitering alert and motion sensors to enhance public safety and protect city assets. We are using two types of cameras on the smart light pole. The Pan Tilt Zoom (PTZ) camera and fixed view camera with a 180-degree viewing angle. The power and data connectivity to the camera is provided by PoE switch as shown in Figure 1.

3.5. Pedestrian counter camera

The pedestrian counter camera on the smart light pole is pointed downwards overlooking the sidewalk and is used to monitor the number of pedestrians and their direction of movement.

3.6. Connectivity

Each smart light is also enabled with fiber connectivity to support a broad range of the features and functionality embedded in the light structure, from camera technology to integration of the smart intersection.

3.7. WiFi

Each light is fitted with WiFi AP (802.11ac) with an external antenna mounted at the top of the light pole.

3.8. Weather station and air quality sensor

The weather and air quality sensor is mounted on the top of the smart light pole and can collect various environmental parameters at specified intervals.

3.9. Emergency button

Each smart light pole has an emergency voice over Internet protocol (VoIP) call box and routes the call to the iPBX over the fiber backhaul. The emergency call box is programmed to dial the local police emergency number. Each emergency call box hardware address and location is registered in the call manager, which enables the first responders to identify call origination location.

3.10. Digital signage and speaker

The digital banner and the speaker can be remotely managed via a cloud-based dashboard. The display image and audio file can be sent over the network to be played at the smart light pole.

3.11. Smart intersection proof of concept

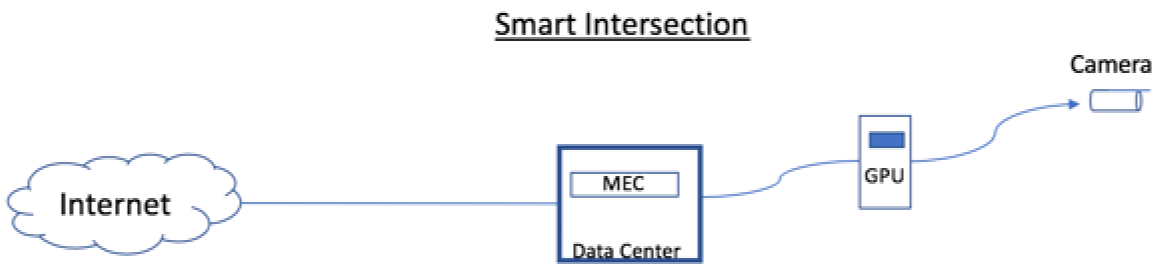


Figure 2 – Smart Intersection System

The smart intersection POC solution as shown in Figure 2 is designed to increase pedestrian safety at an intersection near the university. This POC requires ultra-low latency and uses edge computing technology with high computing power offered by the graphical processing unit (GPU) to process computer vision. There are three cameras mounted at the intersection as shown in Figure 3.

Figure 3 – Smart Intersection Camera Zones

4. Data collection and analysis

In this section, we will discuss the sensor data collection and flow as shown in Figure 4 below. Then we will highlight the data processing capabilities and driving insights in three examples: smart light energy usage, video analytics of surveillance camera and the smart intersection.

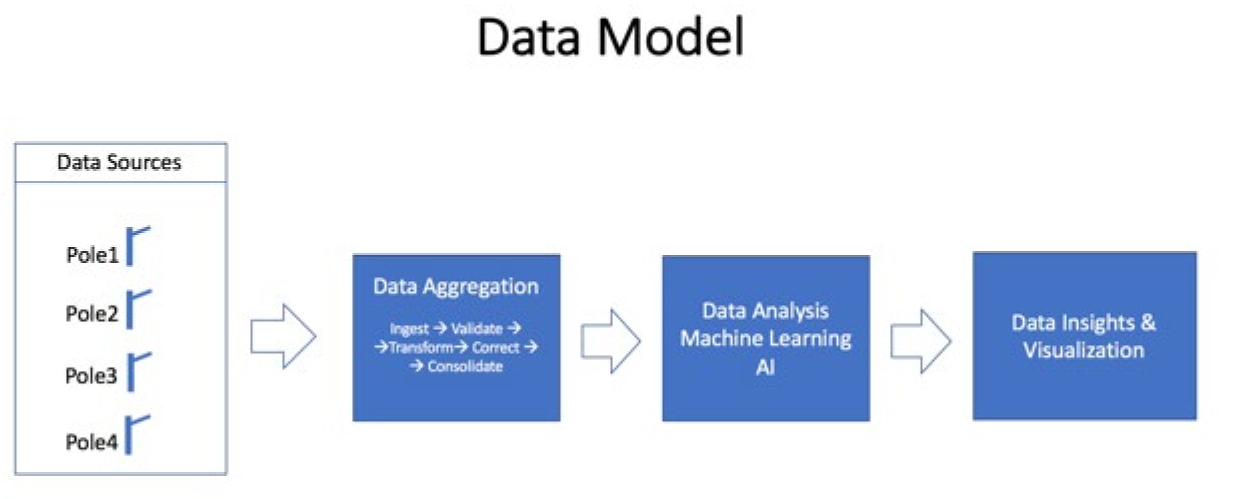


Figure 4 – The Data Model

4.1. Smart light energy usage

The smart light offers significant savings in energy expenses to a city, and we wanted to analyze ways to lower energy usage by using different settings on the unit. A LED lightbulb draws almost half of the energy as compared to High-Pressure Sodium (HPS) lightbulb. These savings can be further increased by using IoT sensors to control the light unit.

