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Towards University Digital Transformation in Antananarivo : An Analysis of User Practices, Needs, and Constraints

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Abstract: Optimizing computer networks is essential to ensure fast, reliable, and secure connectivity for students, faculty, and administrative staff. Such optimization enhances the overall user experience by meeting specific objectives, including improved transmission speed, reduced latency, and efficient bandwidth utilization. A well-optimized network guarantees the seamless operation of applications, facilitates information exchange, and ensures timely access to digital resources. This article investigates user activities within the computer network, the management of data flow, and the corresponding user requirements. Data were collected through structured questionnaires and oral interviews with members of the *École Normale Supérieure d'Ampefiloha* community. The analysis, conducted using SPSS statistical software, enabled the classification of users according to their network usage patterns and highlighted the significance of network optimization in mitigating bandwidth saturation and maintaining fluid data traffic.

Keywords: *Optimization, Network Management, Computer Science, Digital Resources, Bandwidth, Latency.*

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I. INTRODUCTION

In the early 1970s, Vint Cerf and Bob Kahn[1] developed the TCP/IP protocol (Transmission Control Protocol / Internet Protocol), which standardized communication across disparate networks and laid the foundation for the modern Internet. By the 1990s, the Internet began to expand rapidly with the emergence of Internet Service Providers (ISPs) and the widespread adoption of the World Wide Web. It evolved into a globally interconnected network, prompting network administrators to employ sophisticated tools to troubleshoot connectivity issues, enhance system security, and improve network performance.

The 2000s witnessed the rise of wireless networks, marked by the proliferation of Wi-Fi technology and the introduction of the IEEE 802.11 standard. University campuses, in particular, adopted Wi-Fi to support user mobility while maintaining reliable connectivity. Wireless networks enabled more flexible resource management without reliance on physical cabling. However, the growing number of connected devices has increasingly complicated the management of campus networks.

The management of computer networks has evolved substantially since the early days of ARPANET. From managing initial *local area networks* (LANs) to *software-defined networks* (SDNs) and the integration of cloud computing and *artificial intelligence* (AI), the field continues to advance to meet escalating demands for connectivity, security, and performance. In the digital era, computer networks are central to information transmission and the effective operation of information systems, particularly within educational institutions and public organizations.

[1] https://www.invent.org/inductees/vinton-g-cerf visited on 5th November 2025.

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Optimizing network performance cannot be limited to isolated technical improvements. It requires a comprehensive understanding of user behaviors, needs, and practices. Identifying these factors is essential for implementing systems that are efficient, scalable, and user-centered. Effective network capacity planning is critical to anticipate future demands and prevent resource saturation. The implementation of bandwidth management strategies, which prioritize critical traffic, ensures high network performance and an uninterrupted user experience, facilitating academic, administrative, and research activities.

This study focuses on network optimization techniques, highlighting user practices and resource requirements as central determinants of network performance in *École Normale Supérieure d'Ampefiloha* community, Antananarivo. User needs—whether in corporate environments, educational institutions, or individual contexts—vary widely and directly influence network design, management, and optimization strategies. The central research question addressed is: "*How can a user database be effectively modeled?*" The study aims to classify and categorize user behaviors based on resource requirements and to develop a dynamic initial database capturing network usage patterns while accounting for potential network architecture updates and expansions.

The underlying hypothesis posits that a precise assessment of the specific connectivity needs of each user entity enables optimal configuration and management of Internet access, ensuring equitable resource allocation and improved overall network performance.

II. METHODS

➢ *Study Setting*

The study was conducted at the *École Normale Supérieure d'Antananarivo* (ENS), a constituent institution of the University of Antananarivo. ENS is equipped with a diverse range of IT infrastructures, accessed by a large and heterogeneous population of students, faculty, and administrative staff. This high-density user environment provides an ideal context for evaluating network performance, particularly under conditions of congestion, overload, and varied usage patterns.

➢ *Participants*

Participants were selected based on their roles and responsibilities within the institution. A total of 120 users—including faculty members, administrative and technical staff, and students—were surveyed. This selection enabled the study to capture a comprehensive view of user needs across different categories of network use.

➢ *Data Collection*

A quantitative research approach was employed to obtain reliable, representative, and actionable data on actual network usage. An initial observation and audit of the existing IT infrastructure were conducted to assess current capacities and limitations. Structured questionnaires were administered and stratified into three user groups (Faculty, Students, and Administration) to capture:

- Network usage patterns (e.g., browsing, downloading, messaging);
- Difficulties encountered ;
- Specific needs and expectations.

Respondents were asked to select from a set of predefined options regarding usage frequency and methods, allowing for one or multiple responses per question. Additionally, semi-structured interviews were conducted with key resource persons to capture qualitative insights on network perceptions, frustrations, and expectations.

➢ *Data Analysis*

Quantitative data were analyzed using SPSS statistical software to evaluate the alignment between network configurations and user requirements. Metrics such as usage frequency, resource demands, and traffic patterns were examined. Qualitative data from interviews were analyzed using content analysis to identify recurring themes related to user satisfaction, perceived limitations, and expectations.

