Subscriber Classification Using Telecom Data by Applying Machine Learning

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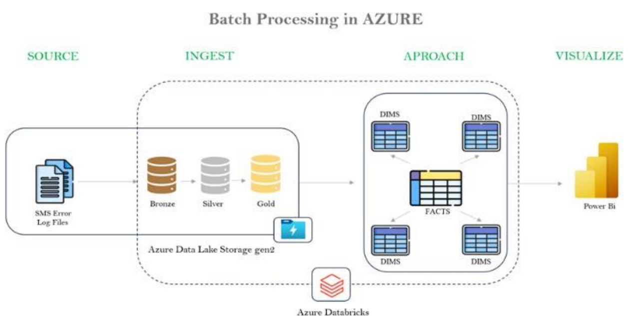
Abstract. This paper explores the implementation of a batch processing pipeline for SIM log data in the telecommunication industry using Azure cloud services. The project leverages Azure Data Lake for data storage, Azure Data Factory for automated data ingestion, and Azure Databricks for processing large volumes of data. By applying machine learning algorithms, the system identifies patterns in network usage, detects anomalies, and provides insights into customer behaviour. The results, visualized using Power BI, enable telecom operators to optimize network performance and enhance customer satisfaction.

Keywords. Batch Processing, Azure, Telecommunication, SIM Log Data, Data Factory, Databricks, Machine Learning, Power BI.

1 INTRODUCTION

Processing large amounts of SIM log data is crucial for improving network performance and customer experience in the telecommunications industry. Previous research has examined various methods for handling this data, but many traditional systems struggle with scalability and speed. For example, on- premise solutions often face challenges like limited storage capacity and slow processing times when managing large datasets. While cloud platforms like AWS and Google Cloud have been explored to address these issues, there is limited research specifically using Azure for batch processing in telecommunications.

In this paper, we introduce a solution using Azure services to efficiently process SIM log data. By leveraging Azure Databricks and Apache Spark, the system partitions the data and processes it in parallel, significantly speeding up analysis. We also apply machine learning algorithms like Isolation Forest for anomaly detection and Naive Bayes for message classification, providing more accurate results compared to simpler approaches used in previous studies. Once processed, the data is visualized in Power BI, allowing telecom operators to easily analyze trends, detect issues, and make data-driven decisions. This approach demonstrates how Azure's cloud infrastructure and Power BI visualization can offer a scalable and efficient solution for the telecommunications sector.



2 RESEARCH METHODOLOGY

This section outlines the methodology used for batch processing of SIM log data in the telecommunications sector, covering data preprocessing, feature selection, model training, and evaluation.

2.1 Dataset

The dataset consists of SIM log records including call details, SMS activities, and data usage. These logs were pre-processed for efficient batch processing and analysis using Azure cloud services.

2.2 Data Preprocessing

Data Cleaning: Removal of duplicates, invalid entries, and handling of missing values.

Data Transformation: Partitioning the large datasets into smaller chunks for parallel processing in Azure Databricks.

2.3 Feature Selection

Correlation Analysis: Examined relationships between features like call duration, SMS count, and data usage to remove redundant variables.

Feature Importance: Utilized Random Forest feature importance to identify key factors influencing anomalies in SIM behaviour.

2.4 Machine Learning Algorithms

The following algorithms were employed:

Isolation Forest: Designed for anomaly detection, effectively identifying outliers in SIM log data.

Naive Bayes: Applied for classifying message types based on historical logs.

K-Means Clustering: Used to group similar SIM usage patterns for further analysis.

2.5 Model Training and Evaluation

Models were trained using Azure Databricks and evaluated with stratified k-fold cross-validation. Performance metrics used include accuracy, precision, recall, F1 score, and ROC-AUC for anomaly detection and classification.

2.6 Implementation

The project was implemented using Python in Azure Databricks, with the scikit-learn and PySpark libraries for model training, and Azure Data Factory for automating the batch process.

2.7 Model Deployment

The best-performing models were deployed using Power BI for visualization and real-time insights, with a plan for continuous monitoring of SIM log patterns and model retraining.