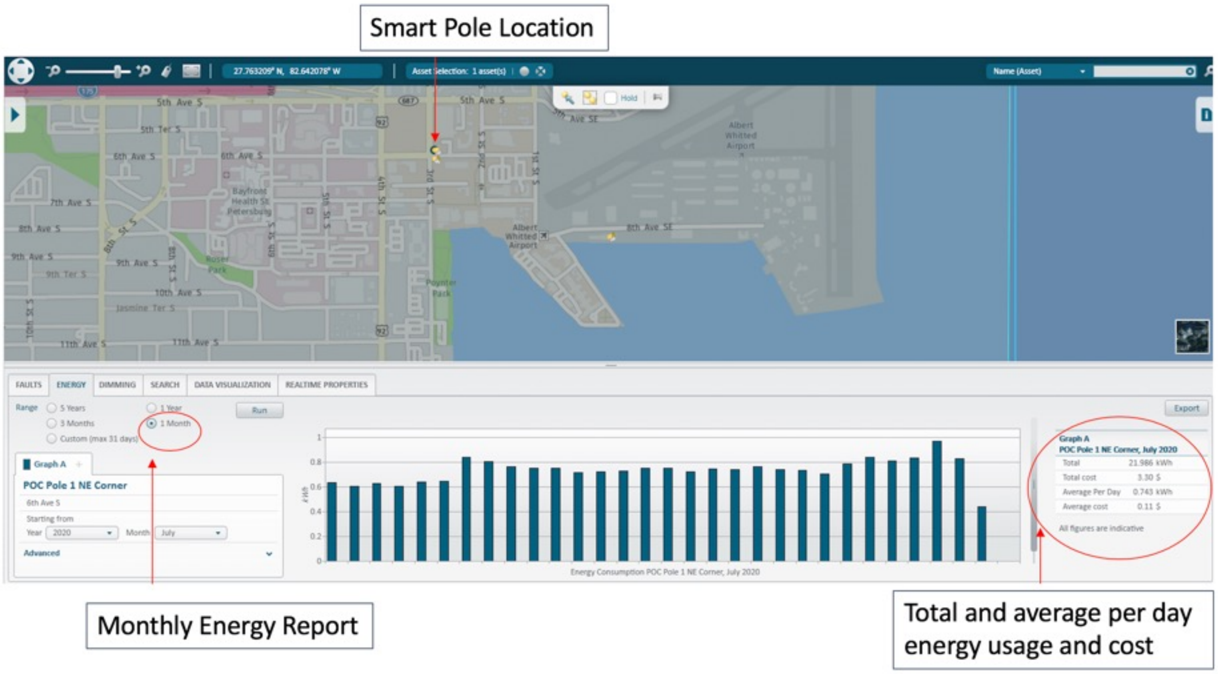


Figure 5 - Dashboard

The dashboard for the smart light as shown in figure 5 provides a means to view, control and manage the smart light remotely, thus increasing operational efficiency and lowering operating costs. The operating rules for the smart light, such as turn on and turn off schedule and managing the brightness level can be set remotely. We tested the two different settings on the smart light pole:

1. With dimming activated - in this setting the brightness changes when pedestrian movement is detected (via motion sensor/camera)

2. Without dimming - the light stays at full brightness level at all times.

We recorded the lowest energy usage with the dimming control activated as shown in Figure 6. The motion sensor increased the brightness of the light only when pedestrian activity was detected. When no activity was detected, the light pole stayed in dim state and provided maximum energy savings and a lower carbon footprint.

