Smart City New Tashkent

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Case

Tashkent is the biggest metropolis in the Republic of Uzbekistan and the political, economic and cultural capitals of the country. The city has a population of over 3 million, which makes the ecological and resource efficiency, safety, and urban comfort problems especially urgent.

Tashkent is a fast-growing city: residential complexes are under construction, roads are being laid, and the space of green areas is growing. But as the city grows so do problems:

- unreasonable irrigation;
- air pollution;
- poor street lighting;
- traffic congestions and collisions at crossroads;
- the absence of functioning urban surveillance systems.

All these challenges demand contemporary digital solutions that are grounded on Internet of Things (IoT) technologies.

Problems identified

A review of the urban infrastructure of Tashkent found the following to be major problems:

Air Pollution.

One of the most acute issues of the environment of Tashkent is air pollution today. Based on environmental research and news articles, it is more than six times the allowable levels of the World Health Organization average yearly concentration of fine particulate matter (PM2.5) in the air of Tashkent. This shows that there is a severe degree of pollution, which directly affects the health of the population negatively.

The systematic nature of the problem is verified by the fact that exceedances of the permitted concentrations of dangerous particles are constantly recorded by monitoring systems that monitor air quality in real-time. The sources of pollution are both natural (dust, dry climate) and man-made (such as):

- vehicle transport,
- industrial enterprises,
- residential heating systems.

There are also reports on the state of the environment in Uzbekistan that the city is undergoing rapid urbanization, population growth, and a sticky infrastructure that is exacerbating the environmental impact of the city. The emission is not properly controlled and this results in a decline in air quality, the rise in respiratory diseases and also the overall measure of environmental safety decline.

Irrational use of water resources and irrigation systems

The issue of water resources is a strategic part of sustainable development in Uzbekistan and the city of Tashkent in particular. Even so, national environmental reports show that more than 90 percent of the surface water bodies of the country are polluted and the water supply and irrigation facilities of most regions are outdated and old fashioned.

The issue of poor use of water to irrigate green spaces is one of the significant problems. The irrigation is conducted in the majority of cases:

- by a predetermined plan,

- and without regard to actual soil moisture,
- without weather conditions (rain, high humidity) analysis.

It causes either excessive use of water or also soil drying up, which is harmful to the health of the vegetation in the city. It is also mentioned that the issue of water shortage is becoming more urgent in the circumstances of climate change and heightened temperatures.

Scientific literature also highlights that soil erosion, desertification as well as poor management of water resources are some of the most important environment-related issues in the country. In that regard, the adoption of an automated smart irrigation system powered by soil moisture and precipitation sensors is a significant way of enhancing the efficiency of water use, minimizing water loss, and keeping the best conditions of plant growth.

Reduction of green spaces and deterioration of the urban environment

Tashkent has experienced the issue of dwindling green spaces as active construction, road infrastructure development, and urbanization are taking place in recent years. As stated in the analytical publications, the percentage of green spaces in the city has depleted dramatically over the last couple of years, which harmed:

- air quality,
- noise levels,
- the city's microclimate,
- the level of comfort of residents.

The loss of green spaces adds to the urban heat island effect, air pollution, and the loss of capability of the urban habitat to act as a natural pollutant filter.

Another issue is the degradation of the infrastructure of the state, such as the water supply system, which causes the loss of water and the loss of efficiency in taking care of green spaces. Combined, all that makes the implementation of smart urban management systems, such as automated irrigation and climate monitoring, necessary.

Traffic Issues and Intelligent Traffic Control.

Tashkent is experiencing a rapid population growth and rise in volume of vehicles that are putting a heavy burden on the transport infrastructure. Traffic congestion and accidents are not the only causes of air pollution, which is a significant issue brought about by heavy traffic.

Traffic lights in most regions of the city have strictly specified algorithms, which do not consider:

- weather conditions (rain, fog),
- actual congestion in crossroads,
- accidents.

This will minimize the efficiency of traffic control and will raise the chances of road accidents. With the phenomenon of rapid urbanization, it is crucial to introduce smart traffic lights, which would be able to adjust to external factors and be a component of a complex intelligent transportation system.

The Issue of Wasting Street Lighting and Overconsumption of Energy.

The ineffective street lighting system of the city is one of the burning issues in the city infrastructure as, in most cases, it has been designed based on a dated principle that it is a fixed schedule without regard to the amount of natural light actually in the sky. Lighting can therefore be turned on:

- where it is daylight enough,
- when clouds are thick and there is no actual necessity,
- during the morning and afternoon during sudden alterations of weather conditions.

Such a model results in the wastage of energy, overloading of the power grid in the city, and other financial expenses. As the populations grow, the road infrastructure expands, as well as the number of residential zones grows, the question of energy efficiency becomes even more significant.

Moreover, road safety is adversely affected because of the unintelligent lighting control systems since:

- illumination can be postponed in the evening and night;
- drastic variations in light disturb the vision of drivers and pedestrians;
- The lighting cannot be adjusted to the weather conditions.

The lighting systems are regarded as one of the central points of the energy conservation in the concept of smart city of the modern days. With use of light sensors (photoresistor):

- automatically switching on the lights when necessary,
- energy saving,
- prolonging the duration of lighting systems,
- enhancing the security of the city space.

Proposed solution

The concept of an integrated system of Smart City was created based on the identified challenges. It will enhance sustainability, energy saving, safety, and comfort of the city of Tashkent. The given solution is premised on the introduction of smart digital solutions to observe and automatically regulate the significant city processes.

The system will be set in a manner that caters holistically to the following objectives:

- environmental pollution reduction;
- use of water resources efficiently;
- using energy in the most efficient way;
- improving road safety;
- enhance the quality of living of the citizens.

