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IMPLEMENTATION OF POCKET QUBE SATELLITES FOR ENVIRONMENT MONITORING

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Abstract

Integrating Pocket satellites into college campuses offers robust IoT connectivity. Placed in Low Earth Orbit (LEO), these satellites ensure uninterrupted communication across vast campus areas, including buildings, outdoor spaces, and remote facilities. This extensive coverage enables diverse IoT applications, making environmental monitoring, waste, and energy efficiency, promoting sustainability and resource efficiency. Implementing these applications can revolutionize college operations, enhancing efficiency and the learning environment.

Keywords: Pocket satellites, Global network, IoT devices.

1. Introduction

Large, complex, and expensive satellite missions have been the trademark of the conventional space exploration paradigm. The introduction of Pocket Qubes, however, has put this traditional strategy to the test and presented a possible replacement for space research, technology demonstration, and education. These tiny satellites, which are only a few centimetres in size, are a notable divergence from the conventional CubeSat form factor (1U,2U, 3U, etc.), enabling even more cost savings and mission scalability. The CubeSat movement, which aspired to lower entry barriers and democratise access to space, is where PocketQubes got their start. With their standardised 10 cm x 10 cm x 10 cm form factor, CubeSats opened the door for more compact and reasonably priced satellites. Building on this achievement, Pocket Qubes—a satellite solution that is even smaller and only 5 cm x 5 cm x 5 cm in size—were introduced. Since they were first introduced, Pocket Qubes have developed to support a range of configurations, enabling a variety of payloads and mission profiles. Cost- effectiveness is one of the main factors influencing the adoption of Pocket Qubes. For academic institutions, entrepreneurs, and up-and-coming space agencies, Pocket Qubes is a desirable alternative because of its lower launch costs, lower development costs, and simplified operations. By making space more accessible, Pocket Qubes has enabled a larger group of space enthusiasts to participate in satellite development and space research.

2. PocketQube Overview

PocketQubes represent a novel class of miniature satellites that have begun to carve a niche in the space industry. While the notion of small satellites is not entirely new, given the prevalence of CubeSats, PocketQubes offer an even more compact and economical alternative for certain applications. The standard size for a PocketQube unit is a petite 5x5x5 cm, commonly referred to as 1p. This is in stark contrast to the CubeSat standard where a single unit, or 1U, measures 10x10x10 cm. Depending on the mission's needs, multiple PocketQube units can be conjoined, resulting in configurations like 2p, 3p, and so on. One of the primary draws of PocketQubes is their cost-effectiveness. Their diminutive size and weight mean they are typically cheaper to design, build, and send to space. This affordability makes them an attractive option for a range of stakeholders, including educational institutions, startups, and countries with budding space ambitions but limited budgets. Moreover, the entire process of designing to deployment can be much faster for PocketQubes, enabling a quicker mission turn around the compact nature of PocketQubes allows for innovative solutions, especially when thinking of satellite constellations or the idea of deploying multiple units in a swarm-like formation. Furthermore, by launching several PocketQubes for varied tasks or experiments in a single mission, the risk gets distributed. This means if one-unit encounters issues or fails, other units can still potentially carry out the mission's objectives While their size provides numerous advantages, it also comes with inherent challenges. The payload capacity is limited, meaning only small instruments or sensors can be housed within. Additionally, their power storage and propulsion capabilities might be limited, possibly leading to shorter mission durations. Communication, given the compact form factor, might also be a challenge, as establishing robust communication links with Earth requires adequate antenna sizes and power.

3. System Methodology

Air quality monitoring systems integrate various technologies and sensors to enhance efficiency, safety, sustainability, and the overall experience for students, faculty, and staff. These systems may vary depending on the institution's goals and resources. Key components of air quality monitoring include MQ sensors and Pico Pi, which work together to detect harmful gases, monitor environmental conditions, and provide real-time data for ensuring healthy indoor environments. MQ sensors, such as MQ-135 for detecting air pollutants and MQ-7 for carbon monoxide detection, are widely used due to their sensitivity and reliability. These sensors can measure levels of gases like CO2, ammonia, and other volatile organic compounds (VOCs). When integrated with Pico Pi, a compact and efficient microcontroller, the system can collect, process, and transmit air quality data to centralized platforms for analysis and visualization.

