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SMART NOISE POLLUTION MANAGEMENT USING AWS IOT CORE AND CLOUD INTEGRATION

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Abstract. Urban and rail transport noise pollution is an increasing concern due to its negative impact on public health, including cardiovascular diseases, sleep disturbances, and cognitive impairments (WHO, 2018). Traditional noise monitoring systems, which rely on static measurements, lack real-time adaptability and struggle to accurately classify noise sources in dynamic environments. This study explores the application of AWS IoT Core in smart acoustic monitoring systems to enhance noise detection, classification, and mitigation.

By integrating AWS IoT Core with advanced noise sensors and spectrum analyzers, real-time noise data can be securely transmitted, processed, and analyzed in the cloud. AWS IoT Core enables continuous data collection and facilitates predictive modeling, improving noise classification accuracy and supporting proactive noise reduction strategies. The study focuses on leveraging AWS IoT Core for real-time noise monitoring, automated noise classification, and data-driven urban planning, ensuring more effective and scalable noise management solutions.

Furthermore, AWS IoT Core's ability to connect and manage thousands of IoT-enabled noise monitoring devices provides a foundation for smart city infrastructure. The research highlights key challenges and opportunities in integrating cloud-based noise monitoring systems, emphasizing the role of AWS IoT Core in optimizing urban noise management, improving public health outcomes, and supporting sustainable city development. Through adaptive noise mitigation strategies and enhanced decision-making, AWS IoT Core offers a scalable and efficient approach to addressing noise pollution in modern urban environments.

Keywords: noise monitoring, AWS, machine learning acoustics, urban noise, rail noise, smart city acoustics, spectrum analysis, noise mitigation.

Introduction

Noise pollution in urban areas and rail transport corridors is a critical environmental challenge, with prolonged exposure linked to cardiovascular diseases, hypertension, sleep disturbances, and cognitive decline (WHO, 2018). Rail noise, often exceeding 85 dB(A), poses significant long-term health risks (European Environment Agency, 2020). Traditional noise monitoring systems rely on static measurements, limiting real-time adaptability and predictive capabilities.

AWS IoT Core provides a scalable and cloud-based solution for real-time acoustic monitoring, enabling seamless connectivity between noise sensors, spectrum analyzers, and cloud computing resources. By leveraging AWS IoT Core's secure device communication and data processing capabilities, noise monitoring systems can collect, transmit, and analyze environmental noise in real time. This allows for improved detection, localization, and classification of noise sources, facilitating adaptive mitigation strategies.

AWS IoT provides the cloud services that connect your IoT devices to other devices and AWS cloud services. AWS IoT provides device software that can help you integrate your IoT devices into AWS IoT-based solutions. If your devices can connect to AWS IoT, AWS IoT can connect them to the cloud services that AWS provides [1].

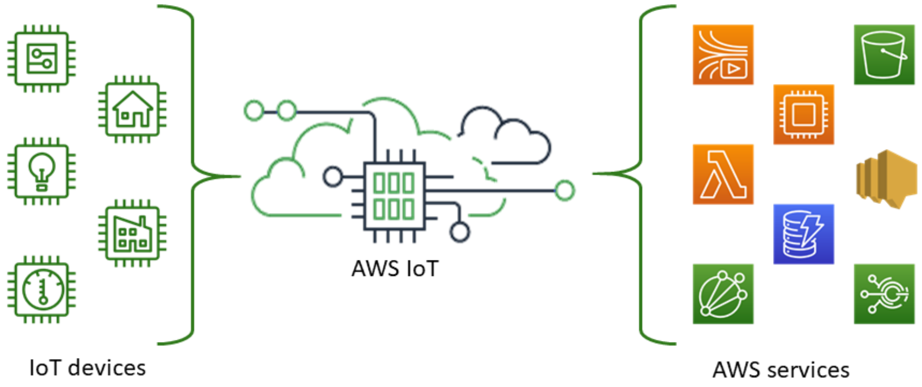

Fig. 1. AWS IoT [1]

AWS IoT enables you to choose the most up-to-date and suitable technologies for your solution. To facilitate the management and support of IoT devices in the field, AWS IoT Core supports the following protocols [1]:

- MQTT (Message Queuing and Telemetry Transport)
- MQTT over WSS (WebSockets Secure)
- HTTPS (Hypertext Transfer Protocol Secure)
- LoRaWAN (Long Range Wide Area Network)

The AWS IoT Core message broker allows devices and clients using MQTT and MQTT over WSS to publish and subscribe to messages. Additionally, devices and clients utilizing HTTPS can publish messages through the platform [1].

