Edge Hill University

The Department of Computer Science

CIS2707 Wireless & Mobile Networks

Coursework 2 – Case Study Report

2024/2025

Thomas William Mason
26040247

Table of Contents

Coursework 2: A Comparative Study of Wi-Fi and Li-Fi Networks.

Introduction:

The evolution of wireless communication technologies has become an essential part of modern-day life. From providing the fundamental internet connectivity for homes, offices and public areas to creating new possibilities for industries with the integration of the Internet of Things (IoT), wireless technology has become an absolute essential.

Across the various wireless technologies, Wi-Fi (Wireless Fidelity), which uses radio frequency signals, is the most commonly used (Jacobs, 2022). However, with the ongoing demand for increasing bandwidth data rates, reduced interference and enhanced security, research has begun exploring the possibilities of alternative technologies to overcome the limitations of radio frequencies. One of the possible alternatives to replace or complement traditional Wi-Fi systems is Li-Fi (Light Fidelity), which uses light (visible light, infrared light or ultraviolet radiation) for data transmission, with a bandwidth 10,000 times greater than the radio frequency band. (Yilmaz and Indrit Myderrizi, 2024).

Li-Fi was first introduced by Professor Harald in a 2011 TEDGlobal talk in Edinburgh, where he demonstrated using Light Emitting Diodes (LEDs) to transmit data through light. Unlike Wi-Fi, which suffers from traffic congestion in the radio frequency spectrum and electromagnetic interference, Li-Fi offers a solution that provides higher bandwidth, better security within isolated areas (homes, offices, etc.) and doesn't suffer from electromagnetic interference (Wikipedia Contributors, 2019).

This report aims to give a comparative analysis and explore the features of Wi-Fi and Li-Fi, including their principles, recent advancements, real-world applications and the widespread deployment challenges they face. The main goal is to determine whether Li-Fi can replace existing Wi-Fi in certain situations, or if both of these technologies can be utilised together in a hybrid environment that fosters both of their strengths.

Discussion on Advancements and Current Trends:

The key technical aspects of Wi-Fi and Li-Fi are summarised in the table below (LiFi.co, 2025), (GeeksforGeeks, 2018).

Feature	Wi-Fi	Li-Fi
Transmission Type	Radio Frequencies (RF).	Visible Light (VLC), Infrared Light (IR) and Ultraviolet Light (UV).
Bandwidth	Up to 9.6 Gbps (Wi-Fi 6), 46 Gbps (Wi-Fi 7).	Researchers have reached data rates of over 224 Gbit/s.
Spectrum Availability	Limited Radio Frequency Spectrum.	Vast light spectrum from 430,000 to 770,000 GHz.
Interference	Susceptible to Electromagnetic interference (EMI).	Immune to Electromagnetic interference (EMI).
Security	Can be intercepted beyond walls.	Confined within rooms, walls block light.
Coverage	Long range, penetrates walls.	Room limited, line of sight.
Maturity & Adoption	Standardised and highly adopted.	Emerging technology had limited deployment.

Wi-Fi has been the cornerstone of wireless communication for over two decades. The technology has evolved over multiple standards with each improving in terms of speed, capacity and efficiency (Wikipedia Contributors, 2019b). Wi-Fi 6, which was released in 2019, introduced features such as OFDMA, BSS colouring and Target Wake Time. These improvements enhance the performance in highly congested areas and improve the energy efficiency, making Wi-Fi 6 ideal for applications such as 4K video streaming, online gaming and a large scale of IoT devices. However, the new Wi-Fi 7 now further pushes these boundaries and represents the edge of wireless technology, pushing these boundaries even further (Wikipedia, 2022).

Wi-Fi 6E improves upon Wi-Fi 6 by extending the available spectrum from 5 GHz to 6 GHz band, which offers 14 additional 80 MHz and seven additional 160 MHz channels. This, in turn, significantly reduces the congestion and improves the user experience, especially in dense environments (Juniper Networks, 2025). Wi-Fi 7, which is the latest generation of Wi-Fi, is currently being rolled out by large vendors and supports features such as Multi-link Operation (MLO), 320 MHz channels, 4K QAM (Quadrature Amplitude Modulation) and coordinated multi-user access (Intel, 2024). Wi-Fi 7 has an increased peak data rate supporting speeds up to 40 Gbps and delivers ultra-low latency for demanding applications such as AR/VR, cloud-based services such as gaming, industrial automation and robotics (George, George and Baskar, 2023). These improvements reflect how the continuous advancements to Wi-Fi's latency, reliability, and efficiency are being focused on areas where performance improvements are most important in today's demanding wireless world.