Urban Environment Environmental Monitoring.

A major focus of the proposed solution would be development of a continuous environmental monitoring system, which consists of air quality, temperature, humidity, and precipitation monitoring. This approach enables:

- immediate detection of poor environmental factors;
- real-time environmental analysis;
- development of an online map of the environmental state in the city.

The practical applicability of this system is that it:

- offer early warnings of harmful pollution rates;
- come up with management decisions that are grounded in objective data;
- Create environmental awareness among the people.

The solution is directly linked to SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) due to the application of digital tools to analyze the environment.

Smart Water Management System.

In order to resolve the issue of the inefficient water consumption, I suggest working out a smart water management system that presupposes the automatic test of the soil and weather conditions. Irrigation is not used on an unnecessary basis and it is helpful:

- do not use too much water;
- enhance the best plant growing conditions;
- prolong the longevity of city plants.

Regarding efficiency, in an urban environment, such a system can reduce water used in irrigation by an average of 30-50 percent, which is of particular concern to the areas that suffer a shortage of water.

This is a solution that is closely related to SDG 6 (Clean Water and Sanitation) and encourages a reasonable attitude towards the consumption of natural resources.

High efficiency street lighting.

To solve the issue of inefficient street lighting, I suggest installing an intelligent lighting control system, which would be able to adapt itself to natural light levels and outside conditions. The use of lighting is minimized and only when there is a need and the results in:

- considerable decrease in energy use;
- low load on electric networks;
- lowered operating expenditures of the city.

By adopting such a system, one can save up to 40 percent of power hence making it highly efficient in a large city.

The solution aligns with SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities).

The Smart Traffic Control.

Within the concept of Smart City, I would also suggest that an adaptive traffic management system should be implemented whereby the operating mode of the transport infrastructure will be automatically adjusted based on:

- weather conditions;

- traffic intensity;
- emergency situations.

The success of this strategy is manifested by:

- a decrease in the number of road accidents;
- Cutting down the waiting time in the crossroads;
- increasing the reduction of pollutant emission through reduction of traffic congestion.

This is related directly to SDG 9 (Innovation and Infrastructure) and SDG 11 (Sustainable Cities).

Conclusion

The introduction of the Smart City system in the integrated version contributes to the positive influence on the following spheres of life:

- Improvements include:
- environmental situation;
- air quality;
- road safety;
- thermolumbar comfort and lighting comfort;
- the city's appearance.

Savings include:

- water resources;
- electricity;
- city budget funds;
- labor resources because processes have been automated.

Improvements include:

- investment attraction in the city;
- Degree of urbanization of infrastructure;
- the living standards of the citizens.

The Smart City system can be expanded to include under an ideal situation:

- a single digital infrastructure management system;
- data storage and analysis system in the cloud;
- predictive automated algorithms of environmental and transport conditions;
- combination with mobile applications amongst the city residents.

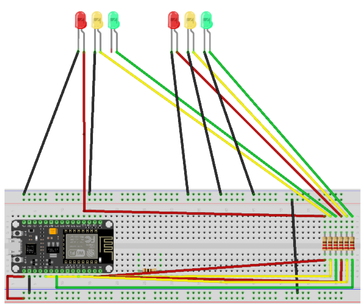
This model will guarantee the complete execution of the principles of sustainable development and digital transformation of the city.

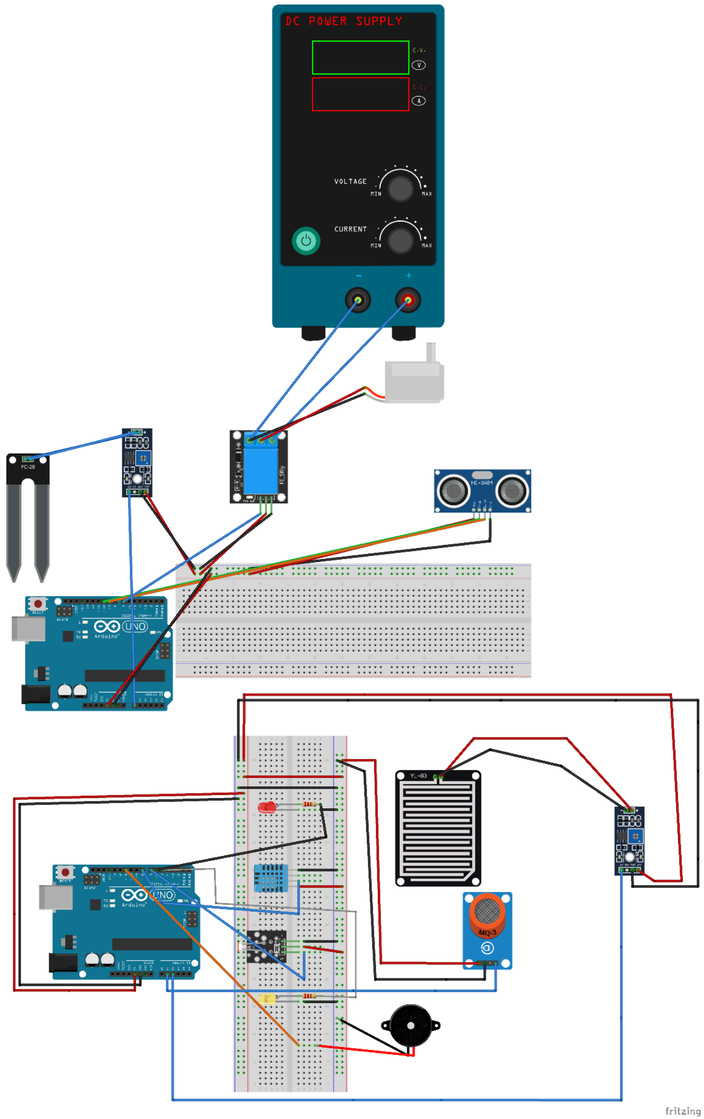
Things used

There are three autonomous functional subsystems in the developed prototype of the Smart City:

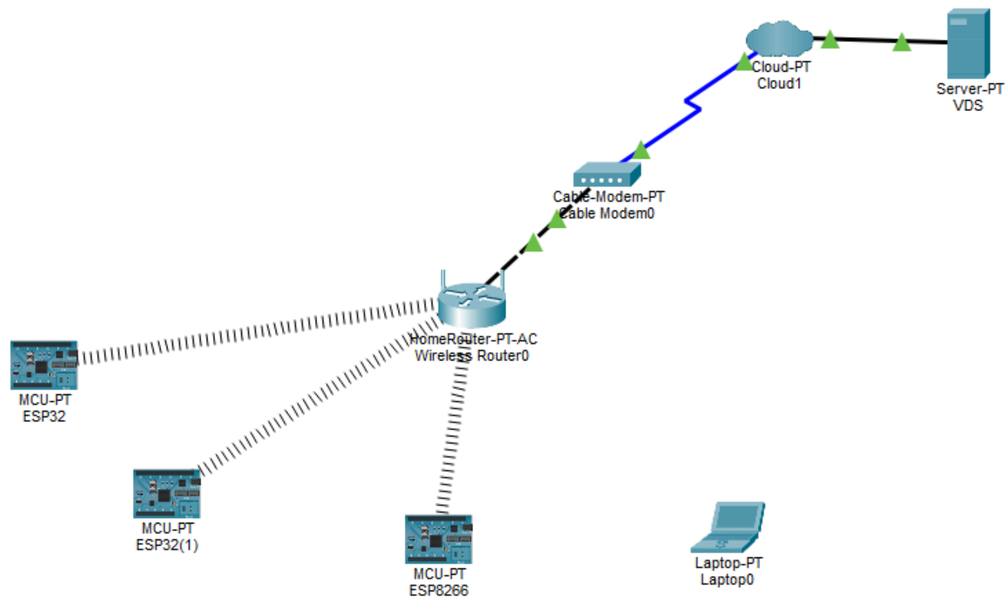
- Light Traffic Control System.
- Automatic Irrigating System.
- Smart Lighting Monitoring System and Air Quality.

The sub systems are deployed on individual microcontroller units and linked to a remote server on a cloud-computing server via Wi-Fi. Electrical connections of all the components have been illustrated in the Circuit Diagram (Appendix A), and the logic connection architecture in the Network Diagram (Appendix B).





Appendix A



Appendix B

Traffic Control Subsystem

Controller

The ESP8266 microcontroller is used to implement the traffic light subsystem. It is the role of this controller to create traffic light phases and connect with the cloud server.

Actuators

6 LEDs ordered in the form of two full traffic lights (RedYellowGreen of each direction).

The LEDs are linked to 220 om current limiting resistor each.

As ESP8266 has a current of 3.3 V, and a common forward voltage of a typical LED is 2.0 V, the current in one LED is:

$$I = \frac{3.3 - 2.0}{220} = 5.9mA$$

For Leds:

$$I_{total} \approx 6 \times 5.9 = 35.4\ mA$$

This is a value that falls under the safe operating range of ESP8266 GPIO pins.

Justification

ESP8266 was also chosen because of its in-built Wi-Fi chip, low-price, and the availability of the right numbers of digital I/O pins. LEDs will give a neat and energy efficient imitation of the actual traffic lights. A specialized controller provides separate and sound traffic controls.

Automatic Irrigating System

Controller

The subsystem is developed based on ESPduino-32 HW707 (ESP32) that includes the Wi-Fi connectivity and the capabilities of measuring soil moisture with the help of the analog input.

Sensors

Soil Moisture Sensor.

- Powered from 3.3 V.
- Connected to an analog input.
- Monitors the humidity of soil in order to control irrigation.

Reason of selection:

Able to run with ESP32 ADC and low cost and adequate sensitivity.

Ultrasonic Sensor

- Powered from 5 V.
- In this tank this is used to measure the water level.

Reason of selection:

Measures non-contact range and enhances the safety of the system, by checking the supply of water.

Actuator

Water Pump with Relay

- External power supply Pump operated by 12 V supply.
- Switched by a relay with Hong-EOK ESP32.
- The high-power circuit is isolated using relay between the high power part and logic.

In case the pump current fluctuates at about 0.5 A, the power used is:

$$P = 12 \times 0.5 = 6\,W$$

Reason of selection:

- Separation of 12 V power line and 3.3/5 V logic ensures electrical safety.
- ESP32 provides high reliability for autonomous irrigation control.
- Relay provides safe switching for high-current loads.

Smart Lighting Monitoring System and Air Quality.

Controller

This subsystem is operated by a second ESPduino-32 HW707 (ESP32).

Sensors

DHT11 (Temperature & Humidity)

- Powered at 3.3-5 V.
- Digital communication.
- Applied in monitoring the climate of the environment.

Reason of selection:

Architectural, out-of-the-box sensor of adequate accuracy to use in Smart City.

Raindrop Sensor

- Operates at 3.3 V or 5 V.
- Detects precipitation.

Reason of selection:

Makes irrigation adaptable and detects weather events automatically.

MQ-2 Gas Sensor

- Powered by 5 V.
- Heater current 180 mA.

$$P \approx 5 \times 0.18 = 0.9\ W$$

Smoke and combustible gases detectors.

Reason of selection:

Very common in prototypes in the internet of things air quality monitoring.

