Emerging Technologies in Smart Computing, Sustainable Energy, and Next-Generation Mobility: Enhancing Digital Infrastructure, Secure Networks, and Intelligent Manufacturing

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Abstract:

In this paper, we discuss some recent emerging technologies in three different areas: smart computing, sustainable energy, and next-generation mobility. In the area of smart computing, we present some recent techniques in the automotive industry, recommendation systems, and computing driven by biomolecules, and discuss a couple of future directions. In the area of sustainable energy, we propose a decentralized edge AI and blockchain-based transactive energy network aiming to reduce market clearing time and improve the secrecy and integrity of prosumers and suppliers, and a machine learning-based response surface method predicting the sound absorption coefficient for the micro-perforated design of acoustic absorbers, and outline more potential applications of emerging technologies for sustainable energy. In the area of next-generation mobility, we introduce a post-decision-constrained trajectory optimization for automated vehicles at roundabouts and present a multiresolution control algorithm for immersive telepresence of autonomous vehicles. Finally, we provide some conclusions and future research directions.

Keywords: Smart Computing, Sustainable Energy, Next-Generation Mobility, Automotive Industry, Recommendation Systems, Biomolecular Computing, Decentralized Edge AI, Blockchain, Transactive Energy Network, Market Clearing Time, Data Secrecy, Data Integrity, Machine Learning, Acoustic Absorbers, Sound Absorption, Automated Vehicles, Trajectory Optimization, Telepresence, Multiresolution Control, Future Research Directions.

1. Introduction

The 21st century ushered in significant changes concerning the digital world. Internet applications now drive a lot of our economy. Newer business models that transform everyday user engagement with these applications have emerged. Such a digital model has been particularly sensational during the past decade. The three primary drivers are: smart computing and newer on-device learning, sustainable power and integrating renewable energy sources, and next-generation software-defined mobility along with newer applications and platforms within wireless power transfer and radio frequency energy harvesting. In this chapter, we focus on these three technology trends and provide a concise snapshot of each area.

In Section 2, we provide a brief overview of these exciting technology trends. In Section 3, we detail emerging applications and trends in smart computing. Section 4 then focuses on next-generation mobility and infrastructure, that is, platforms that integrate and expand the capabilities of wireless power transfer and RF energy harvesting. Sustainable energy sourcing, particularly from RF emissions, which is typically perceived as wastage in modern technology paradigms that operate 24/7 in an always-on mode, is comprehensively outlined within Section 5. Section 6 then summarizes related standard bodies that drive innovation in these technology areas, as well as several ongoing experimentation platforms that are being developed to facilitate translating these technology innovations into next-generation commercial products. Finally, Section 7 concludes with a series of longer-term research questions.

1.1. Context and Significance

Using the internet and internet-enabled devices in daily human life has become very common. All the internet applications, devices, sensors, actuators, etc. have enabled more than communication among humans; they have given rise to the entire smart living environment. However, intelligent decision-making should be done in maintaining, monitoring, and managing various subsystems under the smart living environment in a collaborative and decentralized manner, which is termed Smart Management. Existing management techniques are proven to be highly efficient in selective domains only, and due to the inefficiency of management, the growth of smart living with a large number of devices is prohibited. This chapter presents a review of the efficient, scalable Smart Management technique of smart management using intelligence, self-organization, and decentralized agents in the collective decision-making process.

There are certain specifications that the agents should be able to achieve for the collective decision-making process, such as energy and cost-efficient anthropogenic activity recognition, efficient actuation towards the trade-off between execution time and energy consumption, efficient cross-layer optimization, understanding and utilization of the human brain, and the concepts of soft computing. With the environment mentioned above, the users can be provided with the ability to exploit any idea or technology at their fingertips from any location. Therefore, Information and Communication Technology plays a primary role in the smart living environment. To ensure that smart living offers an extraordinary environment with always better ways of living, technologies that make a significant impact in the real world of the future must be recognized and exploited. Such crucial technologies include smart computing, AI, IoT, robotics, renewable energy, communication networks, next-generation mobility, healthcare, and fuzzy logic control algorithms.

