

ARTIFICIAL INTELLIGENCE INFRASTRUCTURE AND IT'S ENABLE TECHNOLOGIES

Ningthoujam Keinahanbi Devi,
Ph.D. Scholar,
Department Computer Science,
Arunodaya University, Itanagar, India
E-mail: keinahanbiningthou@gmail.com

Sanasam Bimol ,
Assistant Professor,
Department Physics,
Kamakhya Pemton College, Hiyangthang, India
E-mail: bimpusana@gmail.com

R.M. Krishna Sureddi ,
Associate Professor,
Department Computer Science,
Arunodaya University, Itanagar, India
E-mail: Krishna.murali564@gmail.com

Abstract: The necessity of infrastructure related to Artificial Intelligence (AI) and all its enabling technologies has allowed increasing development, implementation and use of AI in various fields like education, medicine, business, and research. AI refers to infrastructure including computing devices and facilities, as well as data storage, means of computer networks, cloud computing, and computer programs ensuring proper functioning of AI applications. All the enabling technologies including such famous things as machine learning, deep learning, natural language processing, computer vision and mere generative AI have broadened the pie of capabilities of AI systems and opened doors for numerous innovations. The paper describes basic components forming AI infrastructure, its evolution in India as well as worldwide trends, and possible directions for the future. The paper also is dedicated to demonstrating the importance of AI infrastructure in the area of education and research, including personalized education, its concerns connected with administration, and usage of data in decision-making processes. At the same time, the text presents various challenges faced while developing AI infrastructure, starting from high costs of the systems and ending with low level of access to the technology.

Keywords: Artificial Intelligence, Higher education, Cloud Computing, Infrastructure, Enable technology, Educational Institutions

I. INTRODUCTION

Artificial Intelligence refers to computer systems' ability to carry out work typically completed by humans, including learning, reasoning, understanding languages, making predictions, and making decisions. The development of the technology responsible for AI operations has advanced using machine learning, deep learning, and generative AI making it possible for computer systems to work more efficiently by processing bigger amounts of data, detecting trends in data, creating output, and helping to do more challenging work. These systems need special hardware and software to function properly, as well as the necessary data and networks, along with governance and algorithms [1].

AI infrastructure refers to all computing capabilities, data and information handling systems, communication systems, software and security technologies that allow creation and implementation of artificial intelligence solutions. Most AI systems rely upon high-performance computers as well as

graphics and tensor processing units due to computational intensity of machine learning and deep learning. Such types of processors ensure parallel processing and quick performance of complex AI systems [2].

In computing technology, the entire hardware system needed for creating, training, deploying, operating, and maintaining AI solutions is understood as AI infrastructure. It includes all of the systems allowing AI applications to be properly used [1]. Discussing the significance of AI infrastructure in the higher education field, it needs to be mentioned that teaching, learning, testing, scientific research, and administration can greatly benefit from using AI. Therefore, it is important to have all the necessary infrastructure for deploying AI solutions correctly from the side of everyone starting from us and up to higher education institutions and organizations [3].

II. CONCEPT OF ARTIFICIAL INTELLIGENCE INFRASTRUCTURE

AI infrastructure refers to the collective infrastructure (data, hardware, software, networking, security, infrastructure, cloud, edge, device, etc.) used to support the deployment and use of AI applications. From a technical perspective, it acts as a cornerstone for the development and deployment of machine learning applications, process raw data at scale, and extend the functionality of any number of human-technology interactions.

AI technology is transforming various fields such as Higher Education, Healthcare, Business and Government sectors. The use of any AI system successfully is based on having the right infrastructure (i.e., computing hardware, cloud platform, networking systems, data storage, software framework) to deploy, train and scale AI applications [4]. In addition, conventional IT infrastructure which focuses on standard data processing and business operations. AI infrastructure is tailored to handle extensive datasets, intricate algorithms and real-time analytics [5].