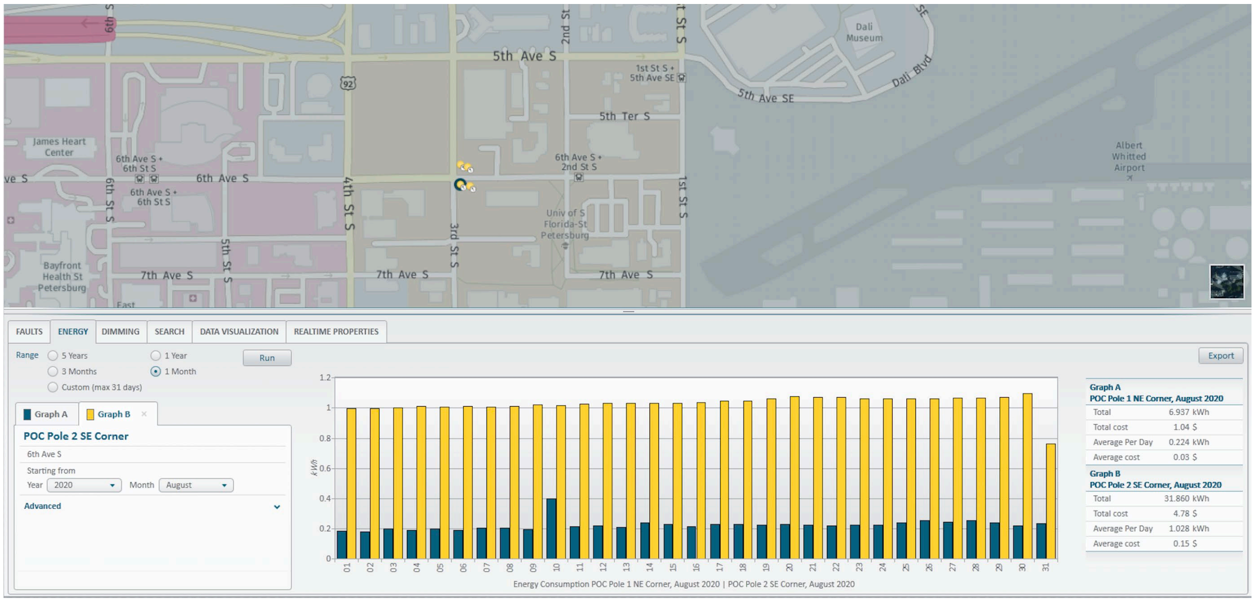


Figure 6 – Energy Usage (Dimming vs No Dimming)

Table 1 – Energy usage per day (Dimming vs No Dimming).

Smart Light Configuration	Average Energy Per Day (Watt Hour)
Without Dimming	1028
With Dimming Activated	224

Energy usage during winter and summer months

We studied the variation in energy usage during the winter and summer months as shown in Figure 7. This information is useful for preparing for the load on the energy grid for each month.

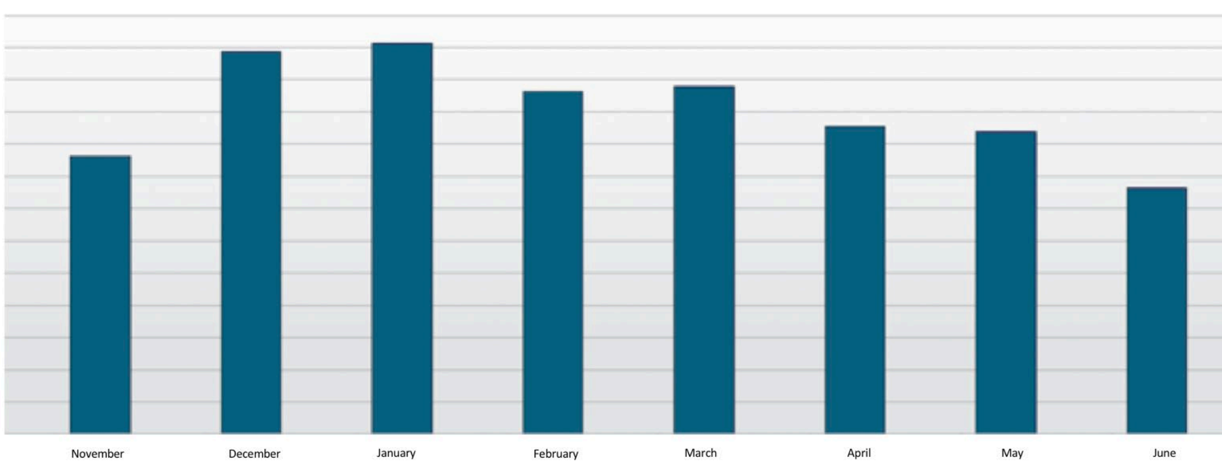
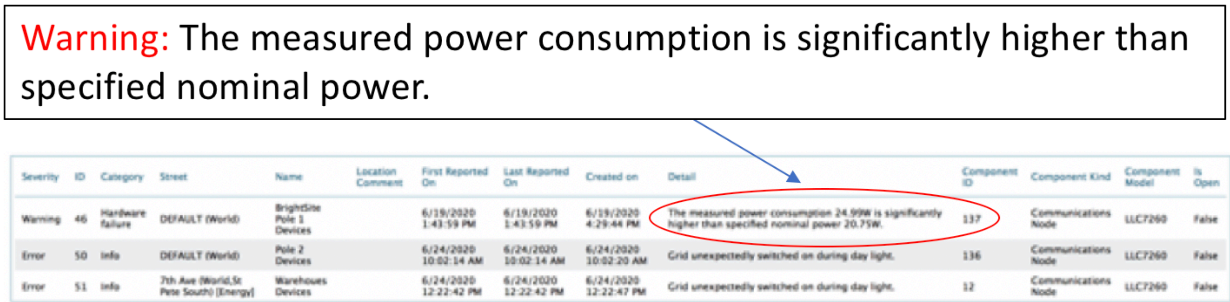


