ITAI 4370 Final Portfolio

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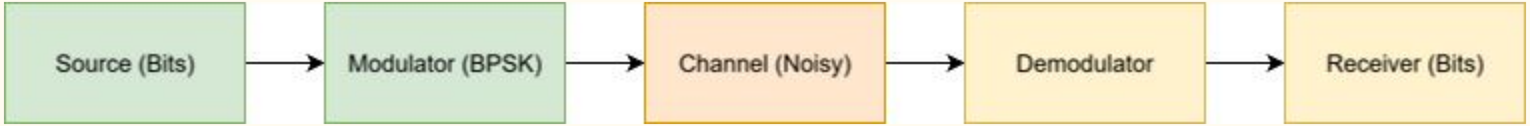
Module 01

In Module 01, I was introduced to fundamental telecommunications network concepts such as what they are, their basic components, the difference between analog and digital telecoms systems, the types of information transmitted by telecoms networks, and their various topologies.

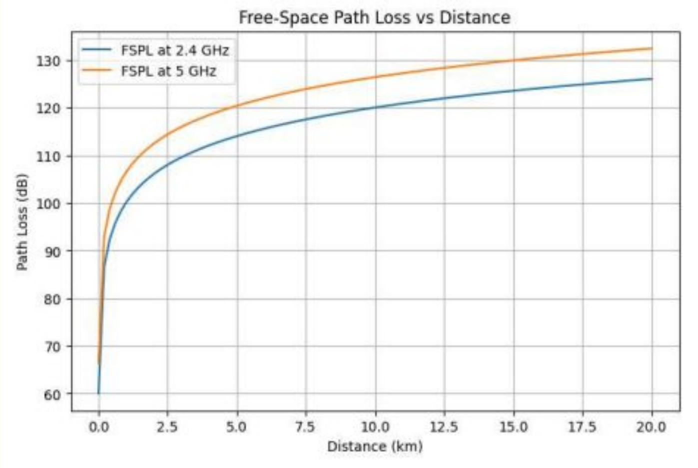
My activities for this module included creating a diagram representing the general structure of telecoms networks (seen in image) and simulated a telecoms transmission using Python code including the system parameters, source bit generation, modulation, and denoising.



Module 02

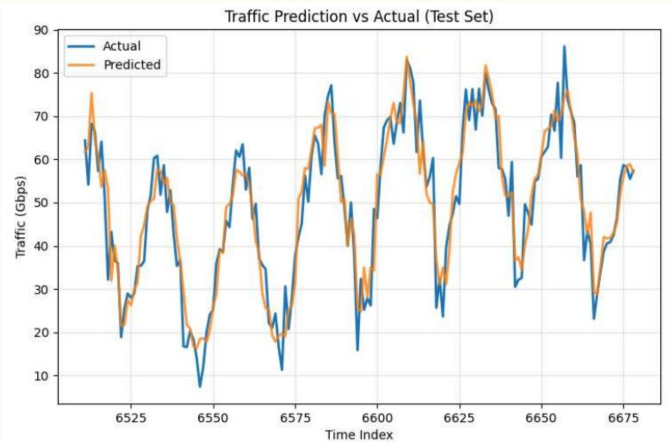
In Module 02, I learned about the Open Systems Interconnection (OSI) model of network communication including its 7 layers: Application, Presentation, Session, Transport, Network, Data Link, and Physical.

Additionally, I learned about wireless network concepts including the evolution from 1G to 6G. I learned the practical application of Radio Frequency (RF) propagation and how it is affected by Free-Space Path Loss (FSPL) with a Python simulation and saw how Wireshark can be used to capture wireless network processes.



Module 03

In this module, I revisited the different types of Machine Learning (ML) including Supervised, Unsupervised, and Reinforcement Learning training methods and how telecoms applications use various ML models such as Random Forest, LSTM, K-means, and SVMs. I also learned about the various applications that these ML models are used for in telecoms systems.

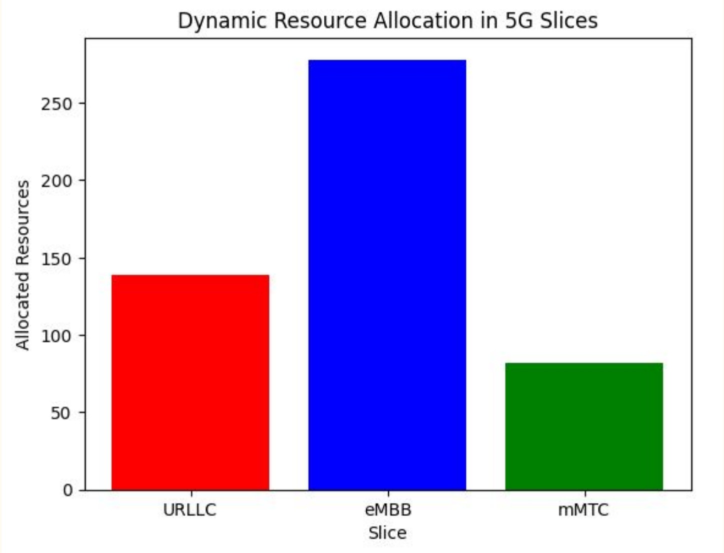


I also completed several practical labs for demonstrating Network Traffic Prediction, Network Anomaly Detection, and Customer Segregation.