➢ *Outcome Measures*

This analysis enabled a comparative assessment of network performance, user satisfaction, and workflow efficiency before and after implementing a personalized allocation of Internet access. The results provide a foundation for optimizing network configurations to better meet the diverse needs of users within a high-density academic environment.

III. FINDINGS

Table 1 User Group Classification

Status					
		Frequency	**Percentage**	**Valid Percentage**	**Cumulative Percentage**
Valid	Students	100	8.3	83.3	83.3
	Teachers	10	8.3	8.3	91.7
	Administration	10	8.3	8.3	100
	Total	120	100	100	

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The composition of the user population is characterized by a predominance of students, who account for 83.3% of the sample, whereas faculty and administrative staff each represent 8.3%. This distribution indicates a balanced representation between academic and administrative personnel but underscores the overwhelming presence of students within the institutional network environment.

Table 2 Distribution of Students

Level					
		Frequency	**Percentage**	**Valid Percentage**	**Cumulative Percentage**
Valid	Bachelor	50	41.7	50	50
	Master	40	33.3	40	90
	Doctorate	10	8.3	10	100
	Total	100	83.3	100	
Missing	Missing System	20	16.7		
Total		120	100		

The analysis by level of study indicates a predominance of undergraduate (Bachelor's) respondents, who account for 50% of valid responses, representing 41.7% of the total sample. Master's students comprise 40% of valid responses, while doctoral candidates account for 10%. This distribution suggests that the majority of the sample comes from first-cycle programs, which may influence the nature of expressed needs, particularly regarding access to IT resources and network services. Notably, there were 20 missing responses, corresponding to 16.7% of the total participant pool.

Table 3 Use of Digital Platforms and Applications

Frequency	***Social network***	***Instant messages ('%)***	***Messaging ('%)***	***Downloading ('%)***	***Files ('%)***	***Research ('%)***
Always	18.3	12.5	22.5	8.3	12.5	16.7
Frequently	22.5	11.7	15.8	18.3	7.5	13.3
Regularly	9.2	16.7	22.5	19.2	22.5	3.3
Often	22.5	8.3	7.5	9.2	9.2	12.5
From time to time	6.7	25.8	5	18.3	18.3	7.5
Sometimes	5.8	10	20.8	7.5	15.8	14.2
Rarely	13.3	5.8	5	9.2	9.2	16.7
Never	1.7	9.2	0.8	10	5	15.8
Total	100	100	100	100	100	100

➢ *Frequency of Social Media Use*

63.3% of participants use social media always, frequently, regularly, or often, showing strong integration into daily routines. Occasional users account for 25.8%, and only 1.7% never use these platforms. This highlights social media's central role in communication, information exchange, and academic collaboration, emphasizing its potential for institutional dissemination and community management.

➢ *Frequency of Instant Messaging Use*

49.2% of respondents use instant messaging regularly (always, frequently, regularly, or often), 25.8% occasionally, and 25% infrequently or never, including 9.2% who never use it. Instant messaging is widely embedded in digital habits and remains essential for rapid academic and personal communication, necessitating seamless network support for platforms like WhatsApp, Messenger, and Telegram.

➢ *Frequency of Email Use*

Email usage is high, with 60.8% of participants using it always, frequently, or regularly, 20.8% occasionally, 5% rarely, and 0.8% never. Email complements social media and messaging tools for formal, academic, and institutional communication, highlighting the need for stable internet access to maintain effective digital correspondence.

➢ *Frequency of Downloads*

45.8% of participants download files always, frequently, or regularly, 25.8% occasionally, and 19.2% rarely or never. Overall, 71.6% engage in regular downloads, emphasizing the importance of robust network infrastructure to support academic resources, multimedia, and software without congestion.

➢ *Frequency of File Sharing*

51.7% of respondents send files consistently, 34.1% occasionally, and 14.2% rarely or never, reflecting file sharing's key role in academic collaboration. Efficient network infrastructure is critical to ensure smooth transfers across collaborative platforms, emails, and cloud services.

➢ *Research Activities*

45.8% conduct online research regularly, 21.7% occasionally, 31.7% rarely or almost never, and 0.8% never. This diversity highlights the need for targeted training in research methods, improved access to academic resources, and reliable internet to support effective use of digital libraries and academic platforms.

