

A REAL-TIME AIR QUALITY MONITORING SYSTEM WITH HIGH-FREQUENCY AQI RECALCULATION FOR RAPID ENVIRONMENTAL FLUCTUATIONS

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ABSTRACT

Air pollution monitoring using conventional Air Quality Index (AQI) frameworks is limited by long averaging intervals, which mask short-duration pollution spikes and delay timely health warnings. This paper presents a high-resolution, real-time environmental monitoring system that detects rapid air quality fluctuations using distributed ESP32-based sensor nodes and low-latency ESP-NOW wireless communication. The system integrates particulate matter sensors, gas sensors, and environmental sensors to continuously measure air quality parameters and compute a Dynamic Real-Time Environmental Score (DRES) using adaptive exponential smoothing. This approach enables rapid detection of transient pollution events while maintaining robustness against sensor noise.

Experimental deployment in a campus environment demonstrated the system's ability to detect abrupt pollution spikes within seconds, significantly outperforming traditional AQI calculations based on long-term averages. The system achieved reliable wireless communication up to 120 meters and successfully captured localized pollution variations that conventional monitoring systems fail to detect. Results confirm that high-frequency monitoring combined with edge-based processing provides superior temporal responsiveness and enables real-time environmental risk assessment. The proposed architecture offers a scalable, low-cost solution for hyper-local air quality monitoring, supporting applications in smart campuses, urban environmental management, and public health protection.

Keywords: AQI, IoT, Sensors, Health, Environment

INTRODUCTION

Air quality represents one of the most critical environmental health determinants in the modern world. Fine and coarse particulate matter (PM_{2.5} and PM₁₀), along with gaseous pollutants such as carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and volatile organic compounds (VOCs), penetrate deep into the human respiratory system, causing significant adverse health outcomes [1]. The World Health Organization estimates that approximately 7 million premature deaths occur annually due to air pollution exposure, making it