This paper explores the role of AWS IoT Core in enhancing smart acoustic monitoring for urban and rail environments, focusing on real-time data processing, cloud-based analytics, and integration with smart city infrastructure.

Problem Statement

As cities expand and rail transport systems grow, noise pollution continues to escalate, posing serious risks to public health and environmental quality. According to the World Health Organization (WHO, 2018), prolonged exposure to noise levels exceeding 55 dB(A) significantly increases the likelihood of cardiovascular diseases, sleep disorders, and cognitive impairments. Rail noise, often surpassing 85 dB(A), further intensifies these health concerns (European Environment Agency, 2020).

Traditional noise monitoring methods rely on static, manual data collection, limiting their ability to provide real-time insights or predictive assessments. These conventional approaches struggle to capture the complexities of urban environments, where noise propagation is influenced by variables such as building structures, weather conditions, and transport infrastructure. The lack of dynamic noise mitigation strategies results in inefficient noise reduction efforts.

AWS IoT Core offers a scalable and cloud-connected solution for real-time acoustic monitoring. By enabling seamless data transmission from IoT-enabled noise sensors and spectrum analyzers, AWS IoT Core allows continuous noise tracking, instant data processing, and cloud-based analytics. This enhances the accuracy of noise classification, enables predictive noise modeling, and facilitates adaptive noise control measures.

This study explores the role of AWS IoT Core in modernizing noise monitoring systems, focusing on its applications in data collection, cloud integration, and real-time analysis for urban and rail environments. It highlights the potential benefits of AWS IoT Core in improving monitoring efficiency, optimizing noise mitigation strategies, and supporting future smart city initiatives.

Review of Modern Information Sources on the Subject of the Paper

Recent research highlights the growing impact of noise pollution from urban and rail transport, with studies showing that prolonged exposure to noise above 55 dB(A) increases the risk of cardiovascular diseases and cognitive decline. The European Environment Agency [2] reports that rail noise often exceeds 85 dB(A), significantly contributing to urban noise pollution. Advancements in AI and machine learning have improved noise monitoring accuracy by up to 30% compared to traditional methods [3]. Spectrum analysis techniques, such as those used in the SVAN 958A analyzer, enhance noise source identification and propagation modeling [4]. Smart city projects are integrating AI-driven acoustic monitoring for real-time noise management, as noted in the Journal of Environmental Management [5].

Microgrid (MG) technologies [6] are becoming essential for integrating renewable energy into power systems. However, the variable nature of renewable energy creates challenges in forecasting and system stability. Studies [6] show that AWS IoT Analytics significantly improves MG operations by enhancing real-time forecasting and optimizing power distribution. A two-stage stochastic optimization, using the Sample Average Approximation (SAA) algorithm, reduced operational costs by up to 7.6% during power outages and 5.9% with changing generator capacities. Real-time IoT-based forecasting also improved optimization performance, reducing gaps by 7.7% and computational time by 3.6% compared to traditional methods. These results highlight the potential of AI-driven analytics for optimizing systems like energy management and noise monitoring. However, challenges remain in refining predictive models, ensuring real-time adaptability, and integrating AI solutions into existing infrastructure. Further research is needed to enhance data accuracy, scalability, and cost-effective implementation.

Recent research [7] highlights the potential of IoT for real-time noise monitoring in urban and rail environments. A multi-agent system (MASAI) based on the AWS IoT platform can manage and analyze audio data from sound sensors, generate notifications, and ensure secure data transmission. This system improves noise monitoring accuracy and scalability, offering a real-time solution for urban noise pollution. However, challenges remain in system efficiency, security, and integration with existing infrastructure. This work [8] presents a novel approach to noise monitoring by integrating the Spectrum Analyzer SVAN 958A with IoT and machine learning technologies. The system addresses the limitations of traditional methods by enhancing real-time data accuracy and scalability, achieving up to a 35% improvement in signal differentiation. It allows for precise identification of noise sources and enables quick responses to noise pollution. Real-time visualization tools assist in decision-making and regulatory compliance. The research [8] demonstrates the system's potential for environmental noise monitoring and its application in smart city frameworks, offering opportunities for future development in advanced acoustic analytics.