Figure 7 – Energy Usage in Winter and Summer Months

Insights from alerts: The smart light system monitors many parameters and can send alerts when it detects an unusual reading from the sensor as shown in Figure 8. These insights can point to expected fluctuations on the power grid or high usage of the camera as result of pedestrian activity in the area, emergency button or WiFi.



Severity	ID	Category	Street	Name	Location Comment	First Reported On	Last Reported On	Created on	Detail	Component ID	Component Kind	Component Model	Is Open
Warning	46	Hardware failure	DEFAULT (World)	BrightSite Pole 1 Devices		6/19/2020 1:43:59 PM	6/19/2020 1:43:59 PM	6/19/2020 4:29:44 PM	The measured power consumption 24.99W is significantly higher than specified nominal power 20.75W.	137	Communications Node	LLC7260	False
Error	50	Info	DEFAULT (World)	Pole 2 Devices		6/24/2020 10:02:14 AM	6/24/2020 10:02:14 AM	6/24/2020 10:02:20 AM	Grid unexpectedly switched on during day light.	136	Communications Node	LLC7260	False
Error	51	Info	7th Ave (World,St Pete South) [Energy]	Warehouses Devices		6/24/2020 12:22:42 PM	6/24/2020 12:22:42 PM	6/24/2020 12:22:47 PM	Grid unexpectedly switched on during day light.	12	Communications Node	LLC7260	False

Figure 8 – Alarms and Alerts

4.2. Camera

The camera is one of the most effective tools in the smart city tool kit for enhancing public safety and protecting city assets. As an example, many cities have some renovation and new development activities in progress. At these construction sites, expensive construction equipment and supplies are stored. After the work shift, when the workers leave the site, there is a possibility of theft or vandalism. Each year around $300 million to $1 billion worth of construction equipment is stolen and only less than 25% is recovered. Florida is ranked third in the nation for construction equipment theft.[2] We tested several camera alarms, e.g., virtual fence alarm, guard zone alarm and loitering alarm as shown in Figures 9, 10 and 11, at a construction site across the street from the proof of concept light pole.

A virtual fence has been useful to monitor unauthorized access at the construction site.

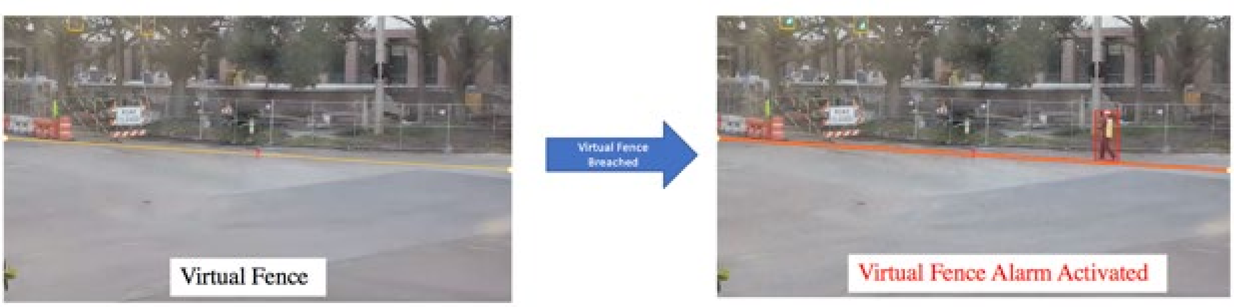


Figure 9 – Virtual Fence

Figure 20 – Loitering Alarm

Figure 11 – Guard zone alert

4.3. Smart intersection

The goal of the Smart Intersection proof of concept is to improve pedestrian safety. The State of Florida has nine of the top 20 least safe cities in the U.S. for pedestrians and is also considered the most dangerous state for the pedestrians.[3] As per the National Highway Transport Safety Administration, pedestrian fatalities in crashes increased 53 percent in the last decade (2009 to 2018), with the pedestrians' share of traffic fatalities increasing 42 percent, from 12 to17 percent.[4]

One initiative cities like St. Petersburg are working on is to bring the number of fatalities or collisions in an intersection to zero. This effort is called Vision Zero. Data collected from road sensors and cameras can help cities better understand everything from crosswalk signal timing to traffic patterns that may lead to these collisions.

