Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2021, 8(4):121-128**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Introduction to Agriculture 4.0

Matthew N. O. Sadiku[1], Uwakwe C. Chukwu[2], Abayomi Ajayi-Majebi[3], Sarhan M. Musa[1]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Department of Engineering Technology, South Carolina State University, Orangeburg, SC, USA
[3]Department of Manufacturing Engineering, Central State University, P.O. Box 1004, Wilberforce, OH, USA
Email: sadiku@ieee.org; uchukwu@scsu.edu; ajayi-majebi@centralstate.edu

Abstract Agriculture 4.0 consists of emerging technologies such as Internet of things, artificial intelligence, robotics, nanotechnology, and blockchain. These technologies fit well into sustainable agriculture. It is the term for the trends facing the agriculture industry. It will not rely only on water, fertilizers, and pesticides, but farmers will use the minimum amounts or even remove them from the supply chain entirely. This paper provides an introduction to the concept of Agriculture 4.0 and the challenges it faces.

Keywords Agriculture 4.0, Farming 4.0, Industry 4.0, Fourth Agrarian Revolution, Green Revolution 2.0

Introduction

Farming is central to every nation´s economy. Humans survive on food that comes from plant or animal. Technology plays a big role in every economic sector. Technology is changing the world, and agriculture is catching up. The adoption of technology in recent years has accelerated production agriculture, boosted productivity, enhanced the efficiency of agriculture, improved the accuracy of the food supply, and contributed to enhancing food security and prosperity. Technology has radically transformed the agriculture industry for the past 50 years.

Smart technology is the future of agriculture. If agriculture is to feed an estimated nine billion people by 2050, it needs to become smart. Looking for better and smarter ways to grow food is imperative. That translates to finding solutions that increase productivity for farmers. The agriculture industry must embrace a digital transformation enabled by connectivity. Without a solid connectivity infrastructure, smart farming is not possible.

The major challenges facing agriculture in the near future include connectivity in farming, demographics (population growth), scarcity of natural resources, climate change, and food waste. These challenges can be met without disrupting the system. The challenges necessitate new agricultural revolution that must enable technologies to boost production while ing environmentally sustainable. Humanity needs such a new agricultural revolution that is centered on reconciling the need to produce enough nutrition for the growing human population. We need to produce more food on less land and with fewer inputs.

Industry 4.0

Industry 4.0 and Agriculture 4.0 emerged recently. The notion of Agriculture 4.0 draws on the term "Industry 4.0". Industry 4.0 technologies assists to overlay an efficient, optimize cost. Industry 4.0 has expanded tremendously and has become a more general concept with mainstream appeal and applicability. This is evident from a multitude of neologisms such Education 4.0, Agriculture 4.0, Healthcare Logistics 4.0, University 4.0, Marketing 4.0, Retail 4.0, Fashion 4.0, Care 4.0, etc. [1].

Industry 4.0 (sometimes known as the 4th Industrial Revolution) refers to the current trend of automation and employment of Internet-based technologies in manufacturing. The first industrial revolution witnessed the transition from handmade agricultural production to mechanical large-scale factory in the 19th Century. The second spanned the period from the 1850s to World War I and saw the age of steam power and electrification of factories. The third industrial revolution took place from late 1950s to late 1970s and saw the age of computerization, a change from analog technology to digital technology. Finally, the fourth industrial revolution is the move towards full digitization and automation of manufacturing processes and is happening right now [2].

As shown in Figure 1 [3], the required technologies for Industry 4.0 transformation include cloud computing technologies, Internet of things (IoT) technologies or industrial Internet of things (IIoT), cyber physical systems (CPS), advanced materials, additive manufacturing, cloud manufacturing, artificial intelligence, machine learning, cybersecurity, big data analytics, cognitive computing, autonomous robots, and mobile services. Industry 4.0 is the new manufacturing objectives with the aim of achieving nearly zero-defects production in the manufacturing industry. Smart technologies are at the forefront of Industry 4.0 [4]. Figure 2 illustrates Industry 4.0 [5].