This article [9] explores the IoT application in industrial settings, emphasizing the importance of architecture and cloud computing in developing IoT solutions. It introduces the concept of Industrial IoT (IIoT) and presents a case study on using AWS Machine Learning to predict chamfer lengths in deburring processes. The study includes an overview of the experimental setup and the practical steps for integrating AML into industrial workflows. This paper [10] explores two methods for monitoring air quality in urban environments, addressing the growing concerns of air pollution and its impact on health. The 1 method utilizes AWS cloud with a microcontroller and sensor, while the 2 method employs Arduino with a Wi-Fi module and sensor to measure pollutant levels and track air quality in a specific area. Both approaches aim to provide efficient solutions for real-time environmental monitoring. This work [11] introduces a cyber-physical system for acoustic monitoring in Lima, aimed at notifying users when noise levels reach unsafe thresholds. It outlines the design of sensor nodes, gateways, and a robust software framework for scalable data analysis. A prototype is also developed to validate the system's functionality, ensuring accurate sound sensor data integration.

Despite these advancements, challenges persist in optimizing AI models for dynamic urban environments, ensuring real-time responsiveness, and integrating them with existing infrastructure. Further research is needed to improve data accuracy, scalability, and cost-effective implementation of IoT cloud solutions.

Main Material Presentation

Noise pollution from urban environments and rail transport systems poses significant challenges to public health and environmental sustainability. Traditional noise monitoring methods, which rely on static sensors and manual data analysis, often lack real-time adaptability and fail to capture the dynamic nature of noise propagation in complex urban and transport settings. A more effective approach involves leveraging cloud-based IoT solutions to enable continuous, scalable, and intelligent noise monitoring.

AWS IoT Core provides a robust infrastructure for real-time acoustic data collection, processing, and analysis. By integrating AWS IoT Core with noise sensors and spectrum analyzers such as the SVAN 958A, monitoring systems can transmit high-frequency noise data to the cloud for instant processing. AWS IoT Core's secure, scalable architecture supports real-time data streaming, enabling precise noise classification, source localization, and trend analysis.

One of the key advantages of AWS IoT Core is its ability to facilitate predictive noise modeling through seamless cloud connectivity. By aggregating data from distributed sensors across urban and rail environments, AWS IoT Core allows for dynamic adaptation of noise mitigation strategies based on environmental variables such as traffic patterns, weather conditions, and infrastructure changes. This capability enhances urban planning efforts, enabling authorities to implement proactive noise control policies before critical thresholds are exceeded.

Additionally, AWS IoT Core enhances the scalability and efficiency of noise monitoring networks. Its integration with other AWS services, such as AWS Lambda for serverless computing and Amazon S3 for long-term data storage, ensures cost-effective deployment and maintenance. Secure communication protocols like MQTT and HTTPS ensure reliable data transmission, addressing concerns related to system security and data privacy.

Despite the advantages of cloud-connected noise monitoring systems, challenges remain in optimizing real-time data processing, ensuring seamless integration with legacy infrastructure, and managing large-scale deployments in urban environments. This article explores the application of AWS IoT Core in noise monitoring, evaluates its effectiveness in smart city and rail transport contexts, and identifies key areas for future development in intelligent noise management solutions.

The proposed system consists of several interconnected layers:

- Data acquisition layer: A peripheral device (Raspberry Pi) records acoustic signals in an urban environment.
- Data transmission layer: The MQTT protocol is used for efficient data transmission to AWS IoT Core.
- Data processing layer: AWS Lambda processes audio files, extracts acoustic features, and transmits them to the AWS RDS database.
- Data storage layer: Amazon S3 is used for long-term storage of original audio recordings.
- Analytics and visualization layer: Grafana provides monitoring and analytical representation of acoustic data.

Raspberry Pi do function of recording and preprocessing audio signals before transmitting them to the cloud.

Characteristics:

- Utilization of a microphone module to record sound data.
- Basic signal processing (normalization, noise reduction).
- Data transmission via MQTT to minimize latency.

AWS IoT Core – Processing Incoming MQTT Messages. AWS IoT Core receiving, routing, and pre-filtering audio data from peripheral devices.

Characteristics:

- Scalable operation with IoT devices.
- High-level security through device certification.
- Automatic forwarding of received messages to AWS Lambda.