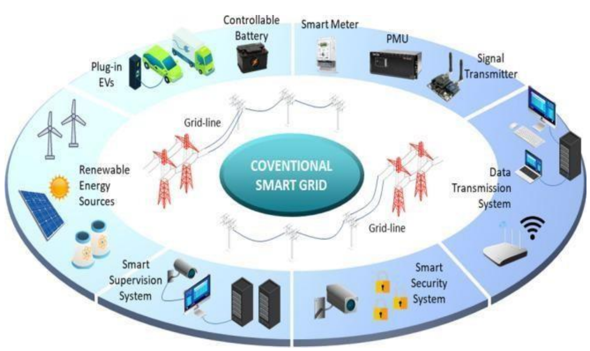

Fig 1 : Data-driven next-generation smart grid towards sustainable energy evolution

1.2. Central Concepts and Foundations

What is smart computing? Smart computing refers to the generation of systems, devices, and machines representing emerging technological paradigms, such as pervasive systems, cyber-physical systems, ambient computing systems, architecture, and many others considered at different scales. Led by central enabling technologies, such as sensors, actuators, and wireless sensor networks; advanced information technologies, such as computer, distributed, and pervasive databases, wireless, and wearable technologies; and the results provided by several production sectors, ranging from e-society to smart grid, from smart house to smart city, from multimedia systems to mobility and sustainable energy, the aim is the development of global-scale solutions and services capable of increasing the richness of information and the automation of processes of enterprises and organizations. Smart computing is an extremely broad subject. From the lowest scale, such as dedicated sensors equipped with their small embedded computing systems, to the highest scale, such as complex distributed, fault-tolerant, and real-time systems, which span across the globe, smart computing involves dozens of theoretical and applicative aspects of modern computing. At a very broad level, smart computing should deal with the entire life cycle of digital information; which includes methodologies and techniques to collect, index, represent, store, retrieve, and process data toward fully automated systems, ranging from embedded intelligent systems to large-scale distributed computer systems complying with the expected quality of service.

2. Overview of Smart Computing

Introduction Our world is witnessing an increasing number of applications related to smart computing that are promising a high-quality life for people in many areas, including health, intelligent transportation, and future cities, among others. This chapter presents new insights, applications, and architectures of smart computing where edge computing and mobile edge computing play a key role. The smart algorithms proposed focus on optimization concerns associated with time duration, available resources, and performance goals associated with the described applications. These applications also provide solutions for real-world problems in various domains. The organization of the chapter is as follows. Section 2 introduces the basic requirements and some enabling technologies of smart computing. Section 3 covers applications in smart healthcare with the Internet of Things, smart vehicles, and cities. Section 4 introduces solid-state lighting that provides infrastructure in smart computing. The final section contains summaries, challenges, and issues to consider for effective smart computing and developments.

Smart computing provides a means with the capability of ambient intelligence to solve real-world problems in various domains. In recent years, with both software and hardware technology advances, edge computing and mobile edge computing are at the frontier, which assists in bringing these concepts to reality. Smart computing involves a broad area. It includes how to sense, optimize, recycle energy, understand commoditized data, reason, act, and communicate. The tight coupling between the cloud and the edge level is critical among those applications whose delay has to be extremely constrained. Awareness of the environment of interest may not be addressed at the edge level. The tasks have to be offloaded to the cloud for processing. One of the intrinsically useful applications is in logistics. Deviations between routes enabled by authorized drivers and the preset paths are required among those logistics tasks. The sensed routes covered by the authorized drivers are correlated to the qualification fingerprint features from the signals, whereas tasks with identification fingerprint features are required to be offloaded to the cloud level for decision support.