Data analytics platforms gather and analyze information from these sensors, enhancing productivity, cost-cutting, and decision-making. However, while implementing air quality monitoring systems offers numerous benefits, challenges and drawbacks must be considered. The first challenge is cost, as implementing and maintaining air quality monitoring systems can be expensive. Initial investments in sensors, microcontrollers, and infrastructure are substantial, and ongoing expenses are necessary for upkeep and upgrades. Privacy concerns also arise when collecting and analyzing environmental data, especially if linked with personal spaces, making strict data protection policies essential to safeguard personal information.

Cybersecurity risks are another challenge, as modern monitoring systems are vulnerable to threats from hackers who may target these systems to access sensitive data, disrupt operations, or launch attacks on the campus network. Robust security measures are necessary to mitigate these risks. Additionally, integrating systems from different providers can be challenging due to compatibility issues, data silos, and interoperability problems, requiring careful planning to create a seamless ecosystem. Data overload is another concern, as accumulating vast amounts of information from numerous sensors can lead to valuable insights being lost without proper analytics and data management procedures Maintenance and downtime further complicate the situation, as air quality monitoring systems require routine maintenance. Any system updates or maintenance can impact campus operations and services. To address these limitations and challenges, institutions should engage in comprehensive planning, conduct risk analyses, and regularly review their air quality monitoring programs. Effective implementation and adoption depend on open communication and the involvement of all stakeholders, including students, faculty, and staff Air quality monitoring has the potential to transform higher education institutions by improving health, sustainability, and the overall quality of campus life. However, to guarantee the effective implementation and long-term sustainability of these cutting-edge technologies, comprehensive evaluation of the related expenses and difficulties is necessary.

4. System Modules

4.1 Air Quality Monitoring System

Air quality monitoring systems integrate various technologies and sensors to enhance efficiency, safety, sustainability, and the overall experience for students, faculty, and staff. These systems may vary depending on the institution's goals and resources. Key components of air quality monitoring include MQ sensors and Pico Pi, which work together to detect harmful gases, monitor environmental conditions, and provide real-time data for ensuring healthy indoor environments. MQ sensors, such as MQ-135 for detecting air pollutants and MQ-7 for carbon monoxide detection, are widely used due to their sensitivity and reliability. These sensors can measure levels of gases like CO2, ammonia, and other volatile organic compounds (VOCs). When integrated with Pico Pi, a compact and efficient microcontroller, the system can collect, process, and transmit air quality data to centralized platforms for analysis and visualization.

Pico Pi also serves as a communication module for transmitting data wirelessly over long distances. It supports LoRa (Long-Range) communication, which utilizes advanced spread spectrum technologies to improve link budget and resistance to network interference. LoRa transmissions use wider bandwidths, typically 125 kHz or more, and can be scaled to 250 kHz or 500 kHz depending on requirements. This wider bandwidth enhances resilience against channel noise, fading, Doppler effects, and sustained frequency shifts. The use of spread spectrum modulation ensures reliable data transmission, even in challenging environments.

4.2 Data Analytics Platform

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5. Proposed System

Our college campus is poised for a transformation driven by PocketQubes, tiny yet powerful satellites that will serve as the cornerstone for integrating cutting-edge IoT technologies. These satellites will act as the central processing unit, managing a network of strategically placed sensors across the campus. These sensors, under PocketQube's control, will enable a range of applications, including air quality monitoring, smart lighting, and environmental management. For air quality monitoring, MQ sensors, such as MQ-135 and MQ- 7, integrated with Pico Pi, will continuously measure air pollutants, carbon monoxide, $CO2$, ammonia, and other volatile organic compounds (VOCs). Real-time data collection will help ensure a healthy campus environment by identifying areas with poor air quality and enabling timely corrective actions.Water usage across the campus will be monitored in real-time, aiding in the early detection of leaks or irregularities, promoting water conservation and cost savings. The centralized control provided by PocketQube will facilitate efficient data processing, analysis, and decision- making, ensuring seamless coordination among various sensors and systems, enhancing campus operations. Our college campus is poised to embrace IoT and PocketQube technologies, becoming smarter, more efficient, and environmentally friendly. This innovative approach promises to enhance student life, promote sustainability, and improve cost-effectiveness across the campus.