Figure 1: Key technologies for Industry 4.0 [3]

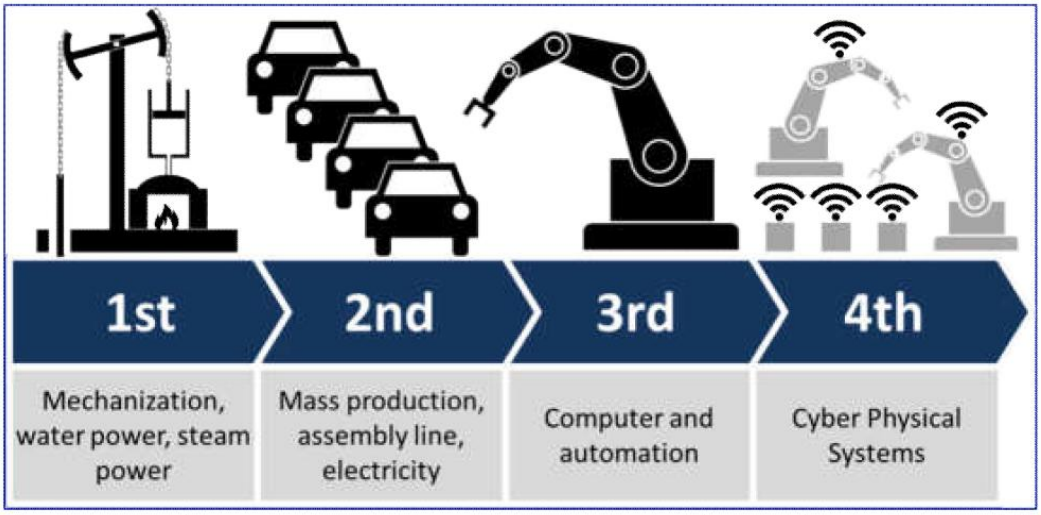

Figure 2: Industry 4.0 - The 4th Industrial Revolution [5]

Agricultural Revolutions

Over the years, agriculture has undergone many revolutions around the world. Each agricultural revolution is radical. It is also a double-edged sword because it has some potential advantages and disadvantages. The first revolution witnessed hunter-gatherers move towards settled agriculture; the second revolution was characterized as part of the British Agricultural Revolution; and the third revolution involves production changes in the developing world with the Green Revolution. At the moment, Agriculture is emerging. It refers to a wide range of technologies and connected to ideas on the Fourth Industrial Revolution or Industry 4.0 [6,7]

- ***Agriculture 1.0***: This describes agriculture from ancient times to about 1920, when farming was essentially with a lot of manual labor. It is still rooted in traditional ways and is labor intensive.
- ***Agriculture 2.0***: This represents a transition from hunting and gathering to settled farming (from 1920 to 2010), where machines, fertilizers, and better seeds helped farmers produce more with less effort. It has also pushed farming in the economic edge and produce plenty of cheap food.
- ***Agriculture 3.0:*** This is the time when high-tech sensors, cloud computing, specialized software, and the Internet of things are being integrated into farming. The Green Revolution of the mid-20th century could be considered the third agricultural revolution. Data becomes crucial in this age of agriculture. The data gathered will be used to help farmers make more efficient use of their land, water, and fertilizer.
- ***Agriculture 4.0***: The concept of Agriculture 4.0 originated as an analogy to the term Industry 4.0, which was coined by the German industry. This term "Agriculture 4.0" is used by the World Government Summit. It is connected with sustainable agriculture. Some regard Agriculture 4.0 as "Green Revolution 2.0." Figure 3 shows multiple perspectives of Agriculture 4.0 [8].
- ***Agriculture 5.0:*** This is still under development. We must transition through the digital agricultural revolution into agriculture 5.0.