2.1. Definition and Importance

Recent advancements in electronics and computer technologies have unified people, devices, and systems, making human life more comfortable and convenient. Given the important role these technologies play in modern lifestyles, numerous researchers and developers are focusing their attention on enhancing and combining these technologies to develop advanced and smart systems known as smart living or smart computing. Smart living or smart computing aims to make people's lives more convenient and sophisticated by using a combination of advanced electronics, signal processing, communications, and computer technologies. Modern smart living enhances the system's smartness by using information and communications theory, signal processing, big data technologies, machine learning, and security. It makes devices smart by using signal processing techniques and feature representations. Devices and systems work together to meet the criteria for smart living.

In addition to enhancing the comfort of people's lives, advanced sensors, and digital technologies can be combined to develop several essential system innovations. Data science, computation, and cyber-physical system technologies are commonly used to make these systems smarter. Technologies for smart computing can be further utilized for many application domains, including sustainable energy, next-generation mobility, smart buildings, smart agriculture, smart environments, and smart healthcare. Promoting smart computing for these purposeful applications leads to smart living and drives advancement in lifestyle, science, and technology. This text will discuss the fundamental techniques and practical aspects of smart computer technology, smart energy, smart environment, and smart microgrid technologies.

Equation 1 : Smart Computing Efficiency Model

$$E_c = \frac{P_t}{C_s}$$

where

E_c = Computational efficiency,

P_t = Processing throughput (operations per second),

C_s = System power consumption (watts).

2.2. Trends in Smart Computing

Smart computing refers to an emerging intelligent society in the future, where a large number of computational nodes are interconnected and cooperate to provide powerful computation capabilities that help humans efficiently conquer complex problems. For this concept, computation resource utilization, application-user friendliness, scalability, elasticity, and fault tolerance are the major issues attracting large concern. To realize a well-balanced research of smart computing, a combined method of artificial intelligence, signal processing, pattern recognition, high-performance computing, network science, control theory, and related domains will be applied. In the developed smart computing, two types of researchers are involved. One group of researchers focuses on advanced theoretical models, algorithms, and tools, while the other group of domain experts uses second-hand resources to empower several emerging applications. To leverage the power of the first group, we provide a Unified Optimization Research Group for all of them to innovate together and get feedback from those problems sent to the second group before landing in real scenarios.

When the data amount reaches the scale of the current global data organization and search, and data organization and search are still heavily flawed, a new smart computing engine with optimal computational complexity needs to be designed to unleash the real intelligence inside the objectivizing data. Therefore, one of the important research concerns is to organize the different layers of raw data into a hybrid feature vector and then conduct a probabilistic bi-directional matching of the feature vectors by taking advantage of a widely broadcasting map. Additionally, the master rose solution and deep computing can be produced for scalable intelligent data processing. Besides that, we also need the top-down design to appeal to applications from a wide range of domains, paying more attention to the feature extraction of data to locate the necessary information, identify useful data, and avoid complex false alarms. Before drilling deep into the data processing chains, it is usually necessary to organize the different weedy sentences into a hybrid feature and then conduct some top-down clustering to be capable of catching the common sense for learning necessary data at multiple granules. Given the preprocessed data, we need to design a fractal block to scaffold the data to involve it in intelligent data processing. That is, reinforcement learning is playing with the internal and external states of a certain block rather than a complete averaging strategy. As cellular biology tells us genes and proteins contained in a cell serve as a black box that handles the raw signals in a highly localized fashion to produce a more meaningful result for accurate signal processing. This research tries to design such black boxes based on the small-world file system concepts to aggregate support in both data organization and inference phases.

2.3. Applications in Various Industries

There is growing interest in electric mobility systems because of the great potential of electric vehicles (EVs) to use renewable energy and reduce greenhouse gas emissions. In the United States, transportation remains the largest consumer of fossil fuels and a significant source of greenhouse gas emissions, making EV deployment and freight electrification essential for the future of America's energy and transportation sectors. To do this, considerable investment in infrastructure will be needed, which will have implications for air quality, public health, and climate change. A major barrier to the widespread adoption of EVs is the need for high-speed charging infrastructure that recharges batteries in a matter of minutes, similar to the time it takes to refill their gasoline or diesel counterparts.