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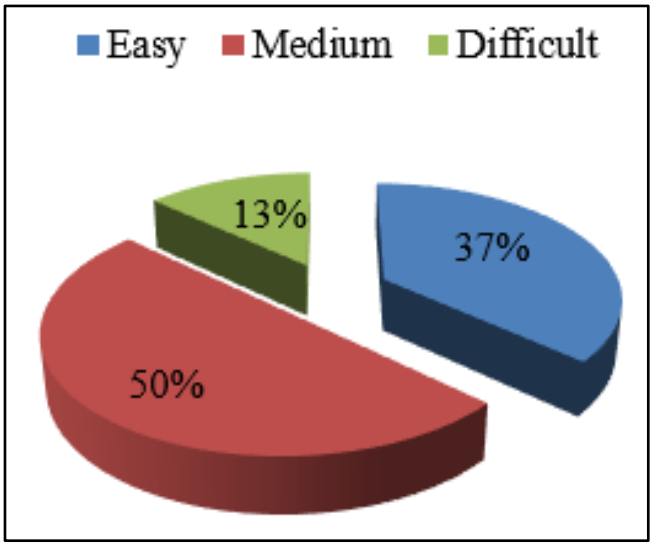

Fig 1 Assessment of Internet Navigation

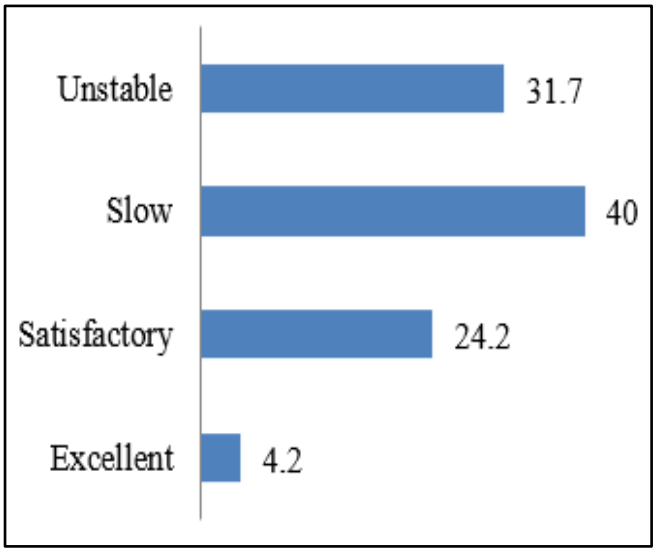

Fig 4 Assessment of the Institution's Internet Speed

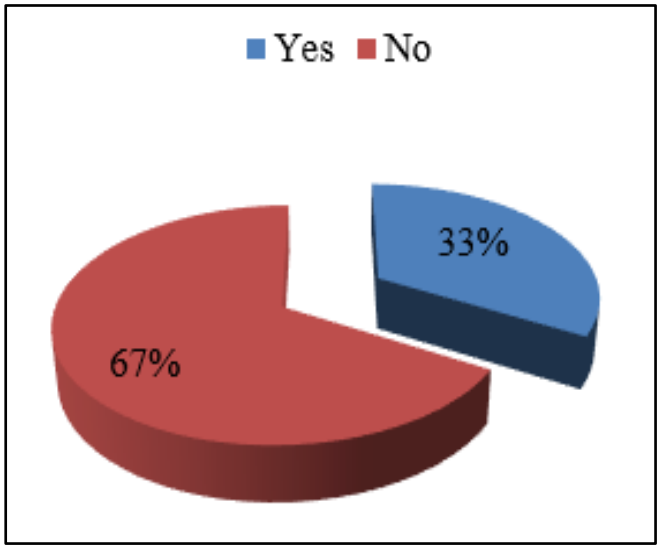

Fig 2 Online Advertising Targeting via Cookies

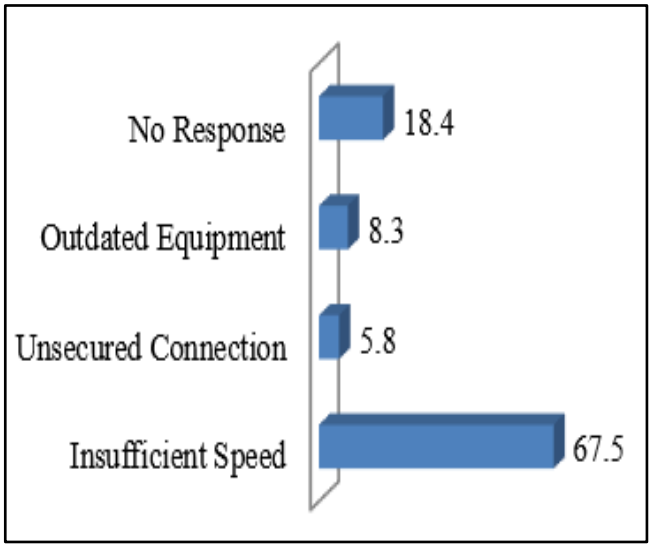

Fig 5 Internet Connection Quality Issues

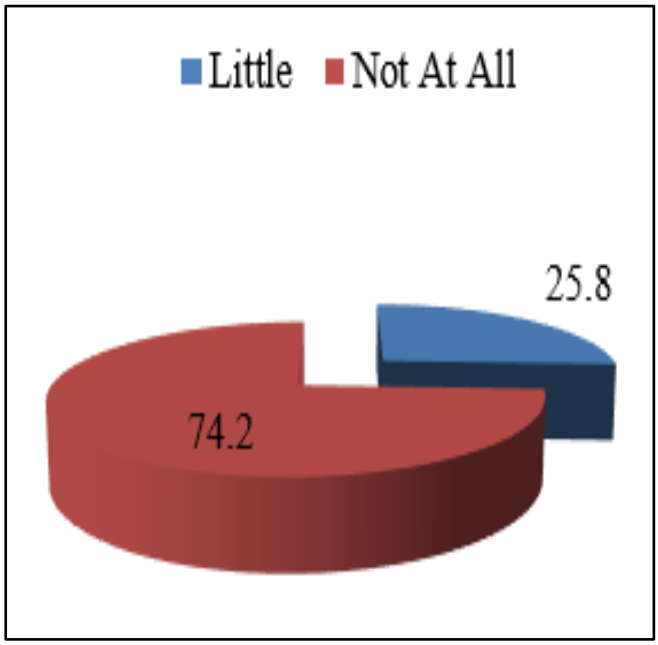

Fig 3 Concerns Regarding Online Advertising Targeting

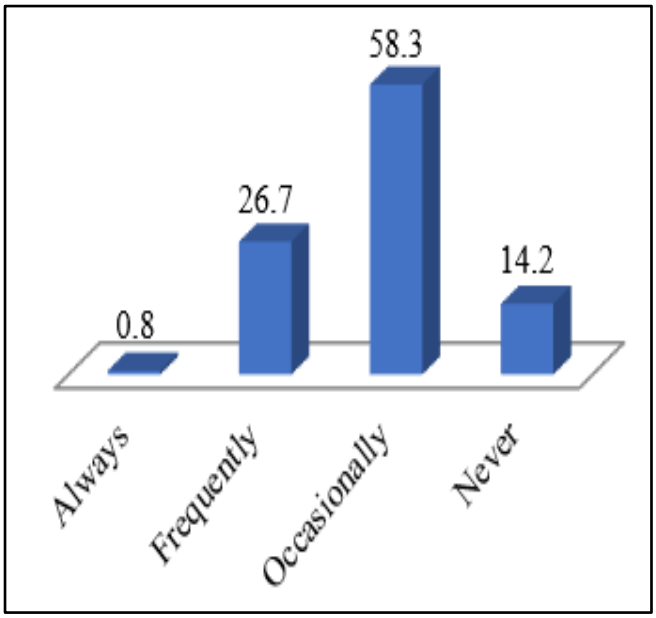

Fig 6 Need for Assistance to Increase Internet Usage

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➢ *Assessment of Internet Navigation (Figure 1) '*

In 2025, the majority of users (86.7%) perceive Internet navigation as easy (36.7%) or moderate (50%), indicating a generally satisfactory familiarity with digital tools. However, 13.3% report significant difficulties, a concerning figure in a university context where smooth Internet access is essential for academic success, research, and access to educational resources. These findings highlight a dual need: improving network quality (stability and speed) and implementing targeted digital skills training for users facing challenges, to ensure effective digital inclusion on campus.

➢ *Awareness of Cookies and Online Advertising (Figure 2)*

The data reveal a widespread lack of knowledge among participants regarding the functioning of cookies and their use for advertising purposes. Only 33.3% of respondents are aware that cookies can target advertisements based on user interests, while 66.7% admit to being uninformed, reflecting a significant gap in awareness of digital privacy issues and personal data collection. This informational deficit exposes users to potential risks, including the non-consensual exploitation of their data and reduced vigilance toward online tracking practices. It may also limit their ability to configure or control privacy settings on browsers and digital platforms. These findings underscore the urgent need to integrate digital citizenship education into university curricula, encompassing cybersecurity, data traceability, consent, and personal data management, in order to promote responsible and secure Internet use among students and academic staff.