The Smart Intersection proof of concept uses computer vision and edge computing to detect the presence of a pedestrian as shown in Figures 12 and 14. The camera's technology can be used to set the zone within the view of the camera that needs to be monitored for pedestrian activity. The anonymous pedestrian and vehicular traffic data is stored in the cloud for further analysis, planning and design of components of the intersection, including stop signs, traffic/pedestrian light timing, crosswalks and sidewalks to improve pedestrian safety.

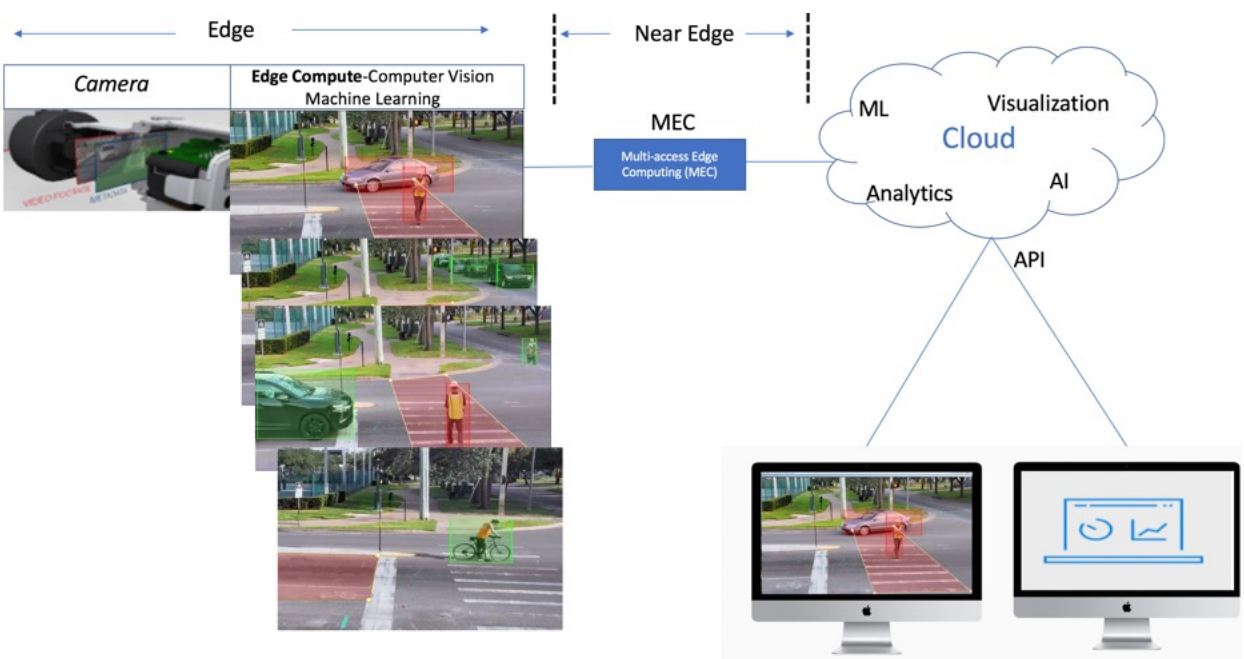


Figure 32 – Computer Vision for Smart Intersection

We are currently collecting the following metadata as shown in Figure 13 to assist St. Petersburg with the design of the intersection that would improve pedestrian safety:

- Number of pedestrians crossing the crosswalk
- Direction of pedestrian movement e.g., north, south, east, west

	Last Hour	Daily	Monthly
North to South	11	242	7260
South to North	22	484	14520
East to West	89	1958	58740
West to East	113	2486	74580
Totals	235	5170	155100

