UNIVERSITÄT OSNABRÜCK

Towards a Weather-Based Prediction Model For Starlink Throughput

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Image: https://satellitemap.space/

General Motivation of Prediction Models

Potential link prediction applications

- Schedulers for edge/cloud computing
- Proactive approaches (instead of reactive) for link reconfiguration

High interest in general performance (measurements, simulations)

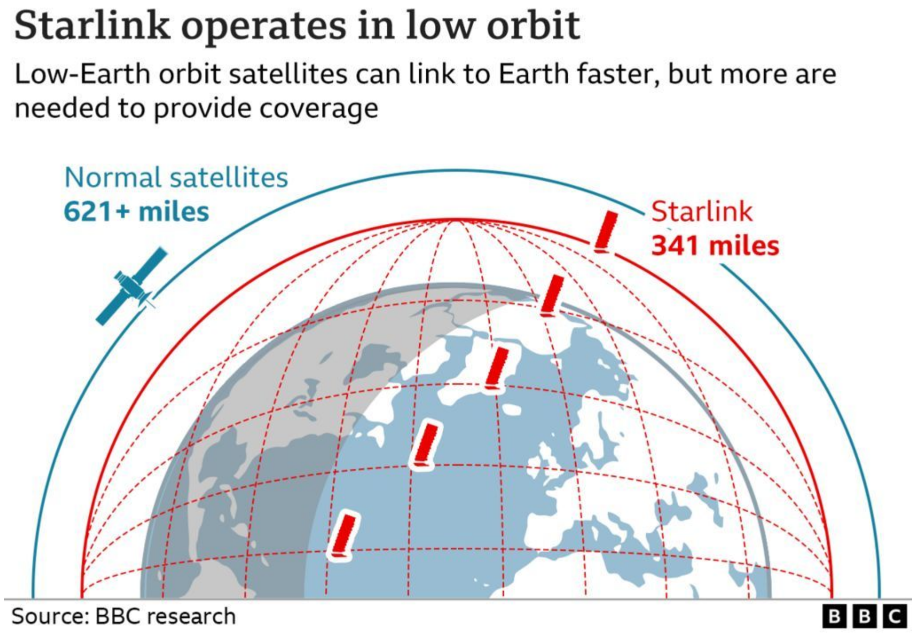
Similar work exists for mobile network performance

[8, 9, 12-15], [4, 10, 11]

Starlink: What's that?

- Rapid expanding collection of Low-Earth-Orbit (LEO) Satellites
- High bandwidth, low latency
    - Inter-Satellite Routing available
- Worldwide consumer level access to the internet

Starlink dish



Why weather-based prediction specifically on Starlink?

Satellite links are generally susceptible to environmental influences

- Space-Events
- Weather-Effects
- Local Environment

Similar work suggest severe impact on performance

- Rain
- Sun flares

[12, 13]

Overview WetLinks Dataset

About 140k datapoints covering network performance

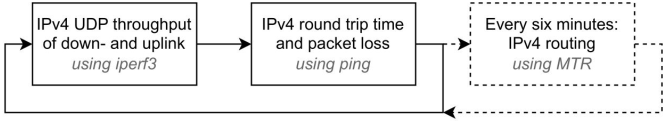
Covers about six months

Supports Deutscher Wetterdienst (DWD) data integration

Represents largest and most complete Starlink dataset to date

Also includes...

- Round-Trip-Time (RTT)
- Packet Loss Rate (PLR)
- Traceroutes
- Weather Data (DWD, on-site)




```
root@vm952:~/collector# ls export
cloud_pictures  cws_sensors.csv  froggit.txt   net_iperf.csv  net_ping.txt         starlink.csv
cws_clouds.csv  cws_sensors.txt  metadata.csv  net_iperf.txt  net_traceroute.csv   starlink.txt
cws_clouds.txt  froggit.csv      metadata.txt  net_ping.csv   net_traceroute.txt
```

[12]

Uni Twente

Uni Osnabrück

WetLinks in our context

Which sides were used?

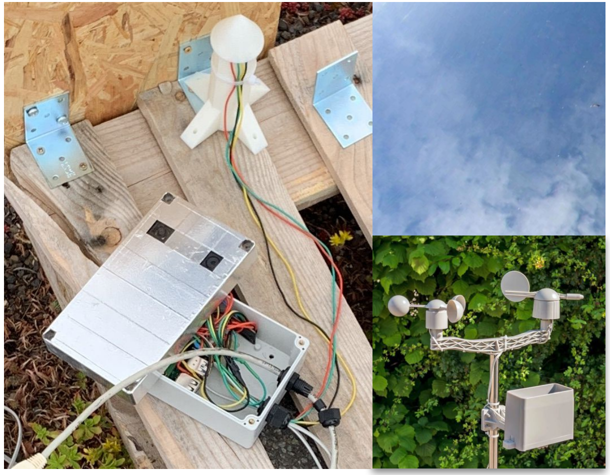
- University of Osnabrück
- DWD
- Cloud-Pictures on-site

Time coverage? 4 months.