Module 04

For this module, I learned about 5G network architecture and how it differs from previous network generations. I learned that 5G introduced cloud-native architecture and supports functions such as network slicing, multi-access edge computing (MEC), and Service-Based Architecture (SBA).

These functions are supported by AI integration for purposes such as RAN interference prediction, and network slice allocation. My activities for the practical lab of this module included simulating network slicing with demand-based resource allocation.



Module 05

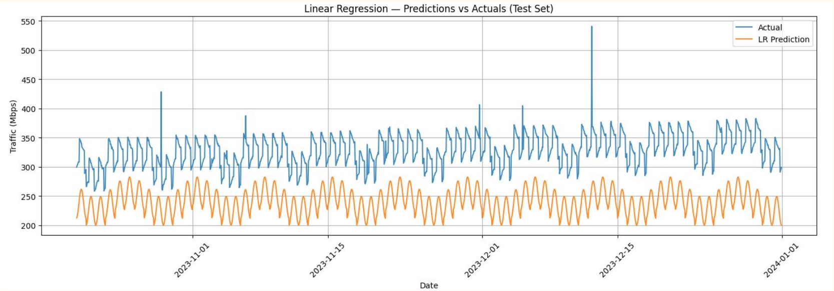
In Module 05, I learned about Open Radio Access Network (ORAN) architecture and concepts. I learned that ORAN differs from traditional RAN (TRAN) by offering open interfaces and disaggregated hardware and software which eliminates the vendor lock-in of TRAN while also increasing network flexibility and development speed.

Additionally, for the practical lab I used a simple linear regression model to predict network traffic to demonstrate how ML can be used for telecoms applications.

```
model = LinearRegression().fit(X, y)
future = np.array([[11],[12],[13]])
print("Predicted Traffic:", model.predict(future))
```

```
Predicted Traffic: [374.         402.18181818 430.36363636]
```

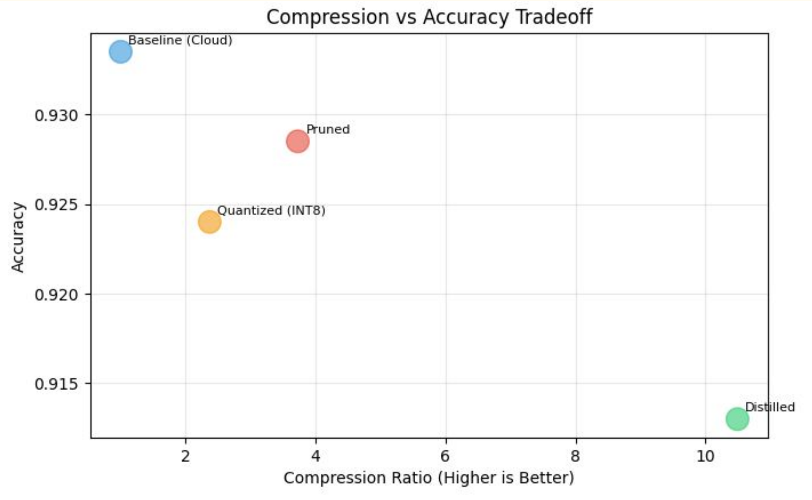
Module 06



In Module 6, I explored how AI and ML are transforming traditional reactive network operations into Intelligent Network Operations (INO). I learned the closed-loop INO workflow (Sense → Analyze → Decide → Act → Learn), time-series forecasting for traffic prediction, how to use statistical (ARIMA) and deep learning (LSTM) models for accurate network traffic forecasting, and the importance of feature engineering and data preparation for real-world network datasets.

For the lab, I built and compared three predictive models (ARIMA, linear regression, and LSTM) on a real-world hourly network traffic dataset.

Module 07



For this module, I learned about IoT and Edge computing and how they relate to AI. I learned that there are over 75 billion network-enabled devices that generate a combined 79+ zettabytes of data per year. This massive amount of devices and data highlights the need for AI to help optimize the networks they rely on and the difficulty of integrating it with edge solutions. Techniques such as compression can help AI run on edge devices, but we must be careful to not lose quality for critical use cases such as autonomous vehicles.

For this module's lab, I demonstrated how an AI model can be compressed for edge device use.

Module 08

In Module 8, I explored the dramatically expanded attack surface of 5G/6G networks and how AI is transforming telecom security from reactive to proactive, automated, and trustworthy defense systems.

I learned about new threats (signaling storms, rogue base stations, supply-chain risks, massive IoT attacks), privacy vulnerabilities (IMSI/IMEI leaks, location tracking), regulatory requirements, AI-driven intrusion & anomaly detection, SOAR frameworks, adversarial ML risks, and the critical role of Explainable AI (SHAP, LIME) in security operations.