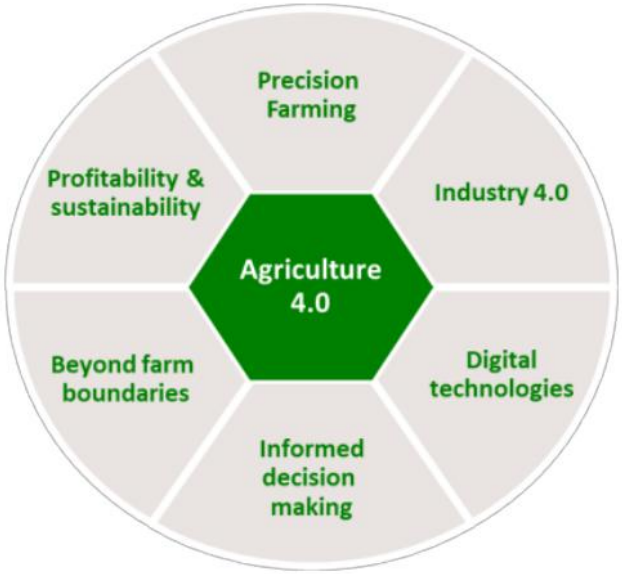

Figure 3: Multiple perspectives of Agriculture 4.0 [7].

It is interesting to observe that these agricultural revolution are being practiced in various places on earth.

What is Agriculture 4.0?

Agriculture 4.0 denotes the next step forward in agriculture: a smarter, more efficient industry that makes full use of new technologies to benefit the whole supply chain. It is the term for the trends facing the agriculture industry, including a greater focus on emerging technologies such as robotics, nanotechnology, cellular agriculture, precision agriculture, digital agriculture, vertical farming, the Internet of things (IoT), artificial intelligence, blockchain, and big data. Some of these enabling technologies are discussed as follows.

- *Internet of things:* Today, our refrigerators, our light bulbs, etc., are all connected and the same is true for farm implements. Farm devices utilization of IoT is becoming the norm. IoT sensors measure soil humidity. For example, smartphones can be used for remote monitoring of equipment, crops, and livestock.
- *Big Data:* Data is the medium by which the agriculture industry can move to next level of sustainability and profitability. In Agriculture 4.0, companies can take advantage of big data analysis and smart sensor technologies.
- *Precision agriculture:* This involves applying what is needed when and where is needed. It enables farmers to do more with less. Precision agriculture can identify parts of a farm that will deliver an investment return or would be better delivering sustainability. Efficiency and productivity will increase in the coming years as precision agriculture becomes bigger.
- *Drones:* Agriculture has been using drones for more than two decades. Crop tracking drones have changed farming business. They can deliver precise interventions like fertilizers, nutrients, and pesticides where crops most need them. Drones become handy tools when farmers need to view the field in its entirety without walking the distance.

These and other technological breakthroughs are making significant disruptor. They have changed the business of agriculture and altered agriculture beyond recognition. It has been observed that Agriculture 4.0 has the potential to be disruptive and transformative in several ways. Some regarded Agriculture 4.0 as part of a Digital Agriculture Revolution which may eventually lead to Agriculture 5.0. Figure 4 shows the distribution of Agriculture 4.0 applications domains [9].

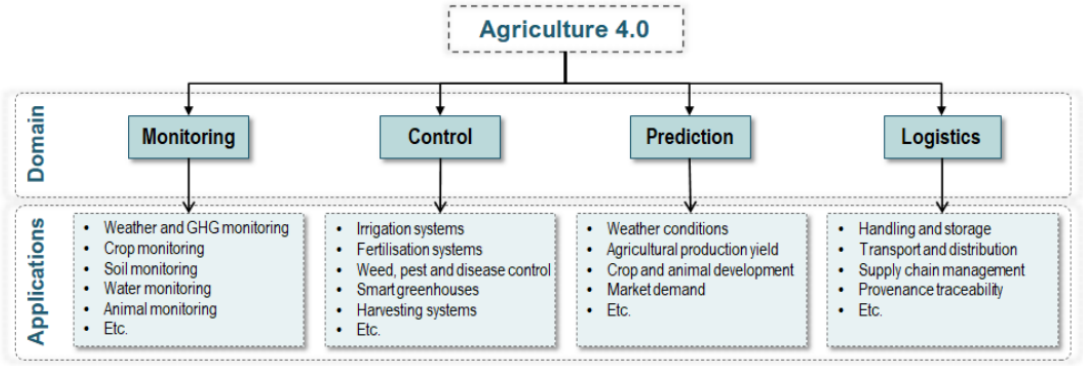

Figure 4: Distribution of Agriculture 4.0 applications domains [8].