Electric vehicle demand side management (VDM) is becoming increasingly important for smart grid operations due to its inherent advantages, including progressive economic profit for both electric vehicle owners and system operators, avoiding possible grid congestion, and reducing investment in grid reinforcement. However, the implementation of VDM is subject to various limitations related to electric vehicles, including the driving schedule, their flexibility as a load, and drivers' preferences, as well as the power grid, including voltage deviations and power fluctuations, which should be taken into account in the planning and operation of smart grids.

3. Sustainable Energy Technologies

Our energy consumption, especially in the industrial sector, has increased drastically as population and energy demand grow constantly. Our way of generating and consuming energy is unsustainable, and this raises serious concerns about the future of the environment. If things keep going in the same direction, the energy industry alone will be responsible for the decisions made. Those decisions will inevitably lead to poor air quality, modern energy poverty, ecological threats, global warming, and more frequent extreme weather events caused by climate change. To save the planet from such threats and to improve the quality of life for future generations, every country will need to make an effort so that clean energy becomes the primary energy source. The momentum and speed of the transition towards the use of renewable resources will make a big difference to the future of the Earth. Renewable energy sources are characterized by their auto-renewal capacity, which means that we can never run out of them.

The harvesting,

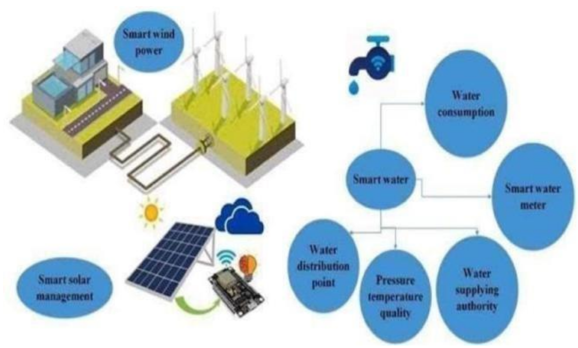

Fig 2 : Sustainable Energy Production in Smart Cities

converting, and storing of these renewable sources into other types of energy are governed by different physical, chemical, and technical principles that are challenging and complex. Let us imagine for a moment that any living organism could directly harvest solar energy to produce fuel. The organism's photosynthesis process takes energy from the sun and uses it to produce fuel molecules with chemical bonds that are rich in energy, and that energy could be released when used. This is very different from the current methods we have to convert solar energy into energy we can use.

3.1. Renewable Energy Sources

Renewable energy is nowadays considered a key solution for sustainable energy systems. Currently, hydro, wind, bioenergy, solar, and geothermal power generation are the forerunners within this sector, particularly wind energy harvesting technologies that are considered the fastest-growing clean energy solutions. Global growth of energy demand, as well as overestimation of the potential outcomes of renewable energy concerning their capabilities in solar radiation, wind speed, overall climatic characteristics, financial resources, concentrated investments, and influential generalized attitudes towards energy sources, are some of the major reasons why solutions based on renewable energy sources fail. In new renewable energy investment approaches, several aspects have to be taken into account, such as market risk factors, distribution impact, more turbulence in the energy market price, renewable energy feed-in tariffs, social costs, renewable energy bank loans, bonds, and investment funds. During the last decade, there has been significant global growth in the number of penetrations of solar and renewable energy sources. The development rate of renewable energy technology is currently accelerating thanks to geopolitical changes, as well as international commitments on environmental pollution. The renewable energy market is now governed by the most powerful and developed economies on the planet. Many of these technologies also make them attractive investments.