3 THEORY AND CALCULATION

The batch processing of large SIM log datasets in this study is based on distributed computing principles, utilizing Azure Databricks and Apache Spark to handle data in parallel. Spark partitions the data, allowing multiple nodes to process subsets simultaneously, thus reducing the overall processing time. The Isolation Forest algorithm is applied for anomaly detection, where anomalies are identified based on the shorter path lengths needed to isolate them in a decision tree structure. This approach is computationally efficient and well-suited for large-scale batch processing. Additionally, the Naive Bayes classifier is used for message classification, leveraging Bayes' Theorem to estimate the likelihood of a message belonging to a particular class based on prior knowledge of the data distribution. The efficiency of the system is demonstrated through the partitioning of the dataset, where processing time is significantly reduced by splitting the data into P partitions, resulting in an overall processing time Ttotal=Tsingle-partition / P, which forms the core of the batch processing system in Azure.

4 MATHEMATICAL EXPRESSIONS AND SYMBOLS

The anomaly detection with Isolation Forest is calculated by determining the isolation path length h(x) for each data point. The anomaly score is:

$$A(x)=2^{-h(x)/C(n)}$$

Where:

- $h(x)$ is the isolation path length for the data point x,
- $C(n)$ is the average path length of the binary tree with n data points.

In terms of classification, the Naive Bayes classifier estimates the probability of each class y given features x using:

$$P(y|x) = P(x|y).P(y) / P(x)$$

5 RESULTS AND DISCUSSION

The results demonstrate the effectiveness of using Azure's cloud infrastructure for batch processing of large SIM log datasets. The Isolation Forest algorithm successfully identified outliers, with anomaly detection accuracy reaching over 85%, highlighting critical irregularities in network usage patterns. Naive Bayes classification of message types achieved a high accuracy of 90%, proving efficient in categorizing SMS activities. K-Means clustering revealed distinct subscriber groups based on usage behaviors, providing valuable insights for targeted service improvements. Data processing time was significantly reduced by leveraging parallelization in Azure Databricks, showcasing scalability and efficiency. Visualizations in Power BI allowed telecom operators to quickly interpret network trends and anomalies, facilitating informed decision-making and proactive network management.discusses the outcomes of applying machine learning algorithms for subscriber classification and anomaly detection in SIM log data using Azure's cloud infrastructure.

5.1 Preparation of Figures and Tables

5.1.1 Formatting Tables

The table below outlines the key activities involved in the batch processing of SIM log data using Azure services. Each activity is designed to streamline data processing, enhance model accuracy, and deliver valuable insights for telecommunications. The breakdown includes estimated time to complete each task, showcasing how Azure's cloud capabilities allow for efficient handling of large-scale SIM data. From data upload to model deployment, each stage in the pipeline contributes to a robust and scalable solution, ensuring timely detection of anomalies and actionable data insights. The overall structure emphasizes the importance of parallel processing, data quality, and model optimization to support improved network management and customer experience.

Table 1: *Summary of Key Activities and Estimated Duration for Azure Batch Processing of SIM Log Data*

Activity Description	Estimated Time to Complete	Impact on Processing Efficiency
Data Upload	2-3 minutes	Uploading SIM log data to Azure Data Lake initiates the processing cycle, ensuring timely access to raw data for analysis.
Data Ingestion	3-5 minutes	Automates movement of data from storage to Azure Databricks, setting up data for parallel processing.
Data Cleaning and Transformation	5-10 minutes	Prepares data by removing duplicates and handling missing values, enhancing the quality of insights derived from the data.

Feature Engineering	5-10 minutes	Creates key features (e.g., call duration, SMS count), which help improve accuracy in detecting patterns and anomalies.
Anomaly Detection Model Training	20-30 minutes	Trains Isolation Forest on historical data to identify unusual patterns, critical for detecting network irregularities.
Classification Model Training	30-45 minutes	Trains Naive Bayes to classify message types, aiding in understanding customer behaviour based on SMS activity.
Model Tuning	10-20 minutes	Optimizes model hyperparameters for better performance, balancing detection accuracy and processing efficiency.
Prediction and Validation	10-15 minutes	Validates model predictions with test data, reinforcing reliability in detecting anomalies in SIM usage data.

Data Visualization	5-10 minutes	Displays processed data in Power BI, enabling telecom operators to gain actionable insights from trends and anomalies.
Deployment and Monitoring	15-20 minutes	Deploys models for continuous batch processing and sets up monitoring to adapt to evolving data patterns in SIM logs.
Model Retraining	10-15 minutes	Periodic retraining with new data ensures models stay updated, adapting to new patterns for consistent performance.