Figure 43 – Pedestrian Count

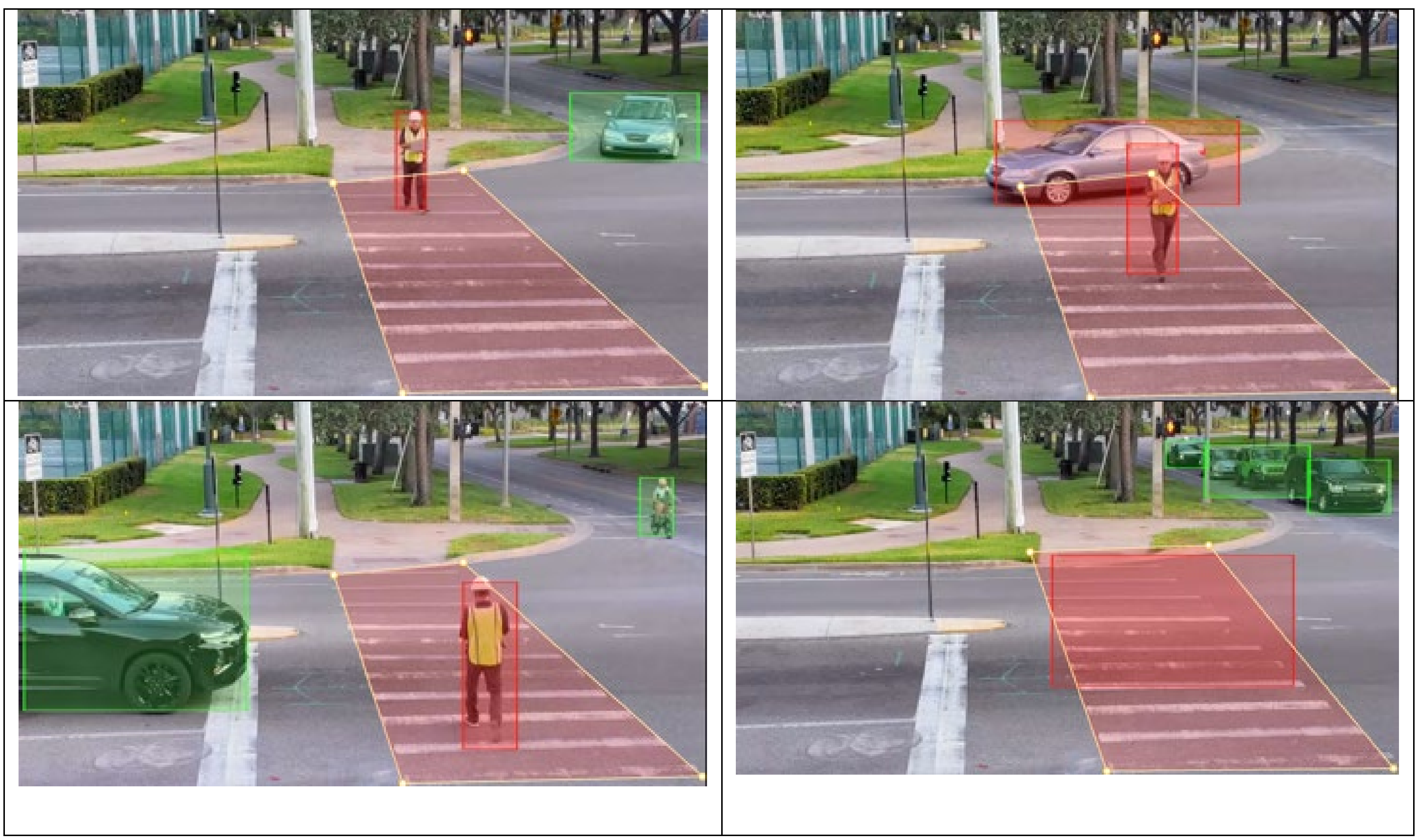


Figure 54 – Monitoring Pedestrian Movement at Smart Intersection

4.4. Environmental

Florida is home to some extreme weather conditions including hurricanes, extremely hot temperatures, humidity, fog and a high number of lightning strikes from thunderstorms. Florida leads the country in both the number of fatal lightning hits and the density of strikes, with just over 20 flashes per square mile every year.[5]

Figure 65 - Weather

Weather can have a big impact on citizen safety, city operations and its economy. Cities and businesses today not only need a general weather forecast for the whole city, but a micro-forecast for each neighborhood. The weather sensors are one of the largest sources of IoT data and help in micro forecasting of weather. Data from local weather sensors can micro-forecast weather that can help utility companies predict the energy load for each part of the city. Cities can predict and monitor flooding in each neighborhood as shown in Figure 15 and prepare the water pumps; detect a lightning strike at a particular location and alert the public; and detect fog on a certain part of the highway and warn motorists.[6]

Air pollution is responsible for five million premature deaths each year and nine out of ten people around the world breathe unhealthy air.[7] The sensors installed on the light pole in the POC collect several weather and air quality parameters as shown in Figures 16 and 17 and provide the city with interesting and pertinent insights on air quality at the location of the sensor.