3.2. Energy Storage Solutions

Renewable energy sources have been studied and utilized for the development of solid and sustainable energy supply chains. Considering the nature of non-stationary and fluctuating renewable energy sources, such as solar and wind, which limit their reliability, electricity generation based on renewable energy sources must be conducted intelligently and efficiently. Energy storage solutions play a critical role in the sustainable integration of renewable energies. Therefore, the development of energy storage solutions, including both the energy and power domains, has attracted increasing interest. In this paper, we focus on five important categories of energy storage technologies, including mechanical energy storage, electrochemical energy storage, electromagnetic energy storage, electrostatic energy storage, and thermal energy storage.

Mechanical energy storage includes pumped hydro energy storage, compressed air energy storage, flywheel energy storage, regenerative fuel cells, and supercapacitors, among others. Pumped hydro energy storage is the most mature and widely adopted energy storage technology. Due to the limited geographical and funding resources in practice, the construction of pumped hydro energy storage is often restricted and requires a long construction period. Therefore, other technologies, such as compressed air energy storage, flywheel energy storage, regenerative fuel cells, and supercapacitors, have been studied and utilized.

3.3. Smart Grids and Energy Management

Our current grid is being subjected to growing pressure and stress and will soon struggle to meet future power supply demands, caused by an increasing density of generation units and loads. Renewable energy sources tend to play a significant role in this evolving power system. Building an advanced power system to effectively integrate renewable energy sources in the future electricity network is a multidimensional problem that demands considerable work and cooperation among many entities. It aims at developing a sustainable and reliable power system that functions more dynamically and smoothly. The smart grid is seen as the next expandable version of the conventional power network to deal with these challenges.

A smart grid is designed to deliver electricity more effectively, reliably, and securely, to increase customer access to electric market services, and to bring diversified energy-saving, sustainable, and renewable smart energy services to homes and allow consumers to have personal energy control and personal optimization of energy usage. The smart grid more extensively employs embedded control devices technology and efficient communication infrastructure simultaneously. It provides many benefits, such as smart meters used to evaluate real-time and integrated energy usage at any location and at any time. In a smart grid, there are also communication systems interconnected with any electricity apparatus that provides customers with higher energy awareness through regularly updated data of market price, risk-controlled demand response in case of complex situations due to heatwaves, and smarter, more economical resilience to guarantee that the power grid remains standard.

4. Next-Generation Mobility

Next-generation mobility refers to the integration of various smart computing platforms, including big data, machine learning, edge computing, and cloud computing technologies into smart transportation, intelligent manufacturing, and energy microgrid applications. The chapter first discusses current transportation system challenges and the potential benefits of integrating recent data-driven AI technologies and sustainable energy solutions to address these challenges. Then, specific research projects such as data-driven transportation models, vehicle trajectory prediction, traffic sign classification, and vehicle benchmarking are discussed to further outline future research opportunities in smart connected and autonomous mobility systems. Finally, the chapter briefly discusses ongoing research to advance the mobility, energy, and infrastructure engineering that are crucial for the sustainability and security of future next-generation transportation systems.

The next-generation transportation mobility plays a crucial role in addressing the challenges that the world faces, including multimodal congestion, safety, and reliability concerns; environmental protection; energy conservation; and equity. However, significant issues remain to be resolved before next-generation mobility eventually provides the envisioned future travel experience. A strong cross-cutting research agenda is set forth to address next-generation mobility and energy challenges. Upon this foundation, there is a response to the pressing transportation, energy, and infrastructure issues by researching the smart city ecosystem services that achieve synergistic benefits in costs and performance reliability between infrastructure and intelligent devices that have the potential to advance the development and widespread application of capabilities at regional to national scales.

4.1. Electric Vehicles and Infrastructure

The growth of electric vehicles (EVs) is key to building a smart transportation sector. The recent advancements in electric and electronic technologies will substantially advance the safety, gasoline mileage, software content, and industrial adoption of EVs and build an EV infrastructure that sustainably uses space and power outlets. The electric drive improves transportation system sustainability by cleaning up the emissions, increasing the transportation fuel flexibility from gasoline, reducing traffic noise, and saving valuable urban land occupied by fuel service stations. Smart grid technologies are deeply connected with the EV sector, where the EV likely becomes the largest mobile energy storage unit and mobile load in large cities or the power peak in the transportation sector.