Benefits

Agriculture 4.0 can transform means of food production, increasing yields, and improving efficiency. Other benefits include:

- *Modernization of Agriculture*: Modern agriculture involves automation techniques that can alleviate operating costs and improve productivity.
- *Smart Farming*: This is the future of agriculture.
- *Safety of Farm:* Safety is a fundamental requirement of farming and the factory production of food and beverage.

Challenges

In spite of the potential benefits of Agriculture 4.0, the technology is perceived to benefit large scale, technology intensive, commercial farming. Adopting Agriculture 4.0 requires considerable reskilling of farmers. Other challenges include [10,11]:

- *Inclusion and Exclusion:* The over-emphasis on emerging, high-tech solutions to our agricultural challenges, has potential to generate inclusion and exclusion effects in terms of who can partake in Agriculture 4.0 and who can benefit from it. How many farmers can afford to purchase and use Agriculture 4.0 technologies? Inclusion involving only a select group of people is unlikely to be fit-for-

purpose. Agricultural research is still dominated by non-inclusive approaches. There is a need to broaden notions of inclusion in responsible innovation and include all relevant actors.

- *Lack of Connectivity:* Connectivity promises easier monitoring and surveying and the fixed costs of developing IoT solutions. In developed nations, almost all farm work is done manually. Those nations lack the necessary connectivity infrastructure to implement Agriculture 4.0. They cannot afford connectivity technologies like LPWAN, 5G, and LEO satellites. Connectivity will deliver the higher yields, lower costs, and greater resilience which the agriculture industry needs to thrive in the connectivity-driven future.
- *Lack of Digitalization:* Digitalization comprises technologies such as big data, Internet of things (IoT), robotics, 3D printing, ubiquitous connectivity, augmented reality, artificial intelligence, machine learning, digital twins, blockchain, drones, satellites, etc. To address some of the challenges facing the industry, agriculture must embrace a digital transformation enabled by connectivity. Yet agriculture remains less digitized compared with many other industries. LEO satellites provide global connectively. They will enable even the most remote rural areas of the world to use extensive digitization and enhance global farming productivity. Digitalization can change farming culture from experience-driven management to a data-driven approach.

Global Agrıculture 4.0

The New Vision for Agriculture (NVA), defined by World Economic Forum in 2009, holds that to meet the world's needs, sustainable agriculture must simultaneously deliver food security, environmental sustainability, and economic opportunity. The NVA engages over 650 organizations and has catalyzed partnerships in 21 countries in Africa, South East Asia, India and Latin America, including Grow Africa and Grow Asia [12]. Global population growth, global warming, climate change and food security are among the most challenging problems around the world. Significant amounts of money have been invested in the investment of Agriculture 4.0 technologies worldwide. There is encouragement to invest in Agriculture 4.0. We consider how some nations adopt Agriculture 4.0.

- *United States:* Agriculture 4.0 is a new approach towards farm management and precision agriculture using technology. To increase agricultural output from available arable land, one option is to invest in technology to meet the global demand for food. Various stages of the agricultural revolution are aimed at developing new ideas around sustainability, food production, energy, and agriculture technologies.
- *Canada:* Canadian agriculture has survived three technology revolutions, and each has transformed farm and food production skills. As fourth agricultural revolution is underway, and Canada needs to be prepared to take advantage of it. Although this new generation of agriculture will require new generation of skills, Canada is poised to meet that challenge. No other nation has as much land, water or market access, and education system to develop. Farmers who can thrive in a data-driven economy. To get there, Canadians need to rethink their approach to education for agriculture and other sectors that affect it and do more to attract young people to farming.
- *Malaysia:* Agriculture remains an important sector of Malaysia's economy. The Malaysian tropical climate is favorable for farmers to produce a number of crops, fruits and vegetables for the domestic market, including rubber, palm oil, and cocoa bananas, coconuts, durian, pineapples, rice, and others. Although rice is a staple foodstuff in the everyday diet of Malaysians, the production of rice does not satisfy the country's needs. Malaysia imports rice from neighboring Thailand and Vietnam. Malaysia produces tons of palm oil, remaining one of the world's largest producers. Also, Malaysia is one of the world's leading suppliers of rubber and cocoa. Malaysia is one of the biggest exporters of hardwood [13]. Research indicates that the average age of Malaysian farmers is 50 years. The average Malaysian farmer does not have the resources to go smart.
- *India:* The demand for food in India is growing with increasing population. Agriculture is the life of the Indian economy as it contributes greatly to India's gross domestic product (GDP). Agriculture industry has evolved from a stereotypic. India is ranked first in the production of milk and is placed second in producing wheat, rice, groundnut, vegetables, fruits, cotton, and sugarcane. As majority of

small farmers in India have small lands, limited resources and access to irrigation to improve their yield. Most of the farmers are not 100% mechanized and are struggling in Agriculture 1.0 level. Agriculture 4.0 will not become reality without government dedicated plan and support.