Wi-Fi is also evolving with the integration of artificial intelligence (AI) and machine learning algorithms that optimise network performance, which automatically adjust the allocated bandwidth, balance loads and predict the users' behaviour; this provides a more responsive and efficient network (Nagarajan, 2025). In addition to this, Wi-Fi 6 has enabled enhanced coverage using multiple interconnected nodes to strengthen signal availability, which helps areas that have large and obstructed environments.

On the other hand, Li-Fi technology has also progressed, starting as small experimental projects and now being used commercially as available systems. Unlike Wi-Fi, Li-Fi modulates light brightness at ultra-high frequencies using LED bulbs (T.D. Subha et al., 2020). These changes to the light are unnoticeable to the human eye. However, sensors such as photodiodes are able to detect these frequency changes and convert them into an electrical current. Since Li-Fi operates in the visible light spectrum, it produces wavelengths between 380nm and 780nm and a frequency band between 385 and 789 THz, and it offers a bandwidth which is 2600 times larger than the entire RF spectrum (Goswami and Shukla, 2017).

Recent developments in Li-Fi technology have brought companies such as pureLiFi and Signify to produce plug-and-play solutions for the transmission and reception of Li-Fi. Furthermore, recent breakthroughs in Li-Fi technology include the development of bidirectional multi-user Li-Fi systems for use in commercial vehicles (Nguyen et al., 2022).

The integration of a hybrid Li-Fi with Wi-Fi enables seamless switching between fast data transfer speeds and coverage from Wi-Fi, while complementing each of their disadvantages and overall increasing the network performance (Ghaderi, 2023). Furthermore, the integration of Li-Fi and Artificial Intelligence (AI) allows the network to have efficient data routing, enhance security and manage dynamic lighting conditions. This, in theory, allows for the potential of intelligent traffic management, secure and interface-free communication in congested areas such as hospitals and low-latency, high-speed data transmission for Augmented Reality (AR) and Virtual Reality (VR) (Himanshu Surendra Rajak, 2024).

Applications:

The following table highlights real-world use cases across various sectors for both Wi-Fi and Li-Fi:

Sector	Wi-Fi Use Cases	Li-Fi Use Cases
Home	Streaming, gaming, and smart home devices.	Data via smart lighting.
Healthcare	General device connectivity.	EMI-free communication near medical equipment.
Aviation	Crew and passenger Wi-Fi.	In-flight secure internet.
Military	Base camp and tactical field communication.	Secure data in radio frequency restricted areas.
Industry	IoT and automation networks.	Reliable and EMI-free control.
Education	Remote learning, virtual classrooms.	High-speed, localised, RF-free access.
Public spaces	Free Wi-Fi in urban areas.	Smart street lighting with Li-Fi nodes.

Wi-Fi still remains the most popular wireless communication standard due to its widespread adoption for availability, affordability and ease of setup and use. Wi-Fi supports numerous applications across homes, offices, education and transport.

While Li-Fi is still emerging, it is proving to be highly valuable in certain areas. It has a massive advantage over Wi-Fi when it comes to electromagnetic interference (EMI), which makes it ideal in industries like healthcare, defence and aviation, which are susceptible to EMI. In education and museums, Li-Fi provides a targeted connection, making it suitable for interactive learning. In the future, it is promising that Li-Fi will take over Wi-Fi in certain domains, and with the upcoming demand for smart city infrastructure, integrating Li-Fi will show the possibility of future urban connectivity.

Challenges and Open Problems:

Despite the compelling advantages of both Li-Fi and Wi-Fi, each faces its own individual challenges of technical, security and legal issues. These issues are essential for ensuring reliability and scalability across different sectors for widespread adoption and safe integration into the future of wireless connectivity.