➢ *Concerns About Online Activity Tracking (Figure 3)*

The results indicate a very low level of concern among users regarding the recording of their online activities for advertising purposes. Specifically, 74.2% of respondents report not being concerned at all, potentially reflecting a lack of awareness of digital privacy issues or a passive acceptance of intrusive tracking practices. An additional 25.8% report being slightly concerned, indicating partial but insufficient understanding of advertising tracking mechanisms. When combined with the previously observed lack of knowledge about cookies, this trend highlights a broader deficiency in digital literacy, particularly concerning personal data protection, online tracking, and cybersecurity. In a highly connected university context, where digital platforms and collaborative tools are extensively used, this limited vigilance may compromise the confidentiality of user data. These findings underscore the need to integrate digital citizenship training into higher education curricula to promote more conscious, responsible, and secure Internet use.

➢ *User Satisfaction with Internet Connection Quality on Campus (Figure 4)*

The results reveal widespread dissatisfaction among users regarding the quality of the campus Internet connection. Specifically, 71.7% of respondents perceive the network as either slow (40%) or unstable (31.7%), indicating a significantly degraded user experience that directly affects academic and professional activities. Conversely, only 24.2% of users consider the connection satisfactory, and a mere 4.2% rate it as excellent, a marginal proportion. In a university environment where access to online educational resources, academic research, communication tools, and digital platforms is essential, this widespread dissatisfaction reflects structural shortcomings in network infrastructure. These findings underscore the urgent need to modernize the system, including increasing available bandwidth, stabilizing the signal, expanding Wi-Fi coverage, and renewing outdated network equipment. Such measures are crucial to ensure efficient, smooth, and reliable digital use across the campus.