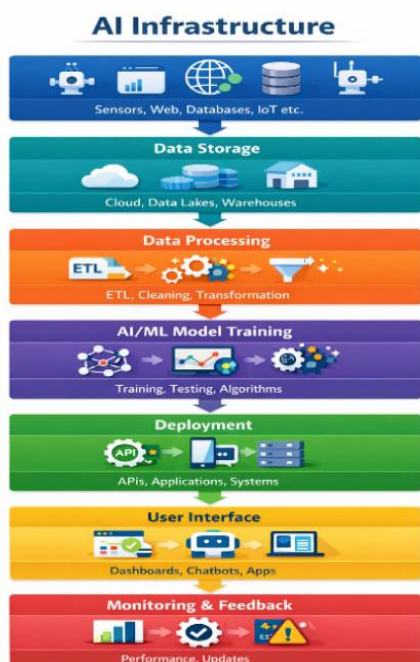


Figure 1. Artificial Intelligence Infrastructure

III. AI INFRASTRUCTURE CORE COMPONENTS

A. Computing hardware

Computing hardware provides the necessary processing capacity for training, testing and implementing AI systems. CPUs, GPUs and TPUs have distinct roles in processing data but GPUs and TPUs are especially suitable for various machine

learning and parallel processing problems. High-performance computing systems enable advanced AI research and data analysis as well as implementation of educational applications that require a lot of computation. Availability of necessary processing capacities should thus be taken into account while planning AI infrastructure.

B. Data Storage

It support the able to collect, retrieve, process, secure and manage data that an AI system might utilize. For instance, academic institutions can utilize such data for storing student records, grades, research outcomes, eLearning material, etc. In order to accomplish this, educational institutions need reliable solutions and effective data management practices to maintain high quality, availability and confidentiality of data.

C. Cloud Computing Infrastructure

Cloud computing means that the computer processing power, storage, network and AI services are available remotely. The cloud services offered by Amazon Web Services, Microsoft Azure and Google Cloud enable institutions to add capacity to their computers as needed. An institution need not make a large investment initially in local infrastructure and can make use of pay-as-you-go cloud computing infrastructure. The costs will however ultimately depend on the computing resource usage, the amount of storage, data transfer requirements and service prices. Cloud computing infrastructure can offer a flexible option for an institution looking to implement AI without needing to run all the necessary computer hardware in-house [6].

D. Networking and AI-Enabled Learning Platforms

For the use of AI on the cloud and transfer of data, adequate bandwidth, robust internet connectivity and network infrastructure is a must. Good internet connectivity and network infrastructure forms the backbone of building communication and collaboration between students, research scholars, faculty members, and administrators. Learning management systems (LMSs) like Moodle and Canvas can be combined with AI tools to deliver personalised learning, automated feedback, learning analytics and digital collaboration. These features are as per the different AI tools, their integrations, and institutional setup implementation. E-khool can also be cited as an e-learning platform if the sources provided are valid sources [7].

E. Software Platforms, cybersecurity, and technical expertise

AI software platforms encompass programming environments, machine learning platforms, libraries, application programming interfaces (APIs), and model deployment tools that are used to build and manage AI applications. Technologies like cybersecurity tools – authentication, authorization, encryption, and monitoring – are designed to secure institutional data and reduce the likelihood of insider breaches. Technical expertise – technological know-how is just as critical, since an institution needs talent to set up the infrastructure, maintain the software, manage data, respond to security challenges, and support faculty and students using the AI applications.

IV. AI INFRASTRUCTURE IN THE INDIAN CONTEXT

The Government of India considers the improvement of digital and AI-driven infrastructure as a vital facilitator for the transformation of Higher Education. The Ministry of Education has launched a National Digital Education Architecture (NDEAR). The NDEAR is intended to provide an interoperable, unified, secure, scalable architecture for digital learning through AI and interoperability [8]. Furthermore, NDEAR can create opportunities to access digital content and apply cutting-edge technologies in education. Another example of a scalable technological platform aimed at increasing access to higher education is the planned National Digital University, which provides quality education [9].

Institutions should develop the infrastructure for using AI in higher education through investment in research and development of AI, high-performance computing, cloud computing, digital learning (software & applications), etc. IIT Madras is an example of the same. IIT is working on research & development of high-performance computing and robotics research and has made notable progress in deploying such technologies for higher education [10]. Similarly, there is growing evidence of using cloud-based learning management systems and AI-enabled educational software/ tools in enabling personalized learning, learning analytics, digital collaboration, and student engagement, when the relevant tools and integrations are available. All these calls for an integrated AI infrastructure comprising the computing hardware, GPU-enabled processing, cloud computing, reliable networking, safe data storage, and well-trained personnel. However, one cannot overlook some of the limiting factors such as financial resources, internet access, institutional readiness, and existing technical expertise that could hinder the implementation of such technologies in some universities/ colleges of this region.