Photoresistor (LDR Module)

- Connected to analog input.
- Operates at 3.3 V.
- Monitors the amount of light in the atmosphere.

Reason of selection:

Low cost, great responsiveness, great in Smart Lighting control.

Actuators

- LED for Gas Alert
- Smart Lighting Indication LED.
- Piezo Buzzer for Gas Alarm

Normal consumption of buzzers:

$$I \approx 20 - 30\ mA$$

Every actuator can safely work within ESP32 limits in terms of current usage in the GPIO.

The subsystem power consumption is estimated as shown below.

- ESP32 with Wi-Fi: 80-150 mA
- MQ-2: 150-200 mA
- Sensors: 20-30 mA
- LEDs and buzzer: 40-60 mA

$$I_{total} \approx 300 - 400\ mA$$

So, the power supply of 5 V / 1 A is enough and gives safe current margin.

Communication Technologies

All three sub systems communicate via Wi-Fi due to the fact that:

- ESP8266 and ESP32 have in-built Wi-Fi.
- Wi-Fi facilities are rampant in urban setting.
- Large data transmission rate means real-time monitoring and control.
- There is no need of any SIM cards or subscription fees.

Protocols Used

- HTTP (POST requests) -- to post sensor data to FastAPI cloud server.

- WebSockets - in real time bi-directional control (traffic lights, pump, lighting).

The use of this method of communication will guarantee:

- Scalability,
- Low latency,
- The synchronization of real-time data,
- Cloud architecture, system level.

Technology used

This section explains about the technologies that might have been utilized in the implementation of the Smart City prototype, a rationale in the choice of the stack used in remote monitoring and control, and the obtained results.

Other Technologies that have been taken into account.

In the context of implementing an IoT-based Smart City system, there were some technological options on various levels:

Backend Layer:

- Django / Django Python Rest Framework.
- Express (JavaScript/TypeScript) or NestJS is a frontend Threat Signal on the Go (Swift.js) Node.js.
- Spring Boot (Java)
- frameworks (PHPlaravel, PHPsymfony).
- FastAPI (Python)

Frontend / user interface:

- Plain HTML/CSS/JavaScript

- React, Vue.js / Angular SPA Annis.
- Mobile applications, Android (Kotlin/ Java and iOS with Swift)
- Next frameworks Next framework or Nuxt framework Server-rendered frameworks.

IoT intermolecular communication configurations:

- HTTP/REST
- WebSockets
- MQTT
- CoAP

Deployment options:

- Local on-premise server
- Shared hosting
- Virtual Private Server (VPS/ VDS).
- Cloud solutions (AWS, Un Azure, GCP, etc).

Both alternatives carry performance, complexity, scalability, cost and learning curve trade offs. In this project, it was emphasized to balance realistic architecture of the Smart City, high development speed, and explicit illustration of IoT principles.

Chosen Backend Technology: Cloud VDS FastAPI.

In the case of the backend, a Virtual Dedicated Server (VDS) and FastAPI (Python) in the cloud were chosen.

Efforts to justify the selection of FastAPI:

- **High performance** FastAPI is an asynchronous Python web framework, which is based on Starlette and Pydantic. It can be used with asynchronous I/O, which can be especially helpful with devices that frequently request a connection of a number of IoT devices (ESP32/ESP8266) transmitting sensor data.
- **Type hints and validation:** Pydantic data validation can easily be used to handle the data in the form of JSON provided by the microcontrollers, and also minimizes the chances of runtime errors.
- **Developer productivity**: It includes a succinct syntax with automatic documentation supported by Open API / Swagger which makes testing and debugging simple.
- **Native JSON and HTTP:** FastAPI can be seamlessly integrated with RESTful APIs, which is quite compatible with the data transmission protocol of the HTTP offered by the ESP devices.

Backend functionality in the system:

Receives sensor data from:

- Light Traffic Control System.(esp8266)
- Automatic Irrigating System.(esp32)
- Smart Lighting Monitoring System and Air Quality.(esp32)

Serves HTTP POST against:

- /api/temperature
- /api/humidity
- /api/rain
- /api/gas

- and the like conclusions of other parameters.
- Ensures real time communication channels through WebSockets to:
    - controlling of actuators (traffic lights, water pump, smart lighting) remotely,
    - initiating pushes by the server onto the frontend and not polling all the time.
- Plays the role of a central integration between Edge devices and the web application and constitutes the Cloud layer of the IoT architecture.

The implementation of the backend on a cloud-based VDS, rather than a local server, is a realistic Smart City scenario: the system can be accessed everywhere in the network and may be expanded or transferred to a more powerful infrastructure (where necessary).

Chosen Frontend Technology React with Next.js.

In the case of the frontend, it was decided to use a web-based solution with React and Next.js.

The background to using React + Next.js is because of reasons that include:

- React:
    - Complexity is reduced in component-based architecture through the substitution of reusable units of UI (service that includes tallying cards, chart, control panels etc.).
    - Huge eco and community back up.