➢ *Identified Issues in Internet Connection (Figure 5)*

Among the 98 respondents reporting connectivity problems (81.7% of the sample), the challenges are clearly identified: 82.7% cite insufficient bandwidth, confirming the previously noted perception of a slow connection; 10.2% report outdated equipment, indicating that network quality is also impacted by aging infrastructure (switches, routers, Wi-Fi access points); and 7.1% highlight an unsecured connection, raising concerns for data privacy and cybersecurity. These findings call for concrete and urgent measures to enhance bandwidth (through increased capacity and better allocation), renew aging network equipment, and improve access security (authentication protocols and intrusion protection) to ensure reliable and safe digital services on campus.

➢ *Need for Assistance in Internet Usage (Figure 6)*

A significant majority of respondents express the need for support in using the Internet. Specifically, 58.3% report needing occasional assistance, indicating a real but intermittent demand for technical or pedagogical guidance, while 26.7% require help frequently, including 0.8% who need it constantly, highlighting a lack of digital skills in nearly 28% of users. Only 14.2% report never needing assistance, a clear minority. These findings support the implementation of digital literacy training or workshops, the establishment of on-campus support points, and the promotion of self-learning tools such as tutorials, FAQs, and online guidance to enhance users' autonomy and competence.

Table 4 Cross-Analysis of User Status, Communicative Interactions, and Recreational Activities

		Status and Patterns of Social Media Use								**Total**
		Always	**Frequently**	**Regularly**	**Often**	**Occasionally**	**Sometimes**	**Rarely**	**Never**	
Category	Students	20	24	9	26	4	2	13	2	100
	Teachers	0	0	0	0	2	5	3	0	10
	Administrative Staff	2	3	2	1	2	0	0	0	10
Total		22	27	11	27	8	7	16	2	120

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		Status and Patterns of Instant Messaging Use								**Total**
		Always	**Frequently**	**Regularly**	**Often**	**Occasionally**	**Sometimes**	**Rarely**	**Never**	
Category	Students	13	12	17	7	29	9	3	10	100
	Teachers	0	0	0	0	2	3	4	1	10
	Administrative Staff	2	2	3	3	0	0	0	0	10
Total		15	14	20	10	31	12	7	11	120
		Status and Frequency of Online Gaming								**Total**
		Always	**Frequently**	**Regularly**	**Often**	**Occasionally**	**Sometimes**	**Rarely**	**Never**	
Category	Students	6	9	18	11	10	9	20	17	100
	Teachers	0	0	0	0	0	0	1	9	10
	Administrative Staff	0	0	0	0	0	0	5	5	10
Total		6	9	18	11	10	9	26	31	120

➢ *Use of Social Media by User Categories*

Students are the most active users, with 79% using social media often or always, mainly for communication, information, and academic exchange; only 15% use it rarely or never. Teachers engage minimally, mostly occasionally, reflecting professional caution or preference for traditional channels. Administrative staff show moderate, balanced use. These differences suggest social media is highly effective for reaching students, while alternative channels may better engage teachers and staff.

➢ *Instant Messaging Use*

Among students, 48% use instant messaging actively (always to often), 29% occasionally, and 13% rarely or never, indicating strong integration. Teachers show minimal use, with 9% reporting low or no activity, likely favoring email or face-to-face communication. Administrative staff are frequent users (80%), reflecting its role in rapid professional communication. Overall, students and staff are primary users, while teachers remain less engaged, highlighting a digital communication gap.

➢ *Email Use*

Students use email regularly (69%), occasionally (24%), or rarely (2%), showing its centrality in academic and administrative tasks. Teachers display moderate use, with 30% using it rarely or never. Administrative staff show diverse usage, with 60% frequent users and 40% less active. Email remains important but not always primary, emphasizing the need for cross-training in digital communication tools.

➢ *Online Gaming*

Among students, 44% play regularly, 19% occasionally, and 37% rarely or never, showing variable engagement. Teachers and administrative staff largely do not play (90% of teachers and 50% of staff never play), reflecting professional focus and differing digital leisure habits.