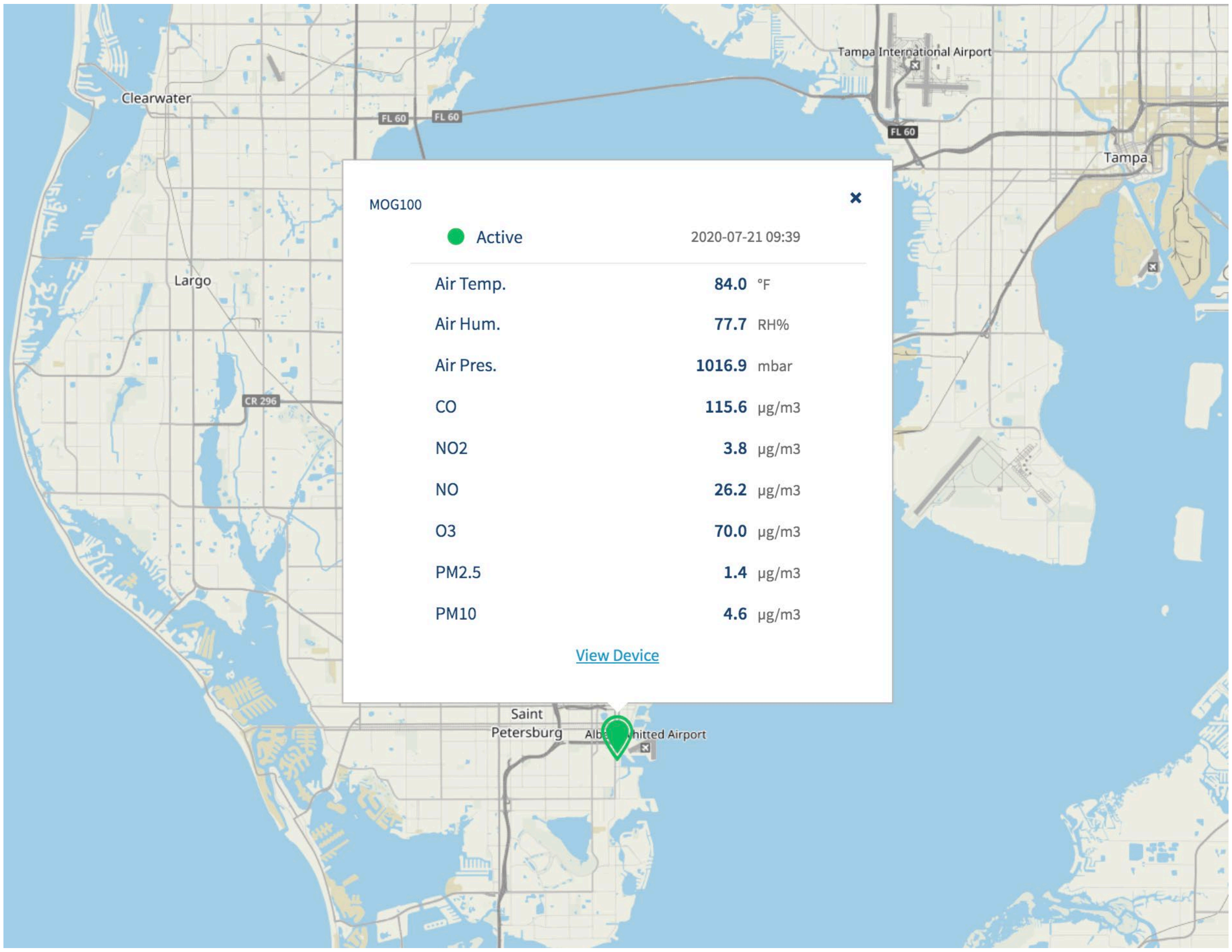


Figure 76 – Air Quality

Following are some of the parameters collected by this sensor:

Table 2 – Weather and Air Quality

Weather	Air Quality
• Temperature • Humidity • Dew Point • Air Pressure • Wind Direction and Speed • Precipitation Intensity • Radiation • Lightning	• Carbon Monoxide • Nitrogen Dioxide • Nitric Oxide • Ozone • PM 1 • PM 10 • PM 2.5