Wi-Fi Challenges:

- **Spectrum Congestion:** The RF spectrum is limited and is increasingly becoming more crowded; this isn't just a problem in airports or public venues but is also becoming a problem in urban areas with a high number of devices (De Vries et al., 2014). Despite new advancements such as Wi-Fi 6e and Wi-Fi 7, using the latest 6 GHz band, interference and congestion are still impacting performance.
- **Security Risks:** Wi-Fi networks, more so public ones, remain incredibly vulnerable to a variety of cyber threats, including packet sniffing, man-in-the-middle and ransomware attacks (Johnson, 2024). While WPA3 encryption improves security levels, legal regulations such as GDPR add pressure for stronger protection.
- **Electromagnetic Interference:** Wi-Fi is very susceptible to interference from other radio frequency emitting devices such as cordless phones, microwave ovens and Bluetooth devices.

These radio frequency emitting devices can cause poor signal quality and packet loss (Taranovich, 2021).

- **Power Consumption:** As Wi-Fi hardware continues to improve, the increasing power demands reduce the overall battery life of portable devices and raise energy consumption, increasing the maintenance cost for network infrastructure.
- **Compliance and Liability:** Businesses that provide public Wi-Fi may be legally responsible for illegal activity that is conducted on their network. Businesses need to comply with laws surrounding logging, encryption and access restrictions to try to minimise this (Musgrove, 2015).

Li-Fi Challenges:

- **Line of Sight Dependent:** While Li-Fi is not strictly dependent on being within the line of sight, since light bounces off surfaces, physical obstacles such as people, furniture or changes in direction can easily disrupt the signal strength (LiFi Group, 2025).
- **Mobility and Handover Limitations:** As Li-Fi requires a line of sight with the light source, maintaining a seamless connection while moving between light zones is complex. Unlike Wi-Fi, Li-Fi coverage is limited to small areas and therefore, transitioning between Li-Fi access points can cause latency or dropped signal issues (Oledcomm, 2025).
- **Deployment Cost and Complexity:** Retrofitting existing lighting systems with Li-Fi-compatible LED bulbs and fitting devices with photodetectors can be costly compared to traditional Wi-Fi solutions (Oledcomm, 2025b).
- **Device Compatibility:** Most current consumer electronics lack support for Li-Fi. Therefore, external receivers or dongles are required, which limits the usability and creates a barrier to its widespread adoption.

Shared and Open Problems:

Hybrid Network Management: Effectively managing handovers between Wi-Fi and Li-Fi in real time without disruption still remains a real challenge since the coverage areas overlap entirely with each other (Wu and O'Brien, 2020). Load balancing, signal prioritisation and dynamic routing protocols all must be defined.

Security in Light-based Transmission: While Li-Fi's confined transmission space improves the privacy and security, it is not immune to all risks. Light signals can be reflected or leaked through windows or any transparent materials, leading to potential interception. There are no current legal frameworks established to handle light-based intrusions.

Scalability and IoT integration: While both technologies must evolve to support the increasing demand for the number of connected devices, the rapid increase of IoT applications requires easy scalability, low latency and security that meets the ever-increasing data protection requirements.

Environmental Sensitivity: Li-Fi's reliability is dependent on the light conditions and can be influenced by the line of sight and surface reflectivity, which impact the signal strength and quality (Velmenni, 2018). On the other hand, Wi-Fi's radio frequencies can be significantly weakened by certain building materials such as concrete or metal walls, which are harder to penetrate (Mistral, 2018).

Legal and Ethical Implications: As data travels through both visible light and radio waves as a hybrid solution, there may be concerns around data ownership, consent and monitoring. Therefore, regulatory standards need to be put in place around new transmission laws to protect users from misuse.

Summary of Open Challenges:

Research is continuing to address the boundaries for open areas, such as:

- Developing energy-efficient handover protocols for hybrid Li-Fi and Wi-Fi networks.
- Creating universal low-cost Li-Fi hardware for widespread device compatibility.
- Refine security models for light networking and analyse potential legal risks, responsibilities, and compliance requirements.
- Establishing internationally accepted rules and guidelines to allow Wi-Fi and Li-Fi to work smoothly across different manufacturers and countries.
- Researchers are currently working on overcoming the current Li-Fi range and speed limitations by improving the performance of off-the-shelf LED bulbs to deliver near-instant communication to make it more competitive with Wi-Fi (THE UNIVERSITY OF EDINBURGH, 2018).