Utilized features from the dataset

- Environment data (temperature, wind, pressure)
- Cloud information and rain (extended by DWD)
- Image statistics (color channel details)

DWD Data



Custom Weather Station with Sky Camera

[12]

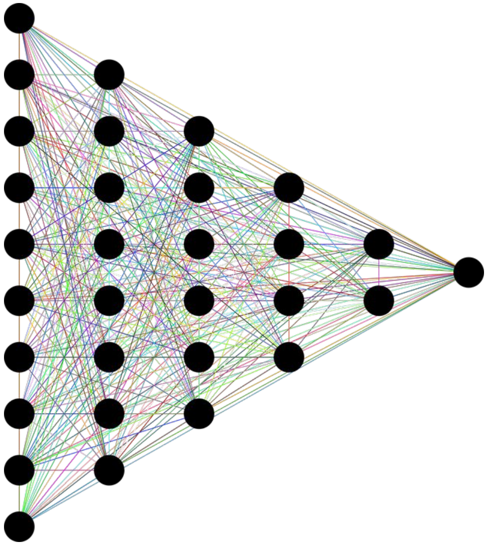
Methodology: Pre-Processing and Models

Pre-processing of dataset

- Started with >500k datapoints in different locations
- Completed with about 1.1k datapoints in one dataset

Models (primarily decision trees)

- Random Forest
- Gradient Boosting
- AdaBoost
- K-nearest-Neighbor
- MTR-Regressor
- (Dummy Regressor)



[3, 16, 7, 5, 17]

Methodology: Evaluation and Tuning

Metrics

- **R^2** "How well does it fit?"
- **Mean Absolute Error (MAE)** "Mean average absolute error?"
- **Root Mean Squared Error (RMSE)** "Square root of errors squared?"

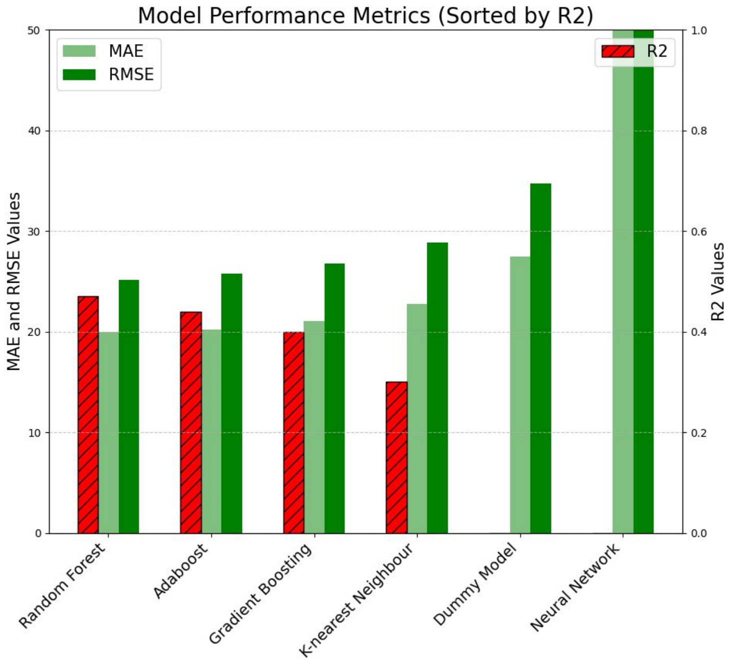
Groups and Training-Subsets

Fine-Tuning via Grid Search

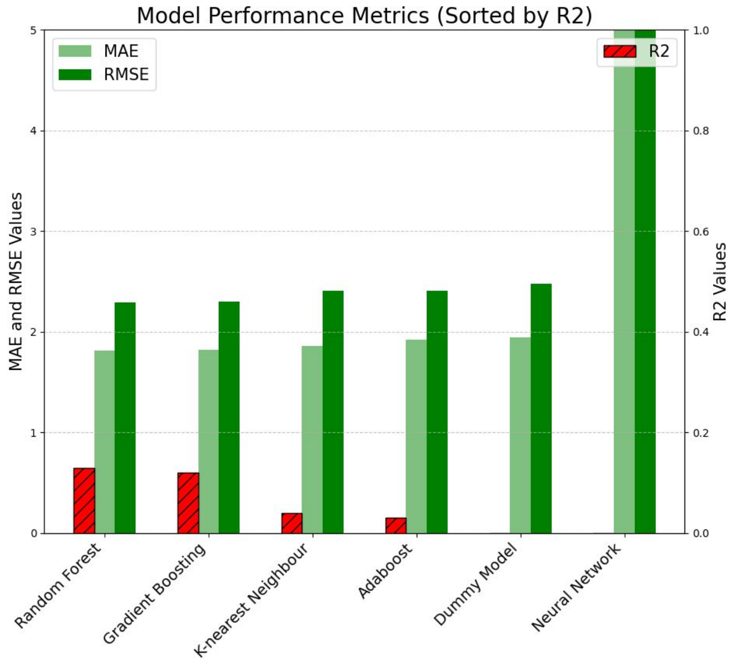
- Max-Features
- Min-/Max- Samples per split
- Estimators