- *Europe:* Agriculture in Europe has overcome various challenges transforming to sustainable food systems. Since the creation of the Common Agriculture Policy (CAP), agriculture in Europe has undergone substantial change. Although food security is ensured in most European member states, increased production can lead to significant harmful environmental consequences in terms of water pollution, greenhouse gas emissions and damage to our natural surroundings. A complete survey on farms in Europe is lacking. Detailed statistics on how the business is organized at the EU level are scarce [14].
- *Vietnam:* Vietnam is and will remain an agriculture nation. Rice has played a major role in the life of the Vietnamese for several thousand years. Smart agriculture is needed to cultivate over 1,600 varieties of rice. The arrival of Agriculture 4.0 in Vietnam signals the end of an exclusive dependence on water, fertilizers, and pesticides. The government knows too well that boosting the adoption of such a new technology by farmers is a necessity for the nation's future. Today, farmers use the smallest amounts necessary, while accessing data, GPS technology and moisture sensors. The future for these farmers will require the adoption of digital technologies to meet the challenges of climate change. Vietnam's growth model achieved at all costs has come at the expense of the environment. Deforestation, water pollution, climate change, and industrialization are creating a storm damaging sustainable agriculture development. In response, the government has taken steps in promoting high-tech agriculture with its $4.4 billion credit line [15].
- *Indonesia:* Lack of food security in Indonesia can be attributed to the fact that the majority of agricultural fields are owned by small farmers. In other words, small farmers produce the majority of the food consumed in Indonesia, but they face challenges in accessing credit, services, technologies, and global markets. To this end, the Indonesian government plans to secure food supplies domestically, and as such is treating it as a national security priority. President Joko Widodo has drafted in the military to ensure the success of the program. The involvement of the military (or militarization of agriculture) will ensure that the country has enough food in times of crisis or war. The agricultural model that may suit Indonesia is one that does not focus on a single crop, like rice [16].
- *Thailand:* Agriculture is the main occupation of Thai population. Thailand is the largest exporter of rice, rubber, cassava, and shrimp. It is also a major exporter of sugar, canned pineapple, chicken, fruits and vegetables. "Thailand 4.0" is a new economic policy which Thai government aimed to move the nation out of middle-income trap, economic disparities, and the imbalance between the environment and society. In Thailand, chicken, duck, and swine are three mains important animals that contributes greatly to livestock and poultry production income. Most of the cattle and native chicken farming in Thailand is owned by individual, small farmers that use simple tool and technology. "Agriculture 4.0" was announced in 2017 mainly to drive traditional agriculture into smart agriculture. Under Thai Agriculture 4.0, the small animal production needs to change from very traditional production system to smart farming system [17].

Conclusıon

We are entering the era of Agriculture 4.0, a new stage of the agriculture revolution. In order for agriculture industry to shrive in the 21thcentury, we must confront these global challenges and complexities. We must tackle food waste and food distribution. Our farmers of the future should consider using robots, drones, artificial intelligence, sensors to enhance their production. These emerging innovations will transform food products.

More information about Agriculture 4.0 can be found in books in [18-20] and a related journal: *Journal of Agricultural Science*.

References

[1]. O. Bongomin et al., "The hype and disruptive technologies of Industry 4.0 in major industrial sectors: A State of the art," https://www.researchgate.net/publication/341867958_The_Hype_and_Disruptive_Technologies_of_Industry_40_in_Major_Industrial_Sectors_A_State_of_the_Art/link/5ed764ff45851529452a6dfa/download

[2]. M. Moore, "What is Industry 4.0? Everything you need to know," https://www.techradar.com/news/what-is-industry-40-everything-you-need-to-know

[3]. A. Luque et al., "State of the Industry 4.0 in the Andalusian food sector," *Procedia Manufacturing*, vol. 13, 2017, pp. 1199–1205.

