**Thesis Outline: Satellite Path Loss Model for Bangladesh Satellite-1**

**Introduction**

**1. Introduction**

This section provides an overview of the importance of **satellite communication and path loss modeling**, particularly for **Bangladesh’s first satellite, Bangabandhu-1**. Path loss due to **atmospheric conditions** is a critical challenge for maintaining stable satellite communication. This research aims to develop and compare **two models**—a **Machine Learning (ML) model** and a **Mathematical model**—for predicting total attenuation.

**2. Motivation**

Accurate attenuation prediction can **reduce the dependency on dummy signals**, improving **efficiency and reducing operational costs** for satellite communication providers like **BCSCL**. The motivation behind this study is to develop a reliable model that ensures **precise attenuation forecasting** without requiring constant monitoring using artificial test signals.

**3. Scope of Work**

The research focuses on **data collection from BCSCL (attenuation data) and BMD (weather data)**, dataset merging, and **developing predictive models** using **Machine Learning (ML) and mathematical approaches**. The scope is limited to **two ground stations (Gazipur and Betbunia)** operating with Bangladesh Satellite-1.

**4. Objective**

* To collect and **analyze attenuation and weather data** for satellite communication.
* To develop and test **two different models** (ML-based and mathematical).
* To **compare** the effectiveness of both models in predicting **total attenuation**.
* To determine whether an **ML model can replace dummy signal testing** in real-world applications.

**Background**

**1. General Path Loss Model**

Path loss represents the **reduction in signal strength** as it propagates through the atmosphere. Various factors like **cloud cover, atmospheric gases, rain, and free-space loss** contribute to total attenuation.

**2. Okumura/Hata Model**

The Okumura-Hata model is an **empirical model** widely used for predicting **terrestrial communication path loss**. While effective for ground-based transmission, its **applicability to satellite links is limited**, making the need for a **specialized satellite-based model** crucial.

**3. IEEE 802.16d Model**

This model, part of the IEEE standards, predicts path loss in **wireless broadband networks**. It incorporates factors like **antenna height, environmental conditions, and frequency-dependent losses**, providing **insights into satellite communication losses**.

**4. Previous Research and Solutions Offered**

Existing studies have explored various **empirical models and machine learning techniques** for path loss prediction. Some research suggests **machine learning offers better accuracy**, but **limited datasets** and **model interpretability** remain challenges.

**Methodology**

**1. ML Model Approach**

The **machine learning model** (Random Forest) is trained using:

* **Input Features:** Weather data (temperature, humidity, pressure, rain rate, cloud thickness, etc.).
* **Target Variable:** **Total attenuation** (sum of cloud, atmospheric, rain, and free-space attenuation).
* The dataset is **preprocessed, encoded, and scaled**, and the model is **trained and tested**.
* **Evaluation Metrics:** Mean Squared Error (MSE), R-squared (R²), Feature Importance Analysis.

**2. Mathematical Model Approach**

A **mathematical model** is formulated based on:

* **Existing empirical formulas** for satellite path loss.
* **Regression-based attenuation calculations**.
* The model incorporates **rain attenuation, gaseous absorption, cloud attenuation, and free-space loss**.

**3. Problems Faced**

* **Data Collection Issues:** Matching weather data with attenuation records **date-wise**.
* **Missing or Noisy Data:** Handling incomplete datasets.
* **Model Complexity:** The **ML model requires significant hyperparameter tuning** to avoid overfitting.
* **Comparison Difficulty:** Since the **mathematical model is deterministic** and **ML model is data-driven**, aligning both for fair comparison is challenging.

**Result Analysis**

**1. Comparison between the two models**

* **Accuracy:** The ML model is evaluated using **R² scores and MSE**, while the mathematical model is tested for **error margins** against real data.
* **Performance:** The **ML model adapts to data** but requires large datasets, whereas the **mathematical model is interpretable but lacks flexibility**.
* **Real-World Feasibility:** If the ML model predicts **near real-world values**, it can be **used as a replacement for dummy signal testing**.

**Conclusion**

**1. Conclusion**

* The study successfully **compared the ML and mathematical models** for predicting satellite path loss.
* The feasibility of **replacing dummy signals with a predictive model** was evaluated.
* Key findings suggest that **ML-based models might outperform traditional mathematical models** in accuracy but require further validation.

**2. Future Work**

* **Expanding the dataset** by including **more ground stations and longer time periods**.
* **Testing deep learning models** (e.g., Neural Networks) for potentially better accuracy.
* **Real-time implementation** with continuous data monitoring for dynamic path loss prediction.