For the lab, I built a full ML-based IDS using the NSL-KDD dataset — preprocessing, training Random Forest and SVM classifiers (excellent results on DoS, Probe, etc.), implementing unsupervised anomaly detection with Isolation Forest and One-Class SVM, and using SHAP to explain which features triggered alerts.

Module 09

In Module 9, I explored telecom sustainability. Networks consume massive energy (base stations alone 60–80%) and contribute to global GHG emissions, making green communications non-negotiable.

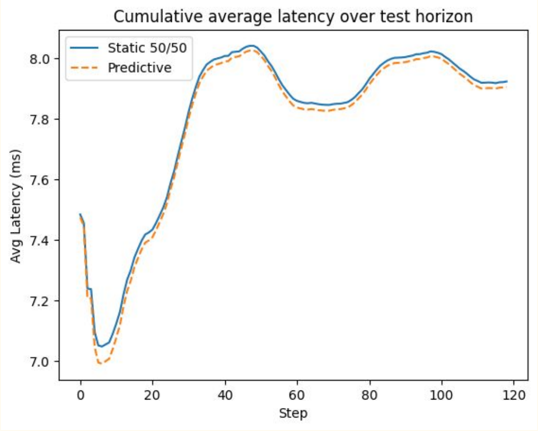
I learned key metrics (PUE, ECR, CUE), renewable integration strategies, circular economy practices, and especially how AI drives real savings: traffic forecasting → cell sleeping, RL for dynamic power control, and DeepMind-style cooling optimization that cuts energy 40%.

In the lab I analyzed real-world energy datasets, built Prophet and LSTM forecasting models, and optimized base-station sleep schedules to minimize both cost and carbon footprint while maintaining QoS.

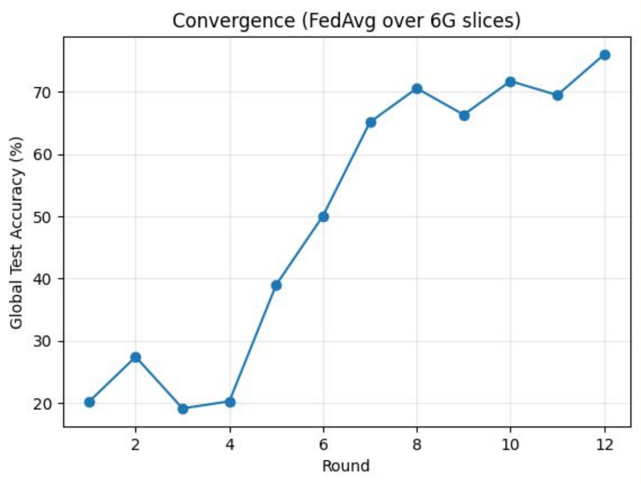
Module 10

In Module 10 I explored the bleeding edge: digital twins, AI-driven network slicing and intelligent spectrum management, blockchain/quantum synergies, and neuromorphic/bio-inspired computing for ultra-efficient networks.

For the midterm labs, I built a live digital twin of a small network using SimPy: three routers in a chain, Poisson packet arrivals, per-router processing delays, real-time queue monitoring, and Matplotlib visualizations
of throughput, latency, and congestion as traffic varied.



Module 11



In Module 11 I studied the 6G vision: AI-native networks designed from the ground up with intelligence embedded in every layer, targeting 1 Tbps peak rates, sub-millisecond latency, terahertz communications, integrated space-air-ground connectivity, federated learning for privacy-preserving optimization, digital twin-driven self-evolution, and intent-based orchestration.

The hands-on lab focused on implementing a federated learning simulation across distributed edge devices for predictive resource allocation in a 6G scenario, followed by performance visualization that clearly demonstrated substantial gains in efficiency, latency, and model accuracy without centralizing sensitive data.

Module 12

In Module 12 I explored how AI-powered telecommunications is already reshaping entire industries: smart cities with real-time traffic and public safety systems, Industry 4.0 factories achieving 30–50% less downtime through predictive maintenance, telemedicine and remote monitoring in healthcare, V2X for autonomous vehicles, and new revenue streams via private 5G, edge platforms, and AI analytics services.

We also covered the impressive economic outlook, telecom AI market hitting $18.4B by 2030 with 30–40% operational cost reductions, major players (Ericsson, Nokia, Huawei, AWS, Google Cloud), regulatory/privacy challenges, and the exploding demand for roles like AI/ML engineers, network automation architects, and IoT specialists.

Module 13

In the final module I examined the critical importance of ethical AI in telecommunications: core principles (fairness, accountability, transparency, robustness, privacy), major frameworks (EU AI Act, IEEE Ethically Aligned Design, UNESCO recommendations), and real-world risks including algorithmic bias in network resource allocation, deepfakes over telecom infrastructure, surveillance creep in 5G/6G, and the societal impact of automation-driven job displacement.

We explored governance approaches, risk-tiered regulation, the need for continuous auditing and human oversight, and emerging trends toward human-centric AI, alignment research, and responsible innovation that balances performance with societal good.