Electric trucks, as part of future smart applications in the mobility sector, can reduce tailpipe emissions from diesel trucks and increase grid benefits by utilizing the extra capacity of future electrified roadways with a catenary. Regarding EV development, we need to reinforce positive external assumptions or requirements, including improved energy efficiency, reduced lifespan energy costs, reduced TCO, and electricity grid balancing to promote clean power penetration with affordable EV technologies and new business models. After key positive assumptions or requirements are established, we can explore potential EV-related technologies that aim for their unique and specific innovations.

4.2. Autonomous Transportation Systems

A Level 4 autonomous vehicle has the highest level of automation and does not require human intervention. However, Level 4 capabilities are very challenging to implement as they require a large amount of situational awareness, including perception of other vehicles and road users, recognition of traffic regulations, precise positioning and predictions of their surrounding environment, and understanding of map information. Many techniques that can improve driving performance facing a single task, type of scene, or environment have been developed and provide a basis for a competitive autonomous system. However, integrating these techniques into a complete system is challenging. Automation is essentially a problem of learning. Systems learn directly or indirectly from experiences and optimize a performance measure. Deep learning is important for processing a large amount of surveillance video. However, in terms of directly processing exaggerated perception layers, existing deep learning techniques demand an enormous amount of labeled data, which is essentially impossible to collect in the real world for an AV.

A multilevel and multi-modal network is developed for 3D environment perception. The 3D object detection approach fuses information from LiDAR and visual sensors. On one hand, the data gap between LiDAR and visual sensors is bridged, as well as performance stabilizing. Coordinates at the corners of the object bounding box are directly regressed, and surrounding point selection output yields higher accuracy through an adaptive volumetric resolution network paired with the visual sensor. On the other hand, the approach consists of practical characteristics. Intensive experiments are conducted to verify the effectiveness and robustness of the proposed method on the virtual dataset, alongside the synthetically created multimodal datasets. Finally, testing of Level 4 autonomous vehicles addresses the above applications and assists autonomous car technology in becoming mature.

When it comes to autonomous vehicles, no method or approach is perfect. Limitations such as environmental lighting variation, inherent vibration, and different types and speeds of sensor overlap can seriously affect the performance of LiDAR-based object detection methods. Many false positives can occur if such details are overlooked and not properly managed. Since LiDAR sensors see with their frequency and field of view, there will always be certain occluded scenes that cannot be seen by the sensor. Meanwhile, how to choose a good pose, route, and other potentially farther-reaching degrees of freedom for such systems remains unanswered. In addition, the deep learning models with the strength to perform real-time object detection need a large amount of labeled data. Even with the help of the truth, some road users or environmental limitations may not be able to continue collecting enough data to further enhance the accuracy score. Considering all these limitations, the widespread use of autonomous cars remains a challenging task. The general goal of autonomous vehicles is to be able to combine various sensors and environmental models to process complex tasks on the road intelligently, safely, and reliably in all situations in any country. However, most state-of-the-art algorithms cannot do so. More work needs to be done for the practical application of automated or autonomous road vehicles with embedded deep-learning models during deep racing.