Therefore, the Indian experience justifies the need for developing a scalable, secure, and affordable AI infrastructure that caters to the heterogeneous needs of students and teachers, more so in resource-constrained small states like Manipur.

V. GLOBAL PERSPECTIVE OF AI INFRASTRUCTURE

Governments and academia around the world are turning their attention towards available computing infrastructure in order to secure the quantity of computing capacity required for fundamental and applied academic research, as well as to support the development of AI in higher education. For example, the European Commission [11] highlights in its Coordinated Plan on Artificial Intelligence, that investment in computing infrastructure, data resources, and cloud services could increase AI performance in Europe. Top research-focused US universities, such as Stanford University and Massachusetts Institute of Technology (MIT) [12], have put in place the needed technology and research infrastructure to enable them to conduct machine learning- and data-based research.

Nevertheless, it is important to note that the mere availability of computational power is not enough to build an effective AI infrastructure. Connectivity has to be consistent, the infrastructure for data provision should be present, technical knowledge and expertise should exist, and the systems should be safe, having mechanisms for equitable AI technologies access. UNESCO [13] stated that accessibility and human-center should be the main principles of any AI development, as it is indicated that ‘the inequalities caused by access to AI technologies need to be considered’. Thus, AI infrastructure development in higher education should be based on computing power, safe cloud storage, efficient data storage, high-speed connectivity, and applicable governance procedures. These priorities also apply to institutions that lack the necessary digital and technical infrastructure; cloud-based infrastructure and distributed computing facilities may be alternative ways of gaining access to computational power. A sustainable, secure and inclusive AI infrastructure can support higher education innovation, research, teaching and learning.

VI. ENABLING TECHNOLOGIES OF AI

A. Machine Learning (ML) and Deep Learning (DL)

These two foundational technologies are the key technologies for AI. These two systems allow to learn through experience from large amounts of data without writing programming, enabling continued improvement. According to Goodfellow, Bengio, & Courville, [14] it can be seen as an adaptive learning

platform in higher education, predictive analytics, and recommendation engines.

B. Natural Language Processing (NLP)

It is a core technology for AI because it provides the means for machines to read, comprehend, and produce human language, including chatbots, automated essay evaluation, and online translation of languages. For example, many Indian E-khool LMS platforms are using NLP to generate individualized feedback to enhance student participation and engagement with the platform [6].

C. Computer Vision (CV)

It is a critical technology required by AI with respect to the machine's ability to interpret visual information from images and videos. In respect to education, examples of AI CV technologies include AI proctoring and attendance systems for education, as well as AI systems to help physically correct someone's posture while doing yoga and during physical education [15].

D. Intelligent Agents and Robotics

Robotic systems allow physical work autonomy by integrating both artificial intelligence and mechanical engineering, however while robotics has become a common tool in manufacturing and healthcare; robotics-based education is showing increased adoption rates in educating children in STEM areas and creating simulated laboratory environments [16].

E. Big Data and Cloud Computing

Cloud computing allows for the integration of applications and data required to manage large sets of data, which makes up a major part of Artificial Intelligence use; using big data analytics allows educational institutions to analyze student behaviour, academic performance and institutional progress [17][2].

F. Internet of Things (IoT)

By combining AI capabilities and sensors together in an IoT environment, real time data collection and analysis can be achieved. Smart campuses utilize sensors with AI interface on energy efficiency, safety and classroom management [18].

Artificial Intelligence is a convergence of human-like cognitive capability, but with advanced computing systems. This

convergence highlights the central pillars; being adaptivity, learning and decision making, as foundational definitions to Artificial Intelligence. However, AI achieves its full potential through the technological enablement of Machine Learning, Natural Language Processing, Computer Vision, Robotics, Cloud Computing, Big Data and Internet of Things; that jointly combine together to provide the foundation of what will be considered Intelligent Systems. In regards to education; both India and countries around the world have been fundamentally changed by these enabling technologies, to create a more personalized, data driven and inclusive educational landscape. These technologies depend on complementary resources such as cloud infrastructure, high-performing computing, GPUs, faster access to high-speed connectivity, datasets, and application development frameworks. In higher their integration education their integration can support personalised learning, intelligent tutoring, research assist, digital library services, and administrative automation. However, their effectiveness depends on the quality of training data, computational resources, appropriate system design, and institutional readiness.