Conclusion:

In summary, this report has explored the comparative features, advancements, applications and challenges of Wi-Fi and Li-Fi technologies. Currently, Wi-Fi is widely recognised as the primary form of modern connectivity, with improvements such as Wi-Fi 6 and Wi-Fi 7, which push the limits of speeds, capacity, and efficiency. Li-Fi has emerged as a possible alternative. It offers ultra-high-speed data transfer and enhanced security and is entirely resistant to electromagnetic interference, making it highly suitable for environments where radio frequencies fall short, such as healthcare, aviation and defence.

Despite their strengths, both of these technologies face essential challenges. While Wi-Fi struggles with spectrum congestion, security vulnerabilities, and interface issues, Li-Fi faces problems such as line-of-sight requirements, limited mobility, and device compatibility issues. However, when utilising both of their strengths together to create a hybrid network, they hold great potential; each of them compensates for the other's weaknesses to deliver a high-performance, seamless wireless network.

Looking ahead, the evolution of Wi-Fi and Li-Fi, especially combined with artificial intelligence and IoT integration, looks extremely promising to deliver consistently faster, more secure connectivity. While Wi-Fi will continue to dominate the consumer market, Li-Fi has the potential to play a critical role in the niche and high-demand sectors. Combined, they offer a powerful path forward, utilising their strengths together to meet the increasing demands of the digital future.

REFERENCES:

De Vries, J.P., Simić, L., Achtzehn, A., Petrova, M. and Mähönen, P. (2014). The Wi-Fi 'congestion crisis': Regulatory criteria for assessing spectrum congestion claims. *Telecommunications Policy*, 38(8-9), pp.838–850. doi:https://doi.org/10.1016/j.telpol.2014.06.005.

GeeksforGeeks (2018). Difference between LiFi and WiFi. [online] GeeksforGeeks. Available at: https://www.geeksforgeeks.org/difference-between-lifi-and-wifi/ [Accessed 24 Apr. 2025].

George, D.A.S., George, A.S.H. and Baskar, D.T. (2023). Wi-Fi 7: The Next Frontier in Wireless Connectivity. *Partners Universal International Innovation Journal*, [online] 1(4), pp.133–145. doi:https://doi.org/10.5281/zenodo.8266217.

Ghaderi, M.R. (2023). LiFi and Hybrid WiFi/LiFi indoor networking: From theory to practice. *Optical Switching and Networking*, 47, p.100699. doi:https://doi.org/10.1016/j.osn.2022.100699.

Goswami, P. and Shukla, M.K. (2017). Design of a Li-Fi Transceiver. *Wireless Engineering and Technology*, [online] 8(4), pp.71–86. doi:https://doi.org/10.4236/wet.2017.84006.

Himanshu Surendra Rajak (2024). The Convergence of Li-Fi and AI - Himanshu Surendra Rajak - Medium. [online] Medium. Available at: https://himanshusurendrarajak.medium.com/the-convergence-of-li-fi-and-ai-0b393071ca72 [Accessed 24 Apr. 2025].

Intel (2024). What Is Wi-Fi 7? [online] Intel. Available at: https://www.intel.com/content/www/us/en/products/docs/wireless/wi-fi-7.html [Accessed 24 Apr. 2025].

Jacobs, D. (2022). The 4 different types of wireless networks. [online] SearchNetworking. Available at: https://www.techtarget.com/searchnetworking/tip/The-4-different-types-of-wireless-networks [Accessed 22 Apr. 2025].

Johnson, D. (2024). Understanding the risks of public Wi-Fi and how to stay protected. [online] Maddyness UK. Available at: https://www.maddyness.com/uk/2024/02/17/understanding-the-risks-of-public-wi-fi-and-how-to-stay-protected/ [Accessed 30 Apr. 2025].