4.3. Mobility as a Service (MaaS)

The advances in information and communication technologies (ICT) and electronic mobility have led to a convergence of various intelligent transportation systems where public, private, and traditional one-user transportation systems integrate efficiently with an integrated, user-focused, and affordable platform. This indicates the evolutionary transformation of a suite of advanced and intelligent transportation technologies. These include drive control navigation and guidance systems, advanced traffic management systems, electronic toll collection, smart card-based systems, traveler information, public transportation management, information systems, intermodal connections, and electronic payment systems. It also emerges with high and traceable implications that the so-called mobility as a service (MaaS) concept is expected to offer where various intelligent transportation systems render many needs a single and seamless transport solution providing real-time, demand-driven control of existing and expanded transportation resources based on shared and unified interaction platforms. This section defines the concept of MaaS highlighting its various economic, social, and environmental effects, identifying its current technological and business prospects, also emphasizing its profound public policy implications, and how MaaS should provide partnerships between both public authorities and conventional global and small-scale mobility service providers leading to a set of joint objectives and common business models. Due to this multi-layered and multi-faceted analysis that MaaS requires, some of the ensuing discussions are not just based on transportation services but also substantially rely on ethical and policy implications that preoccupy our various communities such as the ethical approach to clients' public and privacy sphere, data ownership, and users' rights or the knock-on effects for the overall governance of mobility services. However, the majority of the available MaaS offerings come from private operators that promise door-to-door solutions on demand, easing away the unpleasant responsibility of daily mobility planning from the customers, providing not only savings in time and space for more individual and collective pursuit of meaningful experiences, such as more leisure, personal and working offerings, or free time for discovering new cultures and diversifying hobbies but also a purposeful use of one's efforts, time regarding physical activity and attention provided to other individuals. In turn, they provide a significant amount of profit to rehabilitate the modern city, offering an interrelated resource for finance and service quality upgrades.

5. Digital Infrastructure Enhancement

The development of the above technologies requires massive amounts of data. For example, both data-driven systems and machine learning models rely on ample and high-quality datasets, including training, testing, and validation data, for deployment and evaluation. The transmission, storage, processing, and retrieval processes of generated data need to be high-performing and fast along both communication and cloud computing networks. Information infrastructure and digital infrastructure, the platforms that provide these services, are of great importance and have significant impacts at various levels. Computer systems have become the bedrock of information infrastructure.

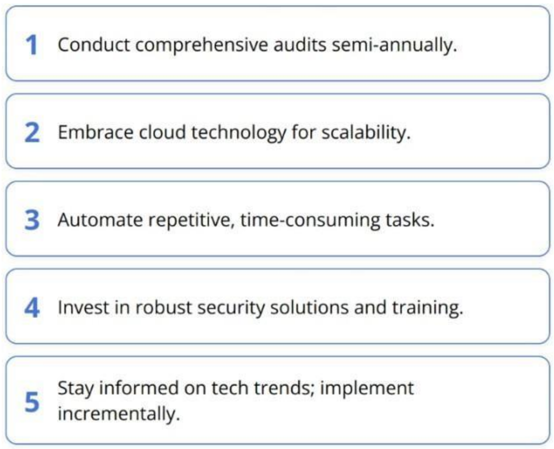

Fig 3 : Digital Infrastructure Optimization

Companies have continued to invest a large number of resources in information infrastructure as they know their business operations are critically dependent on the advancement of information infrastructure technologies.

For many years, the development of information infrastructure was quite steady. As observed, the number of semiconductor devices that could be accommodated on an integrated circuit at minimal cost doubled every two years, the size and price of each memory device decreased similarly, and storage systems became cost-effective, high-capacity, and decent in performance. The same pattern was observed in networking systems, in which data can be transmitted at higher speeds and reliability, as well as in processing systems, before encountering a ceiling about five years ago. Surpassing this ceiling became a challenging research problem that attracted the attention of researchers in different fields because if information infrastructure could be advanced along the same trajectory, we would not only be able to entirely support the two-strong exascale computing but also enjoy clear convergence of computing and communications and interaction among algorithms, communication topologies, and hardware.

Equation 2 : Renewable Energy Optimization for Smart Grids

$$P_g = \eta_s \sum_{i=1}^{n} (S_i A_i)$$

where
P_g = Total generated power (watts),
S_i = Solar or wind power intensity for source i,
A_i = Active area of energy source i,
η_s = System efficiency factor,
n = Number of energy sources.