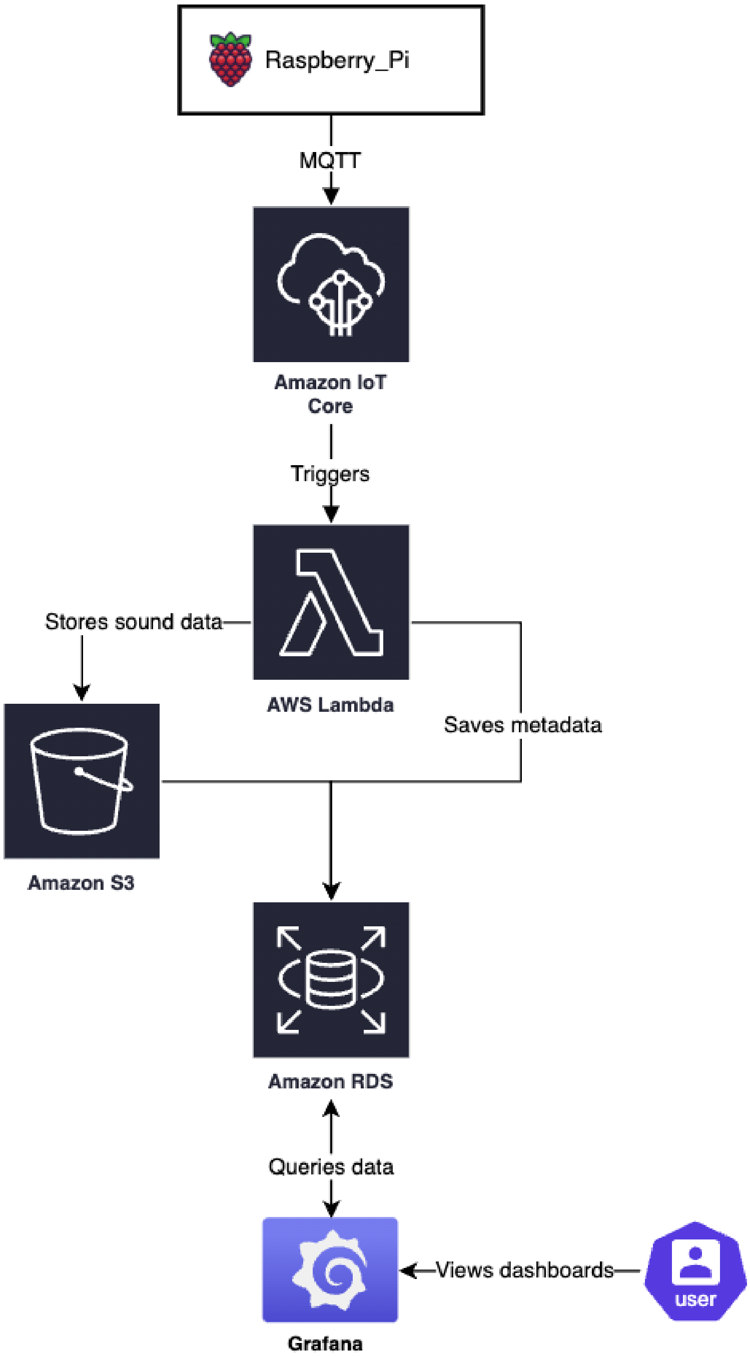

Fig. 2. System Architecture Scheme

AWS Lambda – Acoustic Feature Extraction and Noise Classification AWS Lambda make serverless processing of real-time data using ML algorithms.

Code block example:

```
import librosa
import numpy as npp
def extract_features(audio_path):
  y, sr = librosa.load(audio_path, sr=44100)
  mfccs = librosa.feature.mfcc(y=y, sr=sr, n_mfcc=13)
  return npp.mean(mfccs, axis=1)
```

Characteristics:

- Use of the librosa library for feature extraction (MFCC, spectral centroid).
- Implementation of a pre-trained neural network for noise source classification.
- Automatic transmission of processed data to the AWS RDS database.

Amazon S3 – Long-Term Storage of audio files which archiving audio recordings for further model training.

Characteristics:

- Low-cost, scalable storage for large data volumes.
- Capability of streaming data through AWS Lambda.

AWS RDS – Storing Analysis Results
Function: Database for storing classified noise events.