- Next.js:

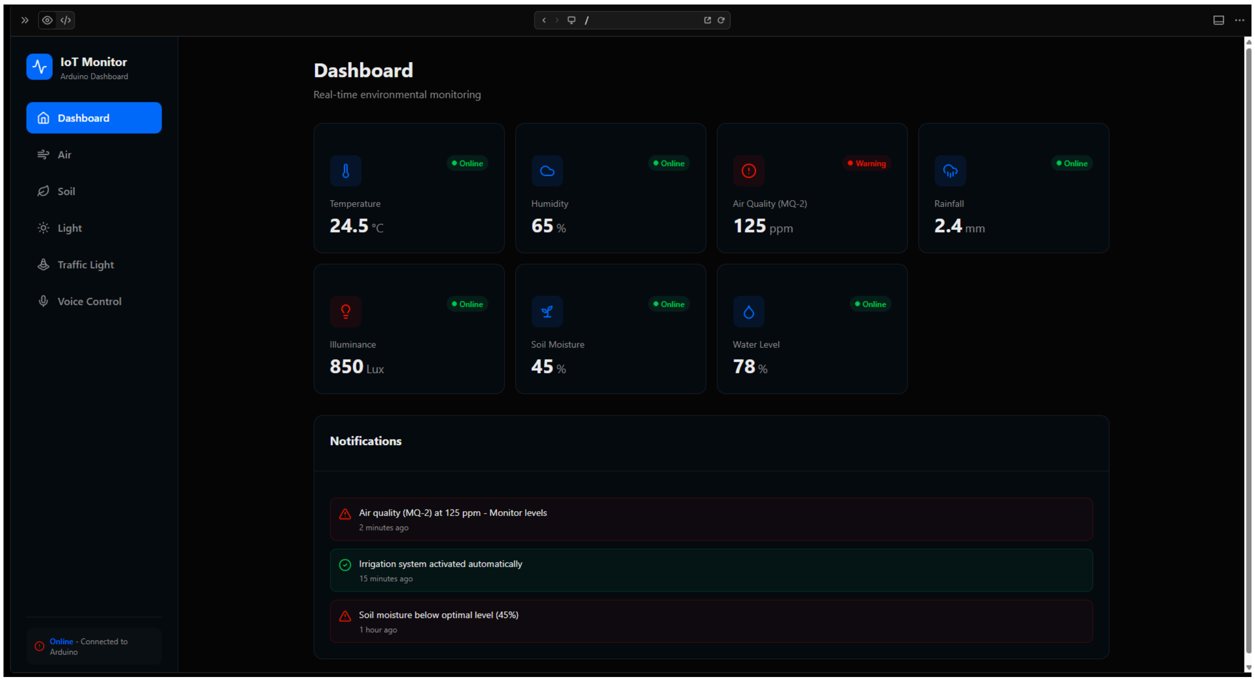
    - Favors Server-Side Rendering (SSR) and Static Site Generation (SSG), which are faster and more optimized in terms of performance and search engine optimization (although this is not the focus of this project, SSR still loads fast at first).
    - In-built routing system makes it easier to organise pages (e.g., dashboard, traffic control, irrigation status).
    - Fetch or Axios unit of easy integration with APIs.

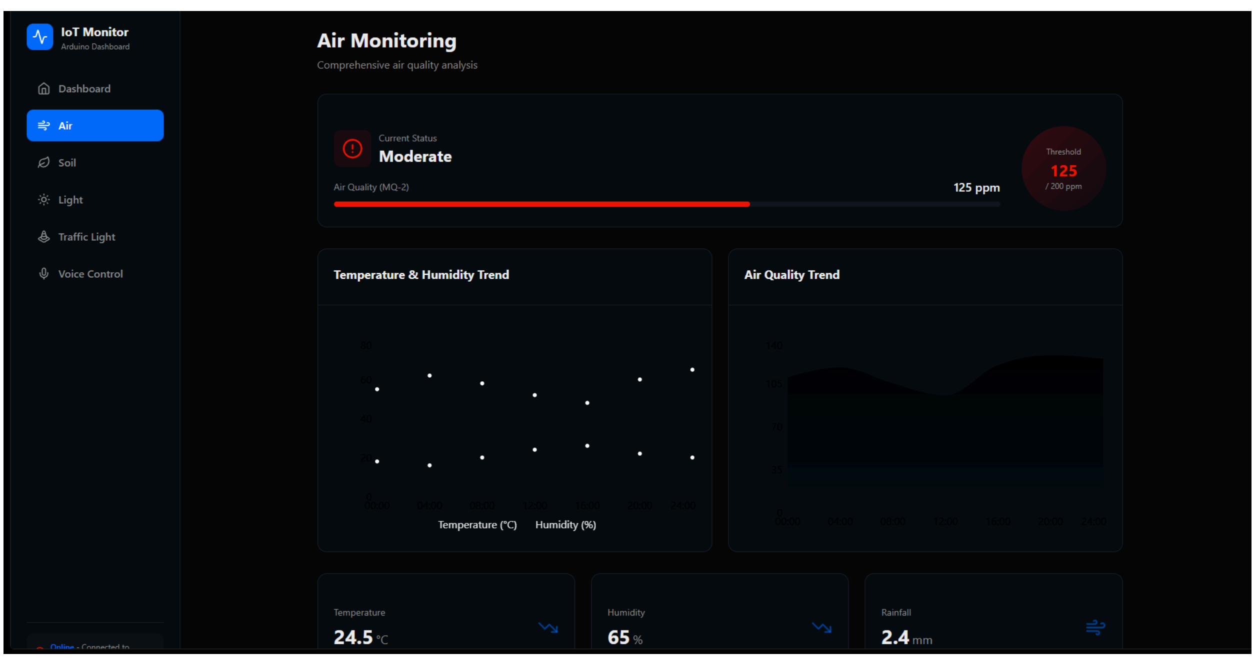
Frontend functions as part of the system:

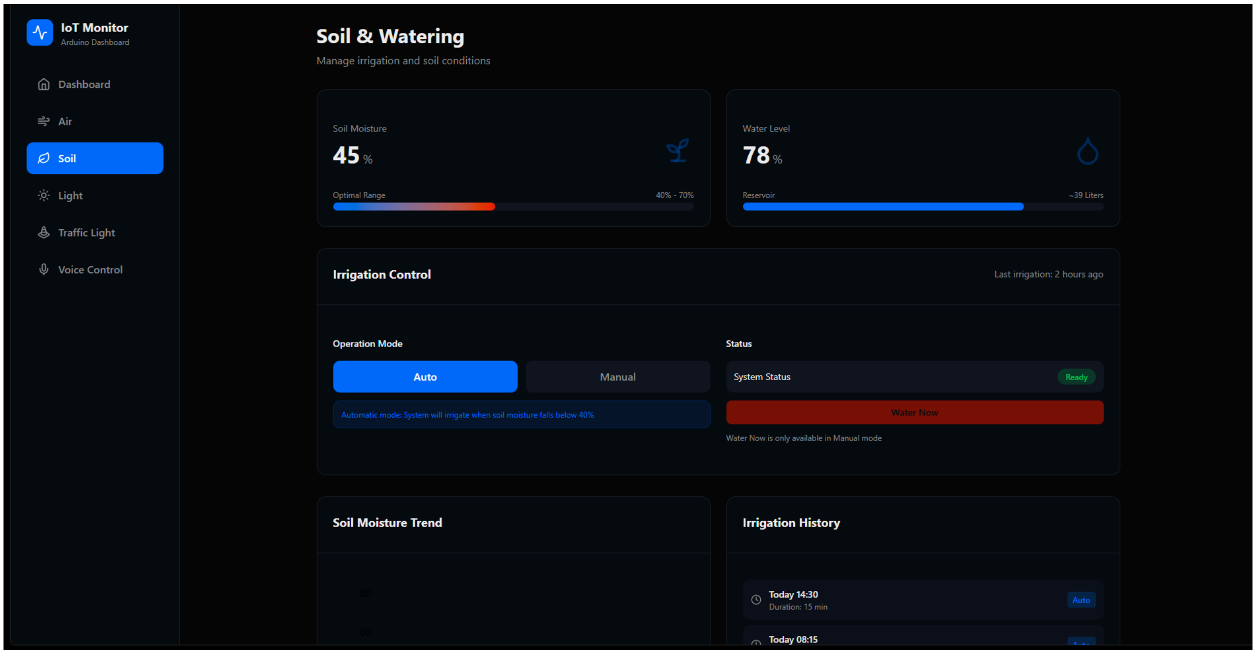
The frontend that will be used to control and monitor the Smart City system is the React + Next.js frontend. It:

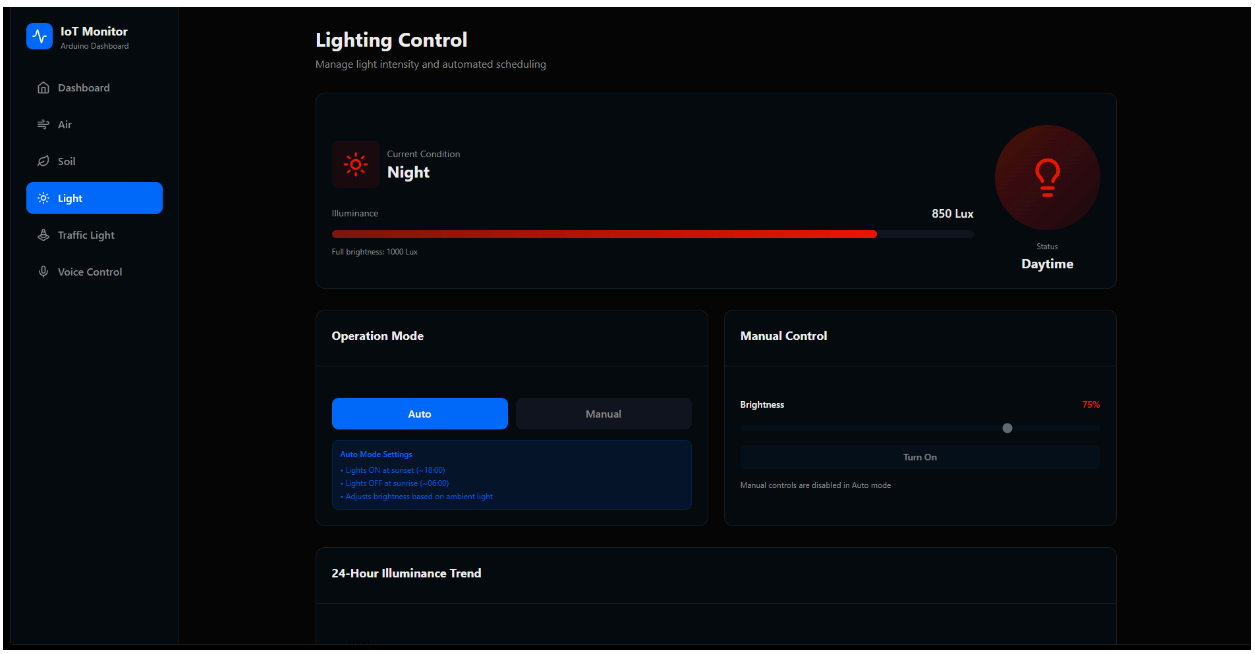
- Shows real-time values returned by FastAPI back end (i.e. temperature, humidity, gas level, rain status, soil moisture, light level).
- Visualises the past or present data as a chart/graph, enhancing the knowledge of the environment and system behaviour.
- Offers control interfaces of:
    - alternating traffic lights modes,
    - activation or deactivation of the water pump,
    - controlling lights upon sensor or manual operations.
- Sends the communication to the backend through:
    - Lots of HTTP (data and configuration request),
    - WebSockets (to receive customer updates in real time and send control commands).