Table 5 Cross-Analysis of User Status and Usage in the Study

		File Sharing									**Total**
		Always	**Frequently**	**Regularly**	**Often**	**Occasionally**	**Sometimes**	**Rarely**	**Almost Never**	**Never**	
Category	Students	15	6	24	7	16	18	9	3	2	100
	Teachers	0	2	2	3	2	0	0	1	0	10
	Administrative Staff	0	1	1	1	4	1	2	0	0	10
Total		15	9	27	11	22	19	11	4	2	120
		Research									**Total**
		Always	**Frequently**	**Regularly**	**Often**	**Occasionally**	**Sometimes**	**Rarely**	**Almost Never**	**Never**	
Category	Students	13	13	1	14	8	12	20	18	1	100
	Teachers	5	3	2	0	0	0	0	0	0	10
	Administrative Staff	2	0	1	1	1	5	0	0	0	10
Total		20	16	4	15	9	17	20	18	1	120
		News									

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		Always	Frequently	Regularly	Often	Occasionally	Sometimes	Rarely	Almost Never	Never	Total
Category	Students	3	1	5	14	5	10	9	9	44	100
	Teachers	0	1	0	3	3	1	2	0	0	10
	Administrative Staff	1	2	0	1	1	0	5	0	0	10
Total		4	4	5	18	9	11	16	9	44	120
		Download									**Total**
		Always	**Frequently**	**Regularly**	**Often**	**Occasionally**	**Sometimes**	**Rarely**	**Almost Never**	**Never**	
Category	Students	7	20	16	9	19	6	11	7	5	100
	Teachers	2	2	5	1	0	0	0	0	0	10
	Administrative Staff	1	0	2	1	3	3	0	0	0	10
Total		10	22	23	11	22	9	11	7	5	120

➢ *File Sharing Practices across Institutional Roles*

Among students, 52% share files regularly or more frequently (ranging from always to often), indicating a routine academic use for reports, assignments, and group projects. About 43% do so only occasionally or rarely, while 5% report almost never or never sharing files.

Teachers display a moderate yet consistent practice, with most sending files frequently or often, though 10% rarely engage in this activity—possibly due to reliance on direct communication or alternative media such as USB drives and online learning platforms.

Administrative staff exhibit a more limited engagement, with only 30% reporting frequent or regular file transfers and 40% indicating sporadic use. This pattern suggests that administrative digitization remains partial. Overall, file exchange is primarily student-driven, underlining the need for efficient digital infrastructure and tools (e.g., Google Drive, OneDrive, Moodle) to support institutional digital transition.

➢ *Engagement in Online Research Activities*

Among students, 41% conduct research frequently to always (13% always, 13% frequently, 1% regularly, 14% often), while 12% do so occasionally, and 38% rarely or almost never. This imbalance suggests differing levels of engagement, potentially reflecting access inequalities or varying academic motivation.

Teachers show uniformly high research engagement: 100% report conducting online research at least regularly, with a majority doing so frequently or always. This strong integration of research practices aligns with their academic duties, including course preparation and scholarly writing, emphasizing the need for a stable, high-speed network.

Administrative personnel reveal more variable use: 30% conduct research regularly, 50% occasionally or rarely, and 20% almost never. This suggests functional use of the internet for specific administrative tasks rather than sustained research.

These contrasts highlight that research is a core and systematic activity among teachers, moderately practiced by students, and sporadic among administrators—calling for differentiated digital training and resource provision.

➢ *Access to Online News and Information*

Among students, 44% never consult online news, while 27% do so frequently or more, and the remainder occasionally. Teachers, in contrast, exhibit stronger engagement, with 40% consulting news regularly and none reporting total disinterest. Administrative staff show moderate participation: 30% consult frequently, 50% rarely or occasionally, and 20% never.

These differences indicate that information monitoring is least developed among students but more integrated among teachers and administrators—an important factor influencing institutional information flow and awareness.

➢ *Frequency of File Downloading*

Students demonstrate active downloading behavior: 43% download files regularly or more (7% always, 20% frequently, 16% regularly), 19% occasionally, and 23% rarely or almost never. This reflects a generally sustained academic use of digital materials.

Among teachers, 90% download files at least regularly, with distributed frequency across categories (2% always, 2% frequently, 5% regularly, 1% often). None report never downloading, confirming that digital access is integral to teaching and academic preparation.

Administrative staff show moderate engagement: of the 10 respondents, 4 download frequently or more (1 always, 2 regularly, 1 often), while 6 do so occasionally. No respondent reports complete non-use. This indicates gradual but uneven integration of digital document practices in administrative work.

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IV. DISCUSSION

The findings of this study provide valuable insights into the patterns of university network usage within the Malagasy context, where digital transformation unfolds amid a developing technological landscape. The predominance of students (83.3%) underscores the university's continued focus on undergraduate and master's programs, a factor that directly shapes digital demands, as these students heavily rely on online educational resources and electronic communication with instructors (OECD, 2021). In Madagascar, access to scientific information remains limited due to structural constraints related to connectivity and documentary resources (MADES, MESupReS, 2012). Consequently, the role of digital technologies in the student experience is magnified by the need to compensate for deficits in physical educational infrastructure, such as libraries, specialized classrooms, and laboratories.

- *Digital Practices: Diversity and Generational Gaps*

The investigation of digital practices at the École Normale Supérieure d'Antananarivo reveals substantial heterogeneity and pronounced generational disparities, particularly in the use of social media, messaging tools, and online learning resources. These differences reflect broader patterns documented in educational and workplace settings, where distinct generational cohorts display varying levels of digital proficiency, comfort, and reliance on technology (Orellana & Sánchez, 2025: Ferreira et al., 2015).