[1, 2]

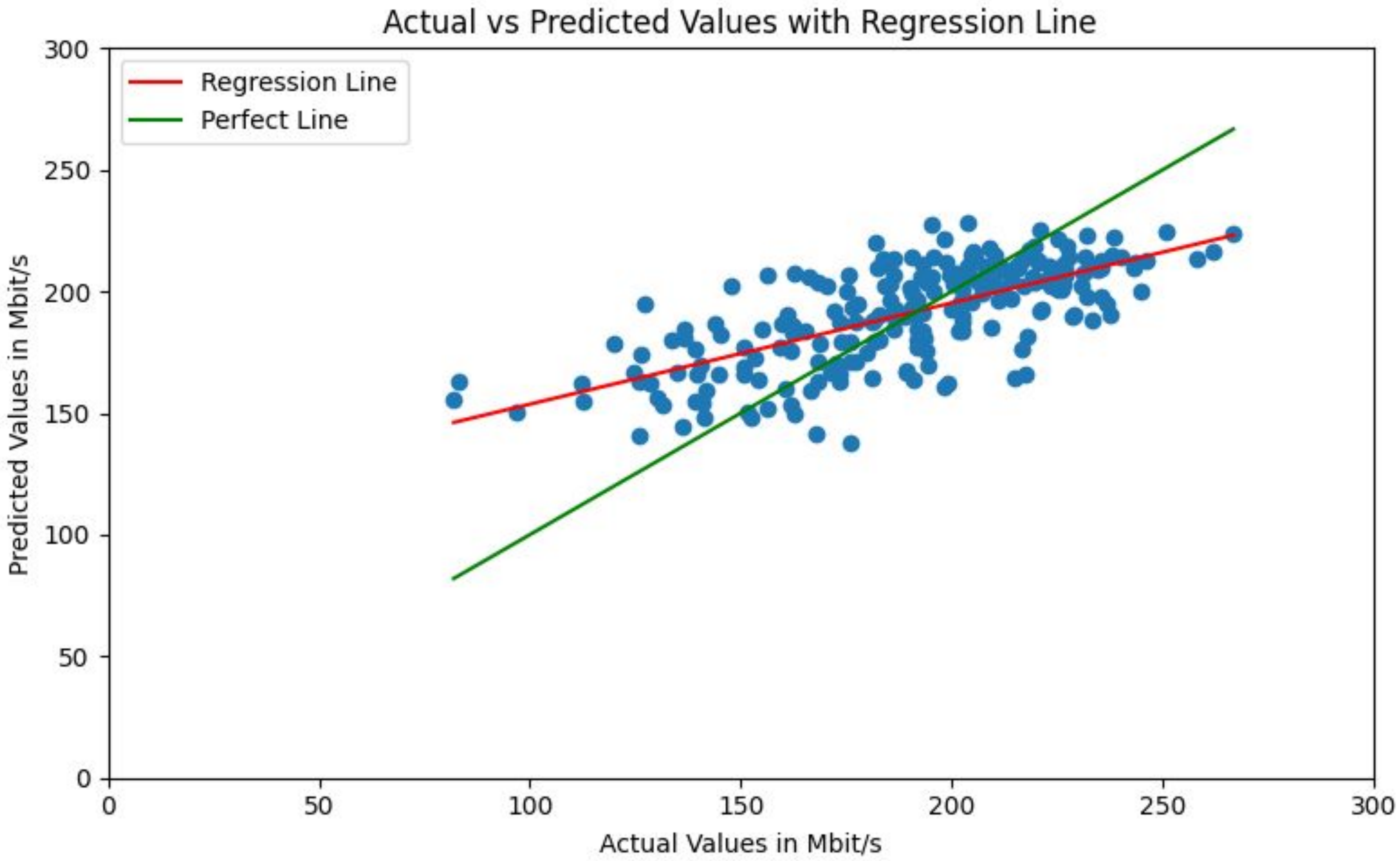
Prediction Results: MAE, RSME and R^2



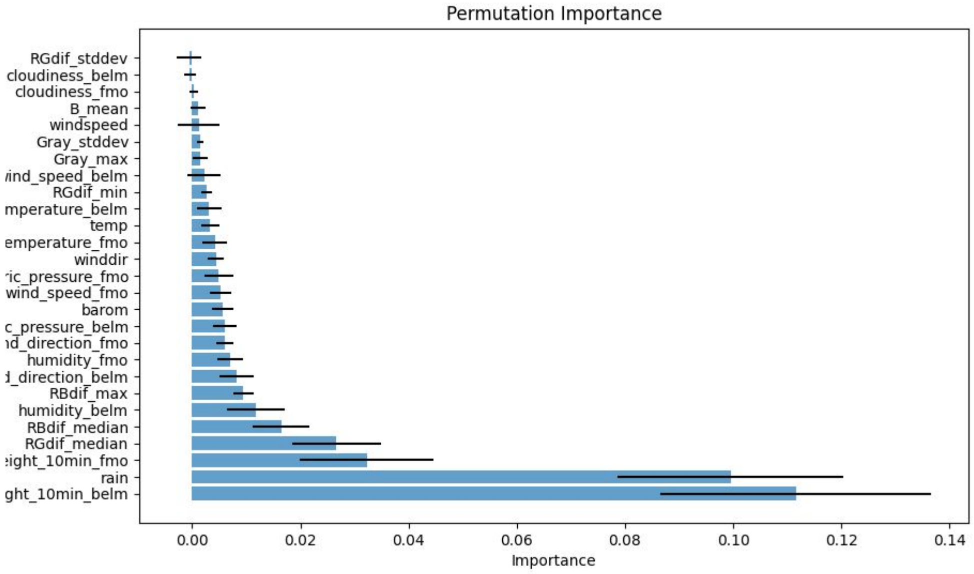
Download

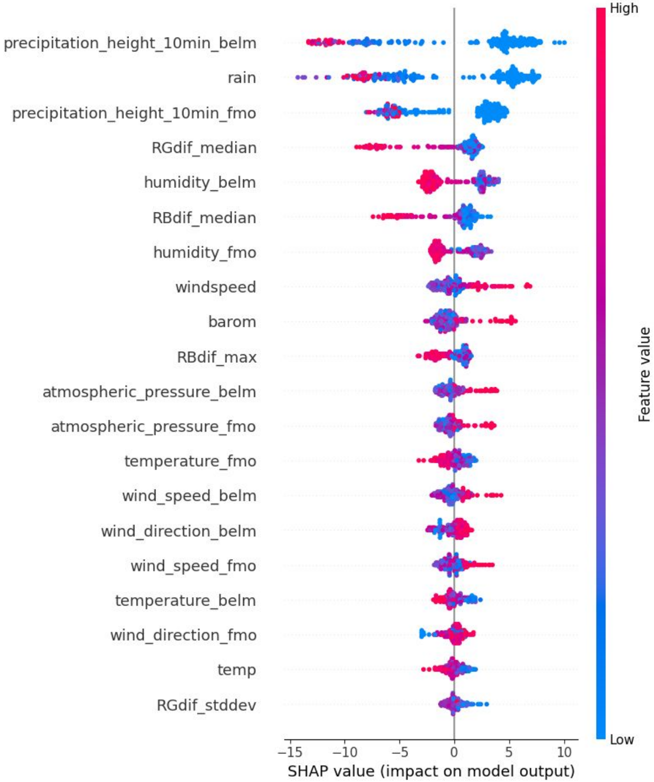


Upload


Actual vs Predicted Values with Regression Line
Regression Line
Perfect Line
Predicted Values in Mbit/s
Actual Values in Mbit/s
0
50
100
150
200
250
300

Prediction Results: Feature Importance





Results in context of other works

Mobile Network Prediction: What did they do?

- Our R^2 is similar around 0.5[1] for ensemble methods
- They also utilized Support-Vector-Machines and Gaussian-Process-Regression, which yielded in better scores (around 0.65)

What can we tell about our result quality?

- Achieved similar performance with comparable models
- More data is needed (requiring a bigger dataset)
- Other models should be explored

[1]This is comparing their prediction, based on signal strength (db), with our throughput prediction (MB/s)

[6]

Conclusion

Able to reproduce similar prediction performance on download throughput

- Rain is the most important feature (as expected)
- Cloudiness seems to be less important, but image statistics suggest otherwise

Upload throughput does not seem to be impacted by weather-conditions

More complete dataset will prove useful

- we saw 20% improvement by adding just one more month (from 3 months)

Neural Networks did not converge on our data

[9, 12, 13]

Future Work

Reduced amount of models were used due to quick turnarounds needed

- Reference work suggest better predictions with highly increased training resources

Further parameter tuning is recommended (due to more accessible data)

More in depths Dataset-/Prediction-Model demo:

At IFIP Networking 2024 in Greece

...and here 😉