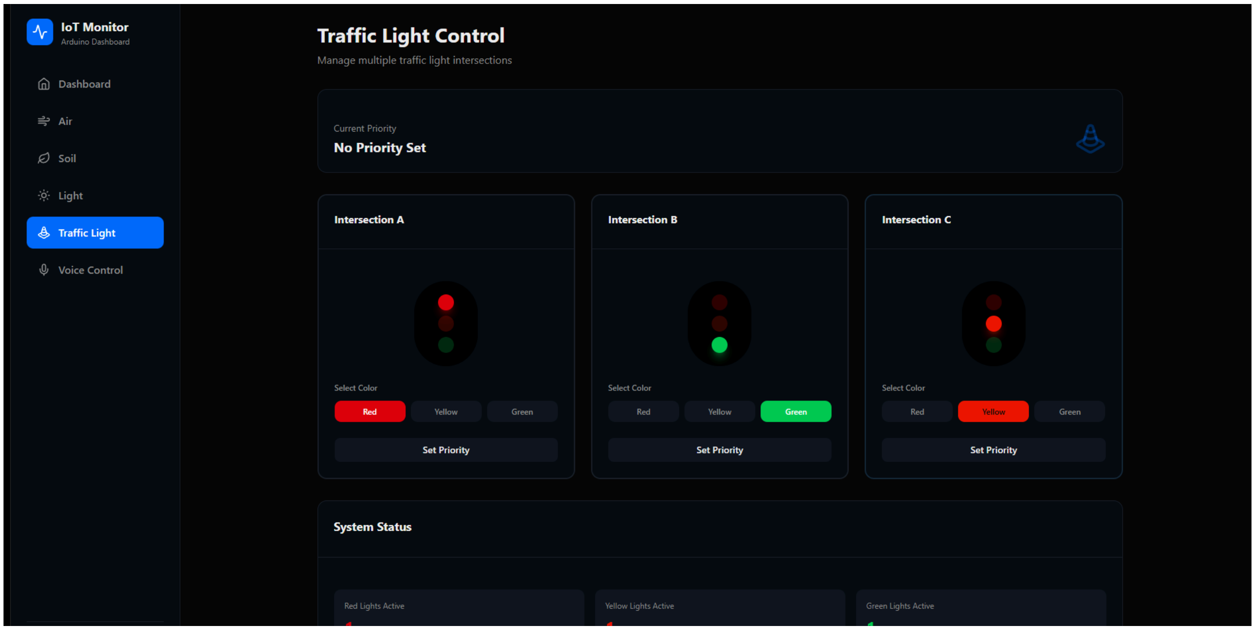
Given a web-based UI, the system will be available on any device with a browser (laptop, PC, tablet), and no additional software needs to be installed. To see it open click this link http://95.182.118.204:3000/

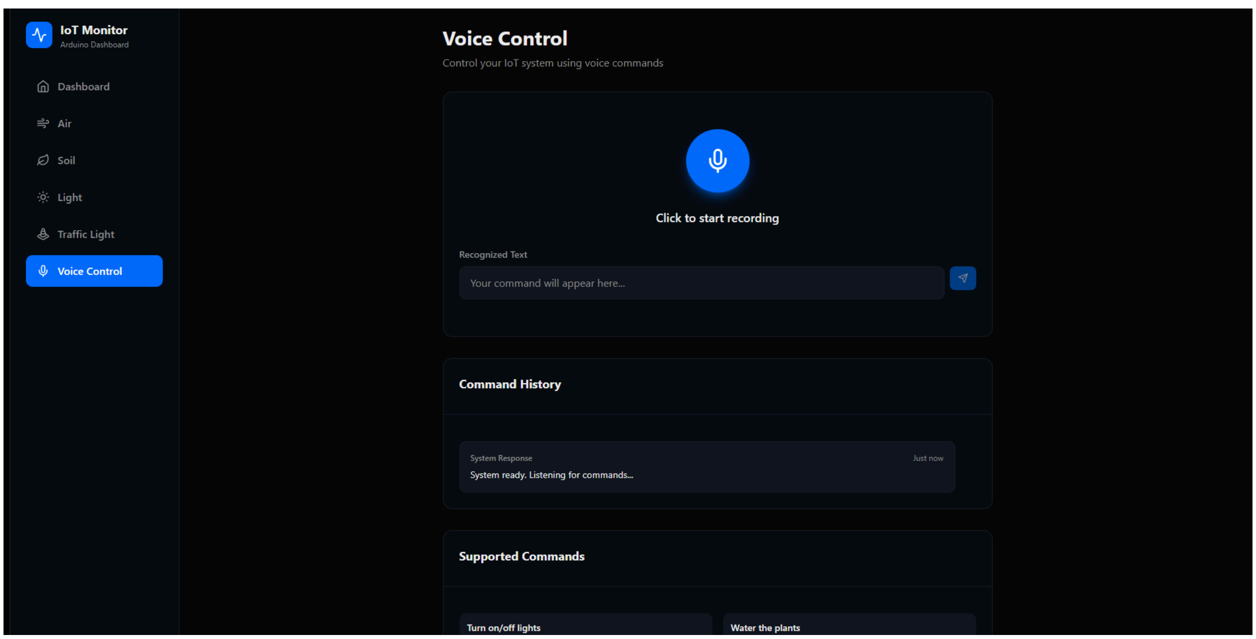





IoT Monitor
Arduino Dashboard
Dashboard
Air
Soil
Light
Traffic Light
Voice Control
Soil & Watering
Manage irrigation and soil conditions
Soil Moisture
45 %
Optimal Range
40% - 70%
Water Level
78 %
Reservoir
~39 Liters
Irrigation Control
Last irrigation: 2 hours ago
Operation Mode
Auto
Manual
Automatic mode: System will irrigate when soil moisture falls below 40%
Status
System Status
Ready
Water Now
Water Now is only available in Manual mode
Soil Moisture Trend
Irrigation History
Today 14:30
Duration: 15 min
Auto
Today 08:15