[4]. M. N. O. Sadiku, S. M. Musa, and O. M. Musa, "The essence of Industry 4.0," *Invention Journal of Research Technology in Engineering and Management*, vol. 2, no. 9, September 2018, pp. 64-67.

[5]. L. Klerkx and D. Rose, "Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways?" *Global Food Security*, vol. 24, March 2020.

[6]. S. K. Verma, "Agriculture 1.0 to 4.0," March 2019, https://www.linkedin.com/pulse/agriculture-10-40-sourabh-verma

[7]. G. Sponchioni et al., "The 4.0 revolution in agriculture: a multi-perspective definition," XXIV Summer School "Francesco Turco" – Industrial Systems Engineering, pp. 143-149.

[8]. S.O. Araújo et al., "Characterising the Agriculture 4.0 Landscape—Emerging Trends, Challenges and Opportunities," *Agronomy*, vol. 11, 2021.

[9]. L. Klerkx, E. Jakku, and P. Labarthe, "A review of social science on digital agriculture, smart farming and Agriculture 4.0: New contributions and a future research agenda," *NJAS - Wageningen Journal of Life Sciences*, vol. 90-91, December 2019.

[10]. L. Goedde et al., "Agriculture's connected future: How technology can yield new growth," October 2020, https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth

[11]. "Farmer 4.0: How the coming skills revolution can transform agriculture," https://thoughtleadership.rbc.com/farmer-4-0-how-the-coming-skills-revolution-can-transform-agriculture/

[12]. "New vision for agriculture," https://www.weforum.org/projects/new-vision-for-agriculture

[13]. "Malaysia – Agriculture," https://www.nationsencyclopedia.com/economies/Asia-and-the-Pacific/Malaysia-AGRICULTURE.html#ixzz6t12rs2tU

[14]. "Precision agriculture: An opportunity for EU farmers – Potential support with the cap 2014-2020," https://www.europarl.europa.eu/RegData/etudes/note/join/2014/529049/IPOL-AGRI_NT%282014%29529049_EN.pdf

[15]. J. Borton, "Backgrounder: Agriculture 4.0 in Vietnam," June 2020, https://www.geopoliticalmonitor.com/backgrounder-agriculture-4-0-in-vietnam/

[16]. H. N. Jong, "Indonesia's 'militarized agriculture' raises social, environmental red flags," October 2020, https://news.mongabay.com/2020/10/indonesia-militarized-agriculture-food-estate-kalimantan-sumatra/

[17]. "Thailand 4.0: Future of livestock and poultry industry in Thailand," https://www.researchgate.net/publication/337648832_Thailand_40_Future_of_livestock_and_poultry_industry_in_Thailand

[18]. R. Singh et al., (eds.), *Internet of Things for Agriculture 4.0: Impact and Challenges*. Apple Academic Press, 2021.

[19]. M. A. Rapela, *Fostering Innovation for Agriculture 4.0: A Comprehensive Plant Germplasm System.* Springer, 2019.

[20]. L. Ahmad and F. Nabi, *Agriculture 5.0: Artificial Intelligence, IoT and Machine Learning*. Boca Raton, FL: CRC Press, 2021.

About the Authors

Matthew N. O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics and computer networks. He is a fellow of IEEE.

Uwakwe C. Chukwu is an associate professor in the Department of Industrial & Electrical Engineering Technology of South Carolina State University. He has published several books and papers. His research interests are power systems, smart grid, V2G, energy scavenging, renewable energies, and microgrids.

Abayomi Ajayi-Majebi is a professor in the Department of Manufacturing Engineering at Central State University in Wilberforce, Ohio. In 2015 he was honored by the White House as a Champion of Change for his significant contributions to the engineering education of minority students. He is a senior member of both the Society of Manufacturing Engineers and the American Society for Quality.

Sarhan M. Musa is a professor in the Department Electrical and Computer Engineering at Prairie View A&M University, Texas. He has been the director of Prairie View Networking Academy, Texas, since 2004. He is an LTD Sprint and Boeing Welliver Fellow. His areas of research interest include computational electromagnetics and computer networks.