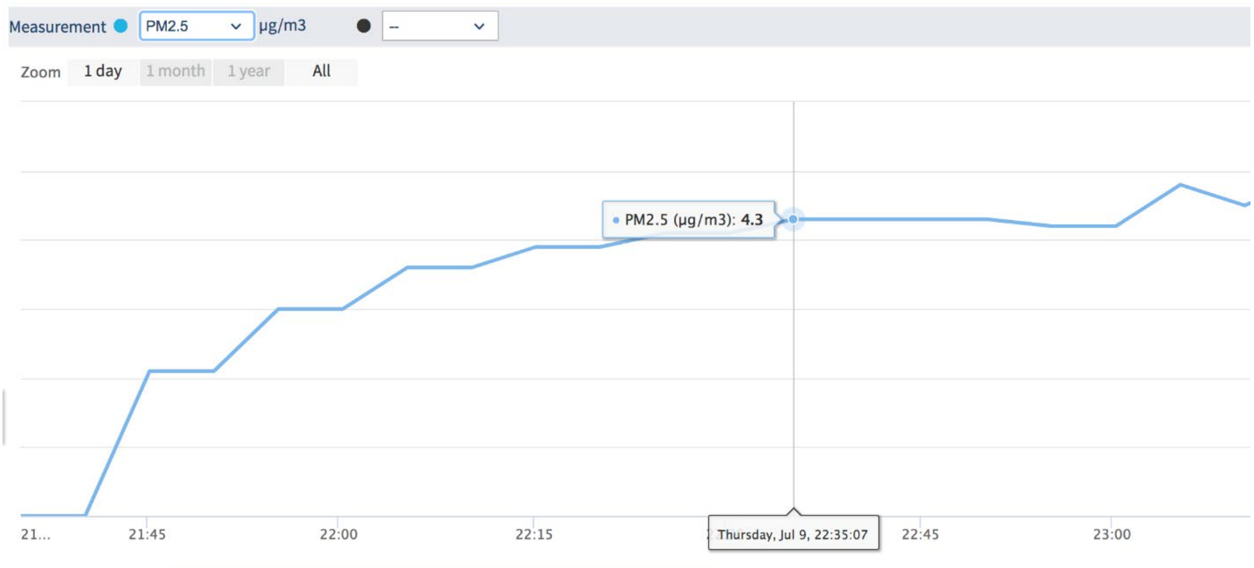


Figure 87 – Air Quality (PM2.5)

The data from all the sensors is collected and sent to the cloud where it is analyzed to draw actionable insights, as shown in Figure 18

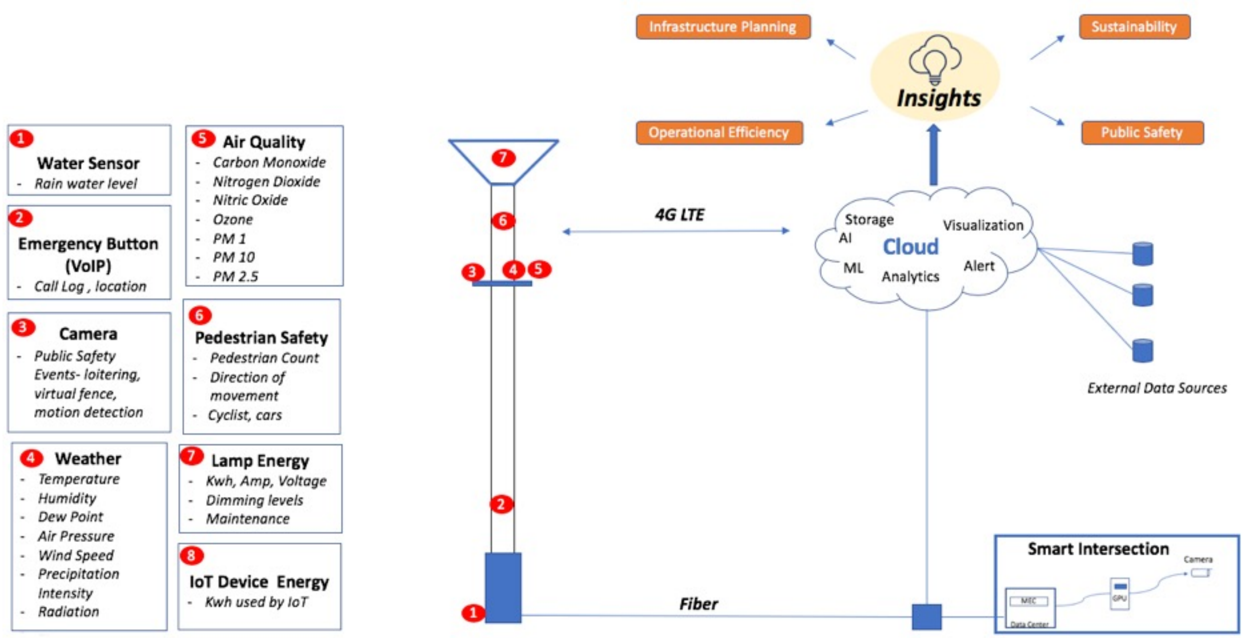


Figure 98 – Insights from IoT Data

5. Conclusion

In this proof of concept, we have demonstrated how much data can be collected and potentially analyzed from a few key IoT sensors.

As we collect more data and datasets get richer over time, we expect to draw more insights. Using the richer data sets, we can train the computer vision model and capture additional metadata to make our roads safer, predict and manage energy usage to lower costs and reduce the carbon footprint, and improve public safety and citizen engagement.

Installation of IoT hardware requires permits and inspections from many city departments before the sensors can be activated. When selecting a location for a POC, pick multiple locations that represent different sections of the city and also future-proof the POC to add scale and capability.

Close collaboration with academia, local communities and the government is important for the successful deployment of smart city solutions. Each city is unique; therefore, smart city solutions and use cases should be customized. The cable companies, with its vast network infrastructure and strong public-private partnership, are well positioned to lead the way in offering smart city solutions.

6. Acknowlegements

The authors would like to acknowledge Alison Barlow from the Innovation District at the city of St. Petersburg, FL and representatives of the University of South Florida St. Petersburg campus, US Ignite and St. Petersburg, FL, for the support and guidance during the execution of the POC.

Abbreviations

IP-PBX	Internet Protocol Private Branch Exchange
MEC	Multi-access Edge Computing
POC	Proof of Concept
PoE	Power over Ethernet
IoT	Internet of Things

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