IoT Monitor
Arduino Dashboard
Dashboard
Air
Soil
Light
Traffic Light
Voice Control
Lighting Control
Manage light intensity and automated scheduling
Current Condition
Night
Illuminance
850 Lux
Full brightness: 1000 Lux
Status
Daytime
Operation Mode
Auto
Manual
Auto Mode Settings
• Lights ON at sunset (~18:00)
• Lights OFF at sunrise (~06:00)
• Adjusts brightness based on ambient light
Manual Control
Brightness
75%
Turn On
Manual controls are disabled in Auto mode
24-Hour Illuminance Trend





Reflection on results and future work

The created Smart City prototype is effective to show how the Internet of Things technologies may be applied to address the actual urban issues like excessive usage of the water resource, poor lighting, air quality surveillance, as well as simple traffic control. This system demonstrated that it is technically possible and works effectively with modern web technologies in a small scale prototype to collect data in real-time, process it in the cloud, and control it remotely.

Nevertheless, the project has a number of limitations as well. The sensors used (including MQ-2, DHT11 and soil moisture sensor) are cheap, hobby grade components, and they lack high industrial accuracy. MQ-2 gas sensor specifically takes long time to warm-up and the calibration is sensitive and thus constrains the reliability of gas measurements. Moreover, it is possible that the applicability of the Wi-Fi as the primary communication medium can decrease system stability in out-of-doors or mass deployments.

The system may be greatly enhanced in the future with professional level environmental sensors, more robust communication systems, e.g. LoRaWAN or NB-IoT and predictive control based on advanced data analytics using machine learning. The combination with real municipal infrastructure and citizen mobile apps would also add more pragmatic value to the system.

Appendix

Appendix A. Circuit

Appendix B. Network

Appendix C. Website

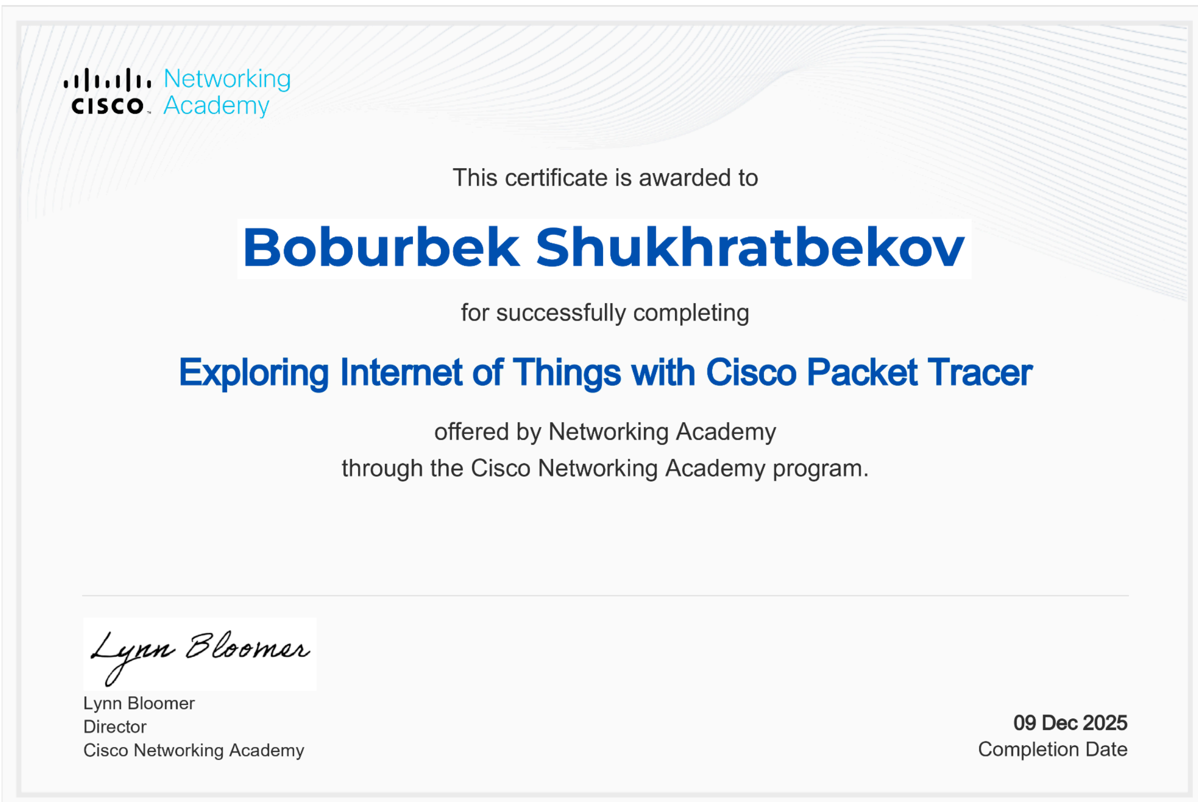
http://95.182.118.204:3000/

Appendix D. Source Code (Github)

https://github.com/shukhratbekovb/SmartCityApp

Appendix E. ESP32

https://dl.espressif.com/dl/package_esp32_index.json



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This certificate is awarded to

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for successfully completing

Exploring Internet of Things with Cisco Packet Tracer

offered by Networking Academy
through the Cisco Networking Academy program.

Lynn Bloomer
Director
Cisco Networking Academy

09 Dec 2025
Completion Date

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Overview of IoT Technologies(CRA Training Program)

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