Among students, 63.3% report frequent use of social media, underscoring its central role in academic life, peer communication, community engagement, and, in some cases, informal pedagogical coordination (Junco, 2012). This reliance highlights how younger generations, including Millennials and Generation Z, seamlessly integrate digital tools into their daily routines and learning processes, using them to complement traditional educational methods (Ferreira et al., 2015). In the Malagasy context, where access to specialized educational infrastructure, libraries, and laboratories remains limited (MADES, MESupReS, 2012), social media and digital platforms assume an even more critical function in supporting learning, knowledge sharing, and academic networking.

Faculty engagement with these platforms, however, is markedly lower, reflecting a generational digital divide that has been documented in other contexts (Manca & Ranieri, 2016). Professors and instructors tend to favor more formal communication channels, such as email, for academic exchanges, highlighting the need for multi-channel strategies that accommodate the diverse technological behaviors, competencies, and expectations of different institutional roles.

Messaging practices further illustrate these contrasts: students primarily use instant messaging applications (e.g., WhatsApp, Messenger), which provide rapid, flexible, and informal communication, whereas faculty rely predominantly on email, perceived as more structured and academically appropriate (Walton et al., 2020). These differences underscore the importance of inclusive communication policies within universities, ensuring that academic announcements, instructional materials, and institutional updates effectively reach all stakeholders.

The generational disparities in digital engagement extend beyond communication, influencing the adoption of digital pedagogy, the use of collaborative platforms, and the design of learning environments (Dogan & Arslan, 2025).Within professional contexts, older cohorts often favor face-to-face interactions, whereas younger students and staff are more inclined toward digital collaboration tools, necessitating targeted training and institutional support to foster intergenerational cooperation and equitable participation (Choudhary et al., 2024).

Ultimately, while generational gaps pose challenges for harmonizing digital practices across institutional roles, they also present opportunities to cultivate intergenerational learning, innovation, and more effective integration of digital technologies in both academic and administrative functions, particularly in Madagascar's evolving higher education landscape.

- *Network Performance: Key Constraints on Pedagogical Use*

The findings from the École Normale Supérieure d'Antananarivo reveal widespread dissatisfaction with network performance, with 71.7% of users reporting slow and unstable internet connectivity. These technical shortcomings constitute a critical barrier to the effective integration of digital technologies in higher education and significantly constrain pedagogical innovation. In Madagascar, despite efforts by the national academic network, iRENALA, to interconnect research and teaching institutions, bandwidth remains insufficient to support intensive academic activities, including real-time video conferencing, access to large digital repositories, and collaborative online learning platforms (iRENALA, 2019).

Wi-Fi coverage, while expanding on university campuses, remains spatially uneven and concentrated in specific locations, creating zones of digital exclusion and inequitable access to online resources (Université d'Antananarivo, 2020). These infrastructural limitations impede students' engagement with virtual learning environments—such as MOOCs, virtual classrooms, and institutional platforms—and restrict faculty and administrative staff from fully adopting digitally mediated pedagogical practices. Consequently, network performance directly affects teaching and learning outcomes, emphasizing the need for reliable, high-speed, and widely accessible connectivity.

Key technical constraints further exacerbate these challenges. Network latency has been shown to negatively influence comprehension and engagement during interactive learning sessions. For instance, delays of up to 420 ms were found to impair students' understanding of complex concepts, such as Fourier analysis, though experience and choice of academic major can moderate these effects. Bandwidth

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limitations, often triggered by simultaneous high-demand usage, can create congestion and reduce performance, a particularly pressing issue in classrooms where multiple users access digital resources concurrently (Ma, 2013). Effective management of bandwidth using Quality of Service (QoS) strategies can mitigate these effects by prioritizing educational traffic, thereby enhancing user experience (Zhou, 2024).

Network architecture also plays a decisive role in enabling real-time interaction. Peer-to-peer systems, for example, have demonstrated advantages in reducing latency and facilitating collaborative learning compared with centralized networks (Kist et al., 2013). Optimizing network architecture is thus essential to ensure stability, support diverse educational needs, and foster equitable access to digital learning tools.

In the context of Madagascar, where digital infrastructure is still developing, these constraints are particularly salient. They highlight the urgent need for comprehensive institutional strategies, including investments in network capacity, broader Wi-Fi coverage, and architectural optimization. Addressing these challenges is not solely a technical matter; it is fundamental to enabling effective, inclusive, and sustainable digital pedagogy. By mitigating network limitations, Malagasy universities can foster active student engagement, enhance faculty adoption of digital teaching methods, and support a more equitable academic ecosystem, ultimately contributing to the broader digital transformation of higher education in the country.

- *Digital Security and User Competencies: An Overlooked Imperative*

The findings from the École Normale Supérieure d'Antananarivo reveal a pronounced deficit in critical digital literacy among university users. Specifically, 66.7% of respondents do not recognize the advertising function of cookies, and 74.2% show little concern for online tracking, reflecting a limited awareness of the implications of digital data collection (Tsohou et al., 2015). In Madagascar, where structured digital education programs remain sparse, particularly outside urban centers, these gaps are compounded by limited exposure to systematic cyber security training, despite initiatives such as ISOC Madagascar campaigns. The restricted reach of such programs underscores the need for more comprehensive and accessible interventions to cultivate responsible digital practices.

