

# A Reflective Journey of Research

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## From Novice to Explorer.

Well, I have to say what an interesting experience this has been. I have never been an artist. But research is an art, I can get a hang of. After a thrilling and motivating 6 weeks, I have found myself a hobby. To start by glancing into the unknown, to map out a sliver of the foggy beyond, I can happily say, that this investigation turned out to be a more intuitively engaging and absorbing process.

Just a month and a half ago, I found myself taking a seat in the undergrad lab of the Department of Electronic and Electrical Engineering in front of a computer with no clue of how the journey would take shape. I started small, as recommended by my extremely supporting and guiding supervisor Dr Harun Šiljak, I installed a lot of software libraries that would help me navigate the field of network science, spent some time getting a hang of how they worked, reading a lot of papers and books, so that I can dive into this project with an understanding of concepts and visual clarity. I admit that I did steal a stack of printing paper from a printer in the CAD lab, but I promise I made good use of the university resources, as I quickly broke down the maths of it all into smaller functions I can build in a program, and by the start of the third week, I had my first flawed yet functioning adaptive network plotter, which was the basic testing system that I needed.

The pace at which I was able to progress had me thrilled, and I cannot stress enough how beneficial having the support and help from my supervisor and all the lab technicians, Ph.D. students and other researchers in the building were, in making this happen for me. There were certainly difficulties since I struggled to find any actual raw data from any of the studies that have been conducted, since I could not get anyone to reply to me, even after the swarm of emails I sent out, but this pushed me to develop this system end-to-end by my own, and work of data generated by my system. By doing this, I gained a much deeper understanding of Control systems in Network Science and made my results more comparable.

I mainly based my research on Albert-Barabasi's work on Network Science. The most fascinating thing about Network Science is how while being one of the newest of the sciences, it has an endless number of repositories of work done by researchers across the world, all

trying different things, trying to establish newer methods, analysis tools and a different perspective of viewing the world. It's remarkable how we can gain valuable insights from even the simplest networks by using the right analysis, all while minimizing our efforts for maximum efficiency.

I will admit going into the project, I had little to no knowledge about the science of Networks. As I walked out of the Berkeley library, here at Trinity, the weight of the thousand pages I walked out with, was the most daunting feeling. Furthermore, the next week I spent reading barely fifty of those was even more.

It was then that I decided to focus my efforts on tasks that could be done and do reading on the side. As a Software Engineer, writing code without really understanding the task is something I can do. So, while my knowledge slowly grew between the first three weeks, I was able to get a lot done by also putting together my code, and my testing benchmark and looking at what other people have been able to do, to get more unique ideas. Now that I look back at the first half of my project, I think it went a lot smoother than I would have imagined at the start. This method of breaking down the task at hand into multiple smaller achievable tasks ended up being quite beneficial for me.

As I wrapped up the third week, I managed to blend various tasks and create the first version of my adaptive network system mapper. Though I was only halfway through my project, this was a moment of great satisfaction. It felt rewarding to turn my initial lack of knowledge into a program I could experiment with, learn from, and enhance in just a few weeks.

One aspect that posed a significant challenge during the project was my struggle to articulate innovative applications for this research, particularly to individuals outside the STEM field. This dilemma became so pronounced that I felt compelled to discuss it with my supervisor. This conversation marked a turning point in my research journey, sparking a period of exhilarating exploration as I delved into potential use cases, benefits, and novel ideas.

Among the most captivating concepts we brainstormed, was the notion of a drone-based adaptive cellular network. This visionary concept involved deploying a fleet of drones, each equipped with remote mobile network towers, capable of being localized to address surges in demand in specific areas. This strategy could prove ideal for locales where extensive, high-demand internet connectivity is not a year-round necessity but can be readily provided during

occasional periods of heightened demand. Imagine the potential applications in stadiums, concert halls, sports arenas, and similar venues, where this innovative approach could ensure seamless connectivity during peak events.

As I ventured further into the realm of adaptive network systems, inspired by the groundbreaking concept of a drone-based adaptive cellular network, I found myself on a journey of profound discovery. This exploration allowed me to appreciate the far-reaching implications that adaptive network systems could have on our interconnected world. The notion of deploying a fleet of drones, each equipped with remote mobile network towers, had already captured my imagination. However, much thanks to my supervisor for introducing me to the Lorentz oscillator that truly breathed life into this visionary concept.

With the Lorentz oscillator in hand, I embarked on a mission to replicate the scenarios we had envisioned earlier - those moments of intense, localized surges in demand. I used the oscillator to mimic the situation described above at a specific node within our network. This marked the inception of my experimentation, where I sought to test the effectiveness of our adaptive network system in addressing these dynamic demand fluctuations.