VII. APPLICATIONS AND SIGNIFICANCE OF AI IN HIGHER EDUCATION

Artificial Intelligence (AI) is being used to innovate higher education through different ways of teaching and learning, research, student support, and institutional administration and management. Educational AI systems leverage AI to diagnose students' learning needs, track learning activities, suggest relevant learning resources, provide feedback, and cater to the needs of individual students. Zawacki-Richter et al. [3] in a systematic review of applications of AI in HE, cited profiling and prediction, assessment and evaluation, adaptive systems and personalisation, and intelligent tutoring systems are the significant areas of applications of AI in HE. AI can be used to facilitate academic research including literature searching, data analysis, extracting information, and supportive scientific writing. In the context of institutional administration and management, student engagement and support, planning of resources, student enrolment management, and institutional data analysis can be areas of application of AI. The adoption of AI would require digital infrastructure, AI literacy among faculty members, financial investments, technical support, and institutional policies; along with addressing the ethical considerations around transparency and accountability, privacy, and data protection, bias and fairness, and academic integrity. UNESCO [13] stresses the need for a human-centred approach to generative AI in education and research that involves appropriate safeguards and makes institutions ready to leverage

the potential of AI. It is important to understand that for the HEIs in India, especially the resource-scarce ones, the use of cloud-based AI tools could enable participation in the AI ecosystem by accessing applications without investing in all the computing infrastructure needed to support those applications. In other words, adoption of AI should not be viewed solely as introduction of AI based tools but as an interplay of technology, institutions, users, and governance.

VIII. CLIMITATION OF ARTIFICIAL INTELLIGENT IN HIGHER EDUCATION BY SUITABLE INFRASTRUCTURE

Artificial Intelligence (AI) is being used to innovate higher education through different ways of teaching and learning, research, student support, and institutional administration and management. Educational AI systems leverage AI to diagnose students' learning needs, track learning activities, suggest relevant learning resources, provide feedback, and cater to the needs of individual students. Zawacki-Richter et al. [3] in a systematic review of applications of AI in HE, cited profiling and prediction, assessment and evaluation, adaptive systems and personalisation, and intelligent tutoring systems are the significant areas of applications of AI in HE. AI can be used to facilitate academic research including literature searching, data analysis, extracting information, and supportive scientific writing. In the context of institutional administration and management, student engagement and support, planning of resources, student enrolment management, and institutional data analysis can be areas of application of AI. The adoption of AI would require digital infrastructure, AI literacy among faculty members, financial investments, technical support, and institutional policies; along with addressing the ethical considerations around transparency and accountability, privacy, and data protection, bias and fairness, and academic integrity. UNESCO [13] stresses the need for a human-centered approach to generative AI in education and research that involves appropriate safeguards and makes institutions ready to leverage the potential of AI. It is important to understand that for the HEIs in India, especially the resource-scarce ones, the use of cloud-based AI tools could enable participation in the AI ecosystem by accessing applications without investing in all the computing infrastructure needed to support those applications. In other words, adoption of AI should not be viewed solely as introduction of AI based tools but as an interplay of technology, institutions, users, and governance.

IX. LIMITATION OF AI IN HIGHER EDUCATION OVERCOME BY SUITABLE INFRASTRUCTURE INVESTMENT

Higher education's use of Artificial Intelligence (AI) has many constraints, such as high computational needs, worries about security and privacy of data, difficulties integrating AI into various aspects of academia, and the lack of available trained professionals or human resources to manage and use AI effectively. However, there are ways through careful investment into the right kind of infrastructure (such as cloud computing; high-performance computing (HPC); data center; and digital connectivity) that these limitations can be overcome to a great extent.

One of the biggest barriers to the implementation of AI systems is their need for a lot of computer processing power and data storage. Many conventional on-premise servers do not have the capability to manage large AI applications. Cloud-based technology offers institutions of higher education all of the advantages of cloud computing's flexibility and scalability without requiring universities to invest heavily in their own infrastructure. For example, NVIDIA worked with the Indian Institute of Technology (IIT) Madras to open the NVIDIA AI Research Centre, which has created highly-effective computing facilities based on NVIDIA Graphics Processing Units (GPUs), for both education and research [10]. Stanford University and the Massachusetts Institute of Technology (MIT) are also taking steps globally to develop supercomputing centres that are strictly dedicated to supporting the worldwide growth of AI through advanced machine learning techniques [12].