Juniper Networks (2025). What is Wi-Fi 6E? | Juniper Networks UK&I. [online] www.juniper.net. Available at: https://www.juniper.net/gb/en/research-topics/what-is-wi-fi-6e.html.

LiFi Group (2025). LiFi Misconceptions. [online] LiFi.co. Available at: https://lifi.co/lifi-misconceptions/ [Accessed 1 May 2025].

LiFi.co. (2025). LiFi vs WiFi. [online] Available at: https://lifi.co/lifi-vs-wifi/ [Accessed 23 Apr. 2025].

Mistral (2018). Mistral Solutions. [online] Mistral Solutions. Available at: https://www.mistralsolutions.com/articles/dos-donts-wi-fi-connectivity-maximizing-range-reception/ [Accessed 1 May 2025].

Musgrove, D. (2015). Legal and Practical Implications of Offering Public WiFi in the UK | Purple. [online] Purple. Available at: https://purple.ai/blogs/legal-and-practical-implications-of-offering-public-wifi-in-the-uk/ [Accessed 30 Apr. 2025].

Nagarajan, V. (2025). Wi-Fi® and AI: Empowering the future of intelligence. [online] Wi-fi.org. Available at: https://www.wi-fi.org/beacon/vijay-nagarajan/wi-fi-and-ai-empowering-the-future-of-intelligence [Accessed 24 Apr. 2025].

Nguyen, T., Anil Yesilkaya, Chen, C. and Haas, H. (2022). A novel mobile multi-user LiFi system. *ICC 2022 - IEEE International Conference on Communications*, [online] pp.589–594. doi:https://doi.org/10.1109/icc45855.2022.9838651.

Oledcomm (2025a). Explorez la technologie LiFi : LiFi Blogs | Oledcomm. [online] Oledcomm. Available at: https://www.oledcomm.net/blog/advantages-disadvantages-of-lifi/ [Accessed 1 May 2025].

Oledcomm (2025b). Explorez la technologie LiFi : LiFi Blogs | Oledcomm. [online] Oledcomm. Available at: https://www.oledcomm.net/blog/how-much-does-lifi-cost/ [Accessed 1 May 2025].

Subha, T.D., Subash, T.D., Rani, N.E. and Janani, P. (2020). Li-fi: A revolution in wireless networking. *Materials Today: Proceedings*, [online] 24, pp.2403–2413. doi:https://doi.org/10.1016/j.matpr.2020.03.770.

Taranovich, S. (2021). The Impact of EMI on Wi-Fi. [online] *Electronic Design*. Available at: https://www.electronicdesign.com/technologies/analog/article/21180942/electronic-design-the-impact-of-emi-on-wi-fi [Accessed 30 Apr. 2025].

THE UNIVERSITY OF EDINBURGH (2018). How fast can LiFi be? | LiFi Research. [online] www.lifi.eng.ed.ac.uk. Available at: https://www.lifi.eng.ed.ac.uk/lifi-news/2015-11-28-1320/how-fast-can-lifi-be [Accessed 1 May 2025].

Velmenni (2018). Busting Common Myths About LiFi - Velmenni - Medium. [online] Medium. Available at: https://medium.com/@velmenni/busting-common-myths-about-lifi-technology-661563f117cc [Accessed 1 May 2025].

Wikipedia (2022). Wi-Fi 6. [online] Available at: https://en.wikipedia.org/wiki/Wi-Fi_6 [Accessed 24 Apr. 2025].

Wikipedia Contributors (2019a). Li-Fi. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Li-Fi [Accessed 23 Apr. 2025].

Wikipedia Contributors (2019b). Wi-Fi. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Wi-Fi [Accessed 24 Apr. 2025].

Wu, X. and O'Brien, D. (2020). A Novel Handover Scheme for Hybrid LiFi and WiFi Networks. [online] University of Oxford. Available at: https://ora.ox.ac.uk/objects/uuid:38e44091-a483-4c5f-af35-f346f1886173/files/scv43nw80m.

Yilmaz, A.F. and Indrit Myderrizi (2024). Increasing indoor Li-Fi system efficiency using light reflective materials and lenses. *Journal of Engineering Research*. [online] doi:https://doi.org/10.1016/j.jer.2024.10.014.