The results of this experiment were nothing short of exhilarating. Initially, the Lorentz oscillator, operating without any adaptive network system, exacerbated the errors within the network, doubling their impact. However, through meticulous tuning and enhancing the strength of our adaptive network system, I achieved a remarkable outcome. The errors, once magnified, were gradually reduced to a negligible amount.

The elation I felt upon witnessing this transformation was immeasurable. It underscored the incredible potential of our adaptive cellular network concept and demonstrated the power of innovation when combined with rigorous experimentation.

From the very beginning of my research, my main objective was crystal clear: to implement adaptive nodes selectively within a network. This wasn't a chance discovery; it was the central focus of my work. I aimed to explore a method that wouldn't necessitate the entire network to be adaptive; instead, I wanted to strategically scatter these adaptive nodes. This approach had the potential to be cost-effective and adaptable to existing networks, offering real-world practicality.

In the initial stages, I began with a random allocation strategy for these adaptive nodes. It was a straightforward approach, allowing me to easily adjust the number of adaptive nodes within the system. This method had its merits, as it helped me visualize how adaptive networks could reduce synchronization errors. I conducted multiple tests, tweaking the number of adaptive nodes and collecting data that clearly illustrated how synchronization errors decreased as the adaptive network strength increased. It was a simple and effective way to demonstrate the advantages of adaptive networks.

However, as my research progressed, I faced a significant challenge. The randomness in generating the network and placing adaptive nodes created a dataset filled with noise. While I could still discern a clear trend of decreasing errors, the noisy data made it difficult to uncover finer details. It made me realize that a more strategic approach to placing adaptive nodes might have resulted in a more robust dataset.

This realization led to a poignant moment of reflection in my research journey. I couldn't help but feel a sense of regret that I hadn't pursued the strategic allocation approach, which had been my initial intention. While the random allocation method provided valuable insights and aligned with my initial goals, the noisy data obscured some crucial subtleties. It became apparent that there was an intriguing unexplored avenue here—a chance to delve deeper into the intricacies of strategically placing adaptive nodes and how it could further optimize adaptive network systems.

This aspect of my research left me with a tinge of sadness at the time, knowing that I had missed an opportunity to explore a path less travelled. It held the promise of revealing novel insights and refining the practical implementation of adaptive networks. If given the chance to continue this research, pursuing the strategic allocation approach is something I would like to explore further. It serves as a reminder that research isn't just about reaching a destination but also about the intriguing journey of discovery along the way, along with the occasional regrets that come with it. Having mentioned all that, I will say that I am still very proud of all the evidence I was able to collect and providing proof that a system like this could improve synchronisation errors in any network.

During this research journey, my perspective on networks and adaptive systems underwent

a profound transformation. What started as a quest to selectively implement adaptive nodes within a network became an expedition into the intricate workings of connectivity and the limitless potential for improvement. This project has left an indelible mark on how I perceive the world of networks, altering my mindset in ways I couldn't have anticipated.

Throughout this journey, I discovered a deep-seated love for the process of exploration and innovation. The excitement of venturing into uncharted territory, of pushing the boundaries of what's possible, became a driving force in my work. I found immense joy in the pursuit of knowledge, in meticulous testing and analysis, and the moments of revelation when patterns emerged from the data. This project has shown me that research is not just a means to an end but a journey filled with wonder and discovery.

As I reflect on the culmination of this endeavour, I am filled with a profound sense of pride. Completing my research project with a robust set of evidence, despite the challenges and uncertainties along the way, is a testament to my dedication and perseverance. It reaffirms my belief that with determination and a thirst for knowledge, I can overcome obstacles and achieve my goals.

Towards the end of this project, a wave of inspiration washed over me. I could envision countless ways to enhance and optimize my network, to delve deeper into the intricacies of adaptive systems. It was a moment of creative fervour that left me yearning for more time to explore the possibilities. Unfortunately, as with all good things, my time on this project came to an end. Yet, I am left with a profound sense of anticipation, knowing that countless avenues are waiting to be explored.

In conclusion, this research project has not only expanded my understanding of networks and adaptive systems but has also ignited a passion within me for continuous exploration and improvement. It has taught me that the journey of discovery is as valuable as the destination and that the pursuit of knowledge knows no bounds. I eagerly look forward to the day when I can once again immerse myself in this world of networks, armed with new ideas and a boundless enthusiasm for what lies ahead. This project has been a transformative experience, and I can't wait to continue this journey of exploration and innovation.