This lack of awareness exposes students and staff to multiple vulnerabilities, including unauthorized surveillance, data breaches, and cyberattacks. Risky behaviors such as poor password management, indiscriminate file sharing, and the use of unsecured networks further heighten exposure to threats, compromising both personal and institutional data. The results thus point to an urgent need for the integration of robust digital literacy and cybersecurity curricula within higher education, encompassing technical skills, responsible online behavior, and knowledge of data privacy protocols.

Understanding cyber threats is central to developing these competencies. Users must be familiar with prevalent risks, including malware, phishing, and ransomware, as well as advanced persistent threats and social engineering techniques, which require both awareness and critical evaluation to prevent compromise (Thakur, 2024); Aggarwal & Gupta, 2024). Implementing security measures—such as strong password management, multi-factor authentication (MFA), regular software updates, and encryption—remains essential for protecting sensitive academic and personal information (Đukić, 2025); Aggarwal & Gupta, 2024).

Equally important is fostering digital literacy and security awareness. Proficiency in assessing online information critically, understanding data privacy implications, and identifying potential threats allows users to navigate the digital environment safely and responsibly (Mujiono, 2024). In the Madagascar context, equipping students, faculty, and administrative staff with these skills is essential not only for individual protection but also for enhancing institutional resilience, ensuring that access to digital infrastructure translates into safe, responsible, and productive engagement.

Addressing digital security and competency gaps is both an educational and technical challenge. Universities in Madagascar must prioritize comprehensive training programs, supported by institutional policies and resources, to cultivate a culture of vigilance and cybersecurity. Failure to do so risks undermining the broader objectives of digital transformation and the integration of technology into teaching, learning, and administrative practices.

- *Digital Support Needs and Implications for Institutional Policies*

The finding that 85% of respondents at the École Normale Supérieure d'Antananarivo express a need for digital assistance highlights a pronounced gap in digital competencies that extends beyond equipment availability. In Madagascar, where universities face structural limitations in infrastructure and organized digital training, this deficit underscores the importance of comprehensive technical support, continuous training, and formalized helpdesk services (Unwin, 2019).

Despite students' substantial engagement with digital tools, persistent network constraints, generational differences, and cultural disparities continue to hinder effective use. Addressing these challenges requires simultaneous investment in technological infrastructure, network quality, and systematic training initiatives, aligning with broader evidence from Africa and developing regions where digital capacity is limited by structural and human resource factors (World Bank, 2021; UNESCO, 2022).

Integrating digital literacy into curricula is essential to prepare students for technology-enhanced learning, academic research, and collaborative practices (Sharpe & Benfield, 2012). Furthermore, targeted improvements in campus connectivity and learning spaces are necessary to ensure

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equitable access for students and faculty and to support innovative pedagogical approaches (Sharif et al., 2025).

Engaging stakeholders in decision-making enhances the responsiveness and relevance of institutional policies, while continuous evaluation ensures adaptation to rapidly evolving technological demands (Sharif et al., 2025). In Madagascar, these findings emphasize the need for coordinated strategies that integrate infrastructure, skills development, and institutional support, fostering an inclusive, competent, and resilient digital academic environment.

V. CONCLUSION

This study at the École Normale Supérieure d'Antananarivo provides a nuanced understanding of how students, faculty, teachers and administrative staff engage with the university's IT network and the conditions necessary for effective digital use. The findings reveal that, although users demonstrate basic familiarity with digital tools, their needs remain largely unmet, shaped by generational disparities, uneven digital competencies, and infrastructural limitations. Persistent network challenges—slow speeds, instability, and outdated equipment—significantly constrain core activities, including research, file sharing, messaging, and online learning. Students, who constitute the majority of users, report a pronounced need for guidance, structured training, and technical support, while faculty and administrative staff emphasize the importance of systems tailored to professional tasks. Furthermore, limited awareness of cybersecurity and data privacy highlights an urgent requirement for targeted education to foster responsible and safe engagement with digital resources.

In the Malagasy context, where universities often face structural constraints in both infrastructure and digital capacity, these findings underscore the necessity of integrated strategies that combine technological upgrades, expanded network coverage, and comprehensive training initiatives. Such interventions should be informed by the needs of users across generational and institutional roles, ensuring equitable participation in the university's digital ecosystem. These challenges reflect broader trends across sub-Saharan Africa, where infrastructure limitations intersect with gaps in digital literacy, shaping the effectiveness of higher education in technology-mediated environments. Addressing them requires coordinated policies that simultaneously enhance infrastructure, embed digital skills development, and provide institutional support.

This study raises a critical question for future research: *how can Malagasy universities design and implement digital strategies that simultaneously strengthen technological capacity and cultivate digital competencies for all users, ensuring both equitable access and effective engagement?*

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