Critical environmental variables including temperature, humidity, and air quality can all be continuously monitored by the system. Wireless Data Collection: It gathers information from a variety of sensors and gadgets and wirelessly sends it to a central control or monitoring system. Real- time Remote Monitoring: Users have remote access to real-time data and insights, allowing them to make timely decisions and react quickly to changing circumstances. In order to predict when equipment or systems could need repair or replacement, the system uses past data to enable predictive maintenance. This helps to avoid expensive breakdowns. Data-Driven Decisions: The system enables users to make wise choices based on current information, enhancing resource allocation and overall operational effectiveness. The system improves resource utilisation and lowers energy waste by continuously monitoring conditions and automatically adjusting as necessary. A state-of-the- art system capable of consistently monitoring pivotal environmental metrics, including temperature, humidity, and air quality [10]. It boasts of wireless data collection, remote real-time monitoring, and predictive maintenance abilities, assisting in data-driven decision-making [11,12]. Furthermore, the system's capability to adapt automatically ensures optimized resource utilization and safety. Seamless integration with IoT platforms makes this tool invaluable for data analysis and related insights [13,14] By sending alerts for unusual conditions, it helps protect the safety and wellbeing of the passengers and enables quick response to possible problems. When environmental conditions diverge from predefined thresholds, the system can be designed to generate warnings and messages, enabling proactive intervention. Data gathering and analysis are made possible by the system's smooth integration with IoT platforms, which also enable other connected systems and devices.

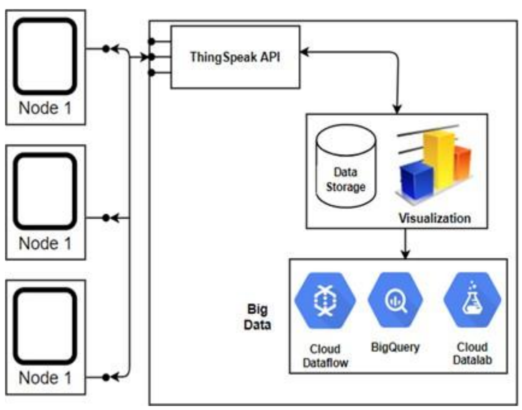

Fig1. Logical Data Model for data visualization

Fig 2. Environment Management System Thinkspeak server output

Fig 3. Environmental Monitoring System Thinkspeak server output

6. Result and Discussions

The use of smart campus technologies has had a positive impact on many aspects of campus life. The advent of these smart campus technologies has ushered our campus into a new era. Marked improvements in productivity, environmental responsibility, and technological sophistication have been observed due to the amalgamation of IoT systems, data analytics, and automation [19,20]. Our campus is now a more productive, environmentally friendly, and technologically sophisticated environment thanks to the integration of IoT systems, data analytics, and automation. The main outcomes and effects of this change are outlined below

7. Conclusion

Significant gains in energy efficiency, student experiences, safety, data-driven decision-making, and environmental sustainability have been made as a result of our journey towards a smart campus. We've had outstanding results thanks to automation, data analytics, and IoT integration While enhancing student access control and classrooms, we have decreased energy expenses and our environmental impact. Our safety precautions, such as emergency alerts and surveillance, put the welfare of our campus community first. Environmental monitoring has fostered healthier interior conditions and economical waste management, while data-driven decisions have simplified operations. As we go forward, our dedication to innovation and development motivates us to investigate fresh options and make use of data insights for an improved campus environment. Our campus is evolving in a dynamic way to ensure quality in education, safety, and environmental stewardship while also assuring efficiency, sustainability, and sustainability.

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