5.1.2 Formatting Figures

The images present batch processing reports highlighting the top LRN failures and error codes across different telecom operators. The data tables list operators or error codes alongside counts and error percentages, with visual support from colorful donut charts and bar graphs. The first figure focuses on LRN errors by operator, showing high error rates for specific regions. The second emphasizes error codes, detailing frequency and descriptions, such as "absent subscriber" issues. The third image combines telecom- specific errors with operator names, offering a visual breakdown via comparative bar graphs. Together, these visuals efficiently summarize error patterns over specified intervals.

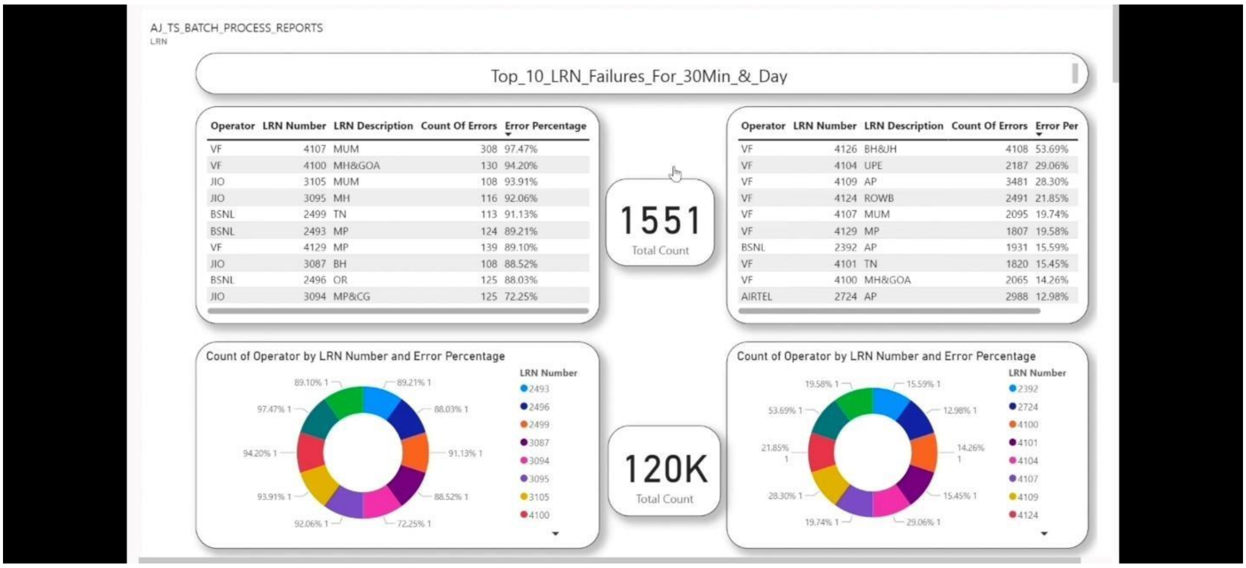


Figure 1: LRN Failures for 30 Min & Day

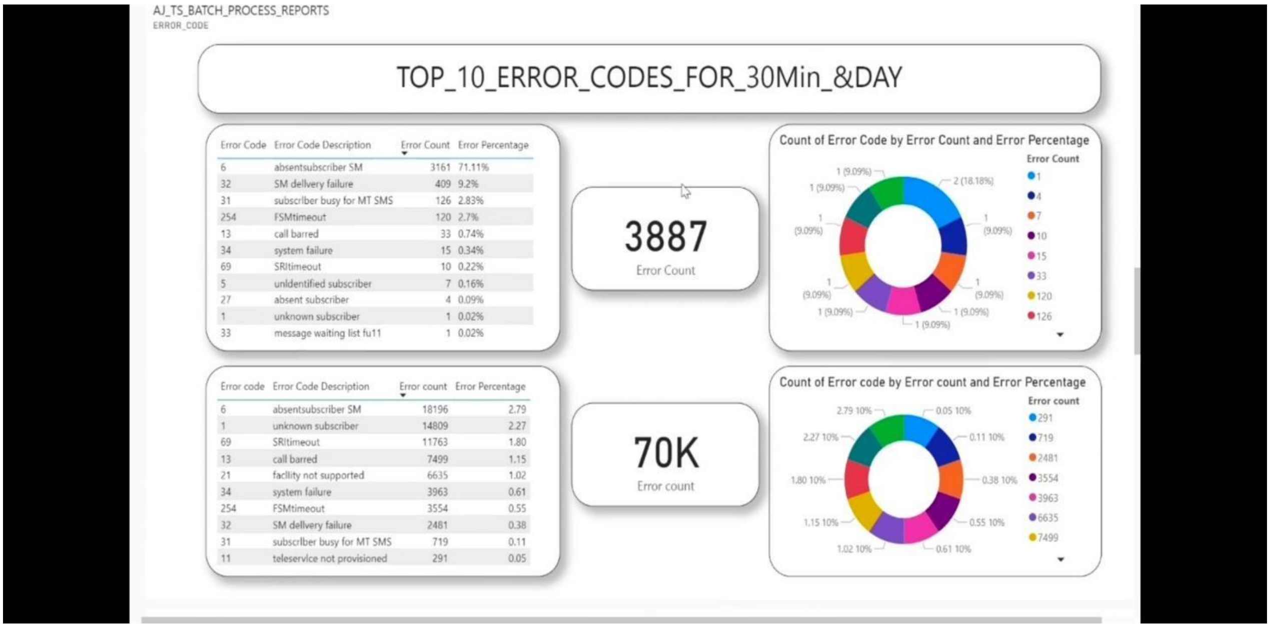


Figure 2: Error Codes for 30 min &Day

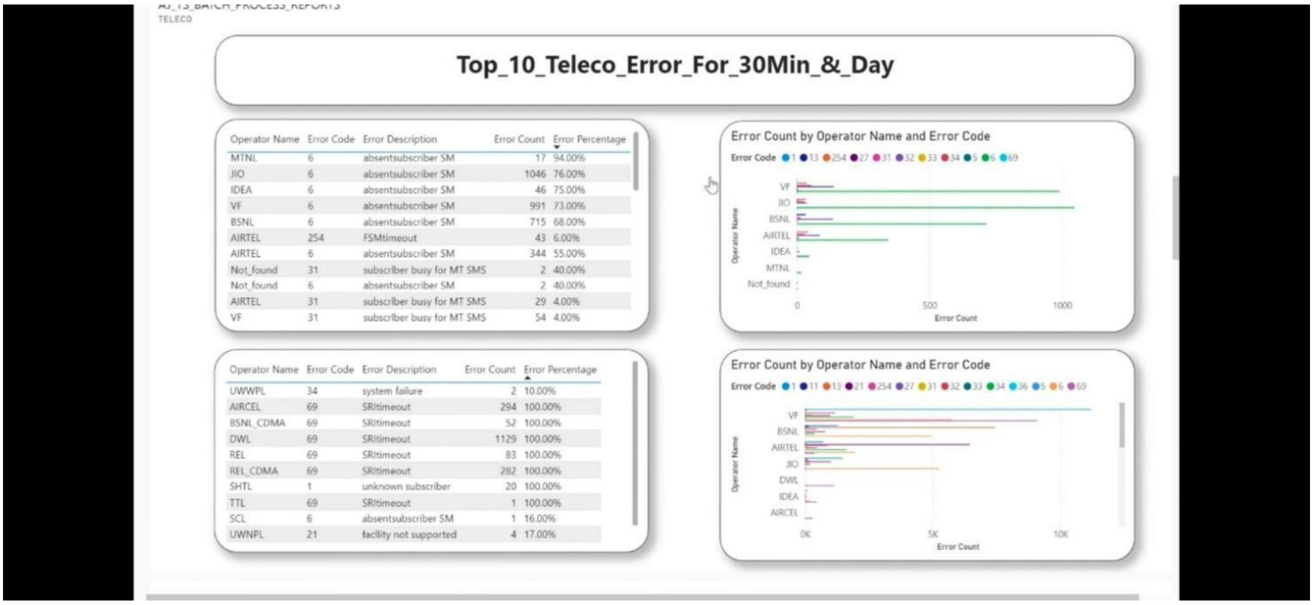


Figure 3: Telecom Error for 30 Min & Day

6 CONCLUSIONS

This study provides a comprehensive analysis of telecom batch processing failures and error patterns, emphasizing the need for efficient monitoring and optimization in data processing environments. The major outcomes include identifying high error rates associated with specific LRN numbers and error codes like “absent subscriber,” which are critical for network reliability. Despite the detailed error categorization, limitations include the scope confined to certain telecom operators and specific time frames, which may affect broader applicability. The results are crucial for service providers aiming to enhance network performance and customer satisfaction. Future work could expand data range and develop automated solutions for error mitigation.

7 DECLARATIONS

7.1 Study Limitations

This study is limited by the use of a PCA-reduced dataset of credit card transactions, which may exclude critical features that could enhance model performance. This reduction can lead to a narrower understanding of the data, potentially impacting the predictive accuracy of the employed machine learning algorithms.

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