Another limit to AI systems is the increased risk to manage and protect data. The use of AI in higher education will require the use of very sensitive data about students and institutions. By establishing secured cloud-based infrastructures designed to meet international compliance standards (for example, GDPR and ISO/IEC 27001) will help to eliminate many of those risks. The Ministry of Education (Government of India) has instituted the National Digital Education Architecture (NDEAR) to develop a single, secure digital infrastructure for AI-based education [8]. Microsoft Azure AI and Google Cloud AI provide the technology in their platforms to support secured data storage, encryption, and compliance to build trust in AI systems on a global scale.

Another limitation on the use of AI in education is exclusion and lack of access. Rural and disadvantaged areas do not have adequate infrastructure to effectively use AI-powered tools. Still, there are not enough qualified people available to

implement AI in higher education. Along with infrastructure investments, there are capacity building projects, like the All-India Council of Technical Education's (AICTE) AI and data science initiatives and the EU's AI skills and education framework [11]. These capacity-building initiatives offer an essential complement to educational infrastructure improvements. Therefore, although there are numerous barriers to implementing AI in higher education, infrastructure investments (whether physical or cloud based) will significantly mitigate these barriers, thereby allowing for the long-term creation of equitable, secure and sustainable AI-fuelled education.

X. FUTURE DIRECTION OF AI ADOPTION IN HIGHER EDUCATION INSTITUTIONS

The future of Artificial Intelligence (AI) adoption in higher education institutions is expected to focus on personalised learning, intelligent tutoring systems, automated administrative services, research support, and data-driven decision-making. Advances in machine learning, generative AI, and cloud computing may enable institutions to provide more flexible, accessible, and efficient educational services. Zawacki-Richter et al. [3] identified several applications of AI in higher education, including student profiling, prediction, assessment, and adaptive learning. However, successful adoption will require adequate digital infrastructure, faculty training, institutional readiness, and effective policies for data privacy, cybersecurity, and academic integrity. UNESCO [13] also emphasises the importance of a human-centered approach to generative AI in education and research. In the future, higher education institutions should prioritise responsible AI use, continuous evaluation, and collaboration among educators, researchers, administrators, and technology developers. For institutions in Manipur, context-specific cloud-based AI solutions may help address resource limitations and improve access to educational technologies, provided that reliable connectivity, technical support, and sustainable funding are available.

XI. CONCLUSION

AI infrastructure and its enabling technologies provide the foundation for developing, deploying, and maintaining intelligent systems across education, research, business, healthcare, and other sectors. The principal components include computing hardware, data storage and management, cloud computing, networking, software platforms, cybersecurity, and governance mechanisms. Technologies such as machine learning, deep learning, natural language processing, computer

vision, and generative AI expand the range of applications that can be developed using this infrastructure.

In higher education, AI infrastructure can support personalised learning, research, knowledge sharing, institutional administration, and data-driven decision-making. However, these opportunities depend on reliable connectivity, appropriate computing resources, high-quality data, skilled personnel, and responsible institutional practices. High costs, unequal access, privacy risks, cybersecurity threats, ethical concerns, and environmental demands remain important challenges.

India's AI development programs offer a chance for broader investments in computing, research, innovation and skills. Cloud infrastructure offers a particularly attractive way for resource-constrained higher education institutions to access and implement AI services flexibly. Its adoption would have to be accompanied by a strategic approach, contextualised design, responsible data use, capacity-building and ongoing assessment. Further research could explore the level of organizational readiness, prototype pilots, stakeholder perceptions, and the cost, benefit, and risk of deployment. The real promise of AI is not just in technology but in broad access, human skills, ethical governance, and institutional sustainability.

XII. ACKNOWLEDGEMENT

We would like to thank all the authors cited here whose valuable contributions and scholarly works have supported this paper development. Without their contributions to the field, this paper could not come out in this present form. We would also like to express our gratitude to authors whose works may not be specifically cited in this study but whose ideas and suggestions helped shape this paper.