Table example:

```
CREATE TABLE NoiseData (
  id SERIAL PRIMARY KEY,
  timestamp TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
  noise_type VARCHAR(50),
  intensity FLOAT,
  tram_type VARCHAR(50),
  duration_sec INT,
  location VARCHAR(255)
);
```

Characteristics:

- Use of PostgreSQL for efficient storage and query processing.
- Support for automatic scaling under load.

Grafana – Analytical Interface which visualizing noise pollution levels in real-time.

Characteristics:

- Building interactive graphs from AWS RDS data.
- Analyzing noise pollution trends and identifying problematic areas.

Conclusions

The integration of AWS IoT Core into noise monitoring systems represents a major step forward in addressing urban and rail transport noise pollution. By enabling real-time data collection, secure transmission, and cloud-based processing, AWS IoT Core enhances the accuracy of noise detection, classification, and predictive modeling—capabilities that traditional monitoring methods lack. The combination of advanced spectrum analyzers with AWS IoT Core facilitates high-precision noise mapping and adaptive, data-driven mitigation strategies.

The ability of AWS IoT Core to support large-scale IoT networks allows for real-time monitoring and predictive noise management, aligning with smart city initiatives. This not only improves noise classification accuracy but also enables urban planners to design more effective noise control measures, such as optimized rail track layouts and strategically placed noise barriers. Such proactive approaches contribute to public health improvements by mitigating noise pollution before it reaches harmful levels.

Despite its advantages, several challenges remain. These include optimizing real-time data processing, addressing data privacy and security concerns, and ensuring the scalability and cost-effectiveness of cloud-connected noise monitoring systems for large-scale deployment. Further research is needed to refine integration strategies, enhance system efficiency, and develop solutions that seamlessly connect AWS IoT Core with existing infrastructure.

In conclusion, AWS IoT Core offers a scalable and efficient framework for modern noise monitoring, enabling real-time insights, predictive analytics, and data-driven noise control strategies.

While challenges exist, continued advancements in cloud computing and IoT technology will further enhance the role of AWS IoT Core in improving urban environmental quality and public health.

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РОЗУМНЕ КЕРУВАННЯ ШУМОВИМ ЗАБРУДНЕННЯМ З ВИКОРИСТАННЯМ AWS IOT CORE ТА ХМАРНОЇ ІНТЕГРАЦІЇ

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Анотація. Шумове забруднення від міського та залізничного транспорту стає все більшою проблемою через його негативний вплив на здоров'я населення, зокрема на серцево-судинні захворювання, порушення сну та когнітивні розлади (ВООЗ, 2018). Традиційні системи моніторингу шуму, що ґрунтуються на статичних вимірюваннях, не мають здатності до адаптації в реальному часі і мають труднощі з точним класифікуванням джерел шуму в динамічних умовах. У цьому дослідженні розглядається застосування AWS IoT Core у розумних системах акустичного моніторингу для покращення виявлення шуму, його класифікації та зменшення рівня шумового забруднення.

Інтеграція AWS IoT Core з передовими шумовими сенсорами та спектральними аналізаторами дозволяє безпечно передавати, обробляти та аналізувати дані про шум у хмарі в реальному часі. AWS IoT Core забезпечує безперервне збирання даних та підтримує створення прогнозованих моделей, покращуючи точність класифікації шуму та сприяючи проактивним стратегіям зниження шуму. Дослідження зосереджене на використанні AWS IoT Core для моніторингу шуму в реальному часі, автоматизованої класифікації шуму та планування міської інфраструктури на основі даних, що дозволяє створити більш ефективні та масштабовані рішення для управління шумовим забрудненням.

Крім того, здатність AWS IoT Core підключати та керувати тисячами пристроїв для моніторингу шуму, що працюють на основі Інтернету речей, створює основу для розумної міської інфраструктури. У дослідженні підкреслюються основні виклики та можливості інтеграції хмарних систем моніторингу шуму, зокрема роль AWS IoT Core у оптимізації управління міським шумом, поліпшенні здоров'я населення та підтримці сталого розвитку міст. Завдяки адаптивним стратегіям зменшення шуму та покращеному процесу ухвалення рішень, AWS IoT Core пропонує масштабований та ефективний підхід до вирішення проблеми шумового забруднення в сучасних міських умовах.

Ключові слова: моніторинг шуму, AWS, машинне навчання акустика, міський шум, залізничний шум, розумна акустика міста, спектральний аналіз, пом’якшення шуму.