XIII. REFERENCES

- [1] OECD. (2023). *OECD digital education outlook 2023: Towards an effective digital education ecosystem*. OECD Publishing. <https://doi.org/10.1787/c74f03de-en> OECD
- [2] Google Cloud. (2022). Google Cloud AI and machine learning. <https://cloud.google.com/products/ai>
- [3] Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—Where are the educators? *International Journal of Educational Technology in Higher Education*, 16, Article 39. <https://doi.org/10.1186/s41239-019-0171-0>

- [4] Gartner. (2021). AI infrastructure: Trends and requirements for enterprises. Gartner Research
- [5] Kumar, R., & Singh, A. (2020). Artificial intelligence infrastructure: Emerging needs for higher education in India. *International Journal of Emerging Technologies in Learning*, 15(22),
- [6] Mell, P., & Grance, T. (2011). *The NIST definition of cloud computing* (Special Publication 800-145). National Institute of Standards and Technology, Report, 2011.
- [7] E-Khool. (2024). Artificial intelligence in education: Applications and trends. <https://ekhool.com>
- [8] MoE. (2021). National Digital Education Architecture (NDEAR): Building digital infrastructure for education. Ministry of Education, Government of India. Retrieved from (<https://www.education.gov.in>)
- [9] UGC. (2023). National Digital University: Empowering higher education through digital infrastructure. University Grants Commission. Retrieved from <https://www.ugc.ac.in/ndu>
- [10] IIT Madras. (2022). IIT Madras partners with NVIDIA to set up AI Research Centre. Indian Institute of Technology Madras. Retrieved from (<https://www.iitm.ac.in>)
- [11] European Commission. (2021). Coordinated plan on artificial intelligence 2021 review. Publications Office of the European Union. (<https://doi.org/10.2759/111510>)
- [12] MIT. (2021). MIT launches supercomputing cluster for AI research. Massachusetts Institute of Technology. Retrieved from (<https://news.mit.edu>)
- [13] UNESCO. (2021). AI and education: Guidance for policy-makers. United Nations Educational, Scientific and Cultural Organization. Paris: UNESCO Publishing.
- [14] Ian Goodfellow, I., Yoshua Bengio, Y., & Aaron Courville, A. (2016). *Deep learning*. MIT Press.
- [15] Raman, A., et al. (2019). Artificial intelligence in higher education: Opportunities and challenges. *International Journal of Educational Technology in Higher Education*
- [16] Kaplan, A., & Haenlein, M, "Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence," *Business Horizons*, vol. 62, no. 1, pp.15–25, 2019.
- [17] IBM. (2022). *What is artificial intelligence (AI)?* <https://www.ibm.com/think/topics/artificial-intelligence>
- [18] MeitY (2021). Ministry of Electronics and Information Technology. *Artificial intelligence initiatives in India*. Government of India.

AUTHOR PROFILES



Mrs. N. Keinahanbi Devi obtained T.D.C. (Computer Sc. Hons.), Master in Computer Application from Manipur University, Manipur, India and she is currently pursuing Ph.D. in Computer Science at Arunodaya University, Itanagar, Arunachal Pradesh, India. She has presented many papers at National and International Conference and actively participated various seminars and workshops. Her current research interests include cloud computing, artificial intelligence, Software Engineering and Database System. She has published research papers in international conference proceedings and journals. Presently she is working as Assistant professor at S.Kula Women's College, Nambol, Manipur, India.



Dr. Sanasam Bimol obtained T.D.C (Computer Sc. Hons.), MCM, MPM, DBD from Manipur University and University of Pune, and M.Phil (Computer Sc.) and Ph.D (Computer Sc.), India. He was served as an approved lecturer in Department of Computer and Management at MPIM, University of Pune. He was Faculty Head, Department of Computer Science. Moirang College, Government of Manipur. He has industrial experience in Master Computer Pvt. Ltd. Ahmednagar (MS). Currently, He is working as a faculty at Kamakhya Pemton College, Hiyangthang, Manipur. He has published Book chapters and research papers in National and International Journals and Conference proceedings (IEEE, Springer proceedings and SCOPUS journals).



Dr. R.M. Krishna Sureddi obtained B.Tech (Computer Sc.), M. Tech Computer Sc. and Engineering (Gold Medalist), from G.V.P. College of engineering affiliated to JNTU and Ph.D Kakinada, India. He published Book chapters and many research articles in National and International journal and Conference proceedings. At present, he is actively participated various seminars and workshops. He also completed many minor and major projects and received many awards in his credit. His current research interests include Computer Networking, Intelligent Systems, and Network Optimization.