5.1. Cloud Computing and Data Centers

With the progression in big data and the emergence of analytics, more and more functions are shifted into cloud storage to increase the volume and the pace, which is a spatial expansion of the efficiency obtained previously in sensor networks. The rise of cloud computing has precipitated the creation of larger and larger, more sophisticated, and power-hungry data centers. Eventually, seemingly unrelated developments in our society will all meet at the threshold of the data center – where issues surrounding creating and maintaining massive computing capacity will severely affect ICT and society. In addition, an energy-craved global industry of computing is driving the need for massive data centers and other commercial facilities containing hundreds of thousands of servers all focused on solving the enormous big data conundrum. These are posing new challenges in providing end-to-end sustainable networking and computing solutions. Data centers no longer play a discrete but central role in the computing world; they may even provide the security and energy-saving answers to many of the challenges ahead. Traditional data center networking solutions are indicated by the number of controversies in their design and the high deployment cost. There are several challenges to the current data center architecture: limited network bandwidth and limited network scale, low network utilization rate, dirty traffic, DDoS attack threats, and low power efficiency, which are the major obstacles to the development of cloud computing.

5.2. Edge Computing and IoT Integration

Edge computing is deployed from the core of the network to the edge of the network, which can effectively reduce transfer delay, reduce network traffic, and equip with the ability for real-time analysis of big data. The performance of edge computing is maximized when combined with relevant cloud technology. It can also effectively reduce data processing in the cloud. On the other hand, the Internet of Things (IoT) is the basic support for the generation and development of edge computing. It provides the foundation for the development of edge computing. For IoT, the interaction between the device and the user is of low latency, which also benefits from the deployment of more data processing at the edge nodes. A common design principle of edge computing and IoT is to put data processing close to its source. They can do data processing directly at the source, and then upload it to the cloud after processing and analysis, improving efficiency and flexibility. At the same time, it also provides real-time support for data processing and response to internal changes, real-time steering, response, and analysis.

The deep integration of IoT and edge computing is the development trend of future communication networks. On the one hand, the development of edge computing technology depends on the support of the underlying network and IoT. IoT using edge computing can significantly reduce data delay, reducing reliance on the support capability of the central cloud, increasing the ability to process large amounts of data, and increasing the ability of data analysis. Edge computing also brings a change to the IoT architecture, which will lead to changes in the demand for communication network construction. Edge computing can undertake real-time data processing and reaction responsibilities for emerging industrial IoT wireless technology applications. These applications are closely related to key new technologies such as intelligent manufacturing, intelligent driving, and smart grid. In this section, we first discuss several real-time data processing key technologies in the edge computing environment. On this basis, we will design and analyze the IoT edge computing system and then introduce the specific application of the hybrid sensor array to demonstrate its outstanding features. Finally, we summarize the entire content.

5.3. 5G Networks and Connectivity

5G networks are the next generation of wireless communications that will be recognized by their capability to connect people, things, machines, transportation, and cities beyond just traditional mobile devices. The future generation wireless communication systems shall offer high data rates, high bit-rate availability, high reliability, massive device connectivity, high quality of service support, low energy usage, resource efficiency, and low latency communication. In particular, the widespread utility and high-speed wireless access are tremendous challenges faced by diverse technologies. Such technical targets and requirements can be realized by designing a new network architecture to extend and consistently interface wireless and wired network applications, services, business domains, and principles. Then, based on the flexibility requirement of inter-network and distributed network traffic for the future network, network slicing is proposed as the up/down solution to the technical challenges of the architecture. The time-domain SDN/NFV will enhance spectrum awareness and security from network elements up to management and control applications.

This new 5G network will integrate the ground cellular network infrastructure, aerial cellular configuration, and ground-aerial network without a physical medium to supply better latency, energy efficiency, and spectrum opportunity. Based on a self-organized, adaptive, and cooperative network, a new bandwidth-on-demand and bandwidth-scheduling network is proposed for the 5G network to address the traffic and resource problems within the virtual environments. In more detail, a variable bandwidth scheduling is proposed for different levels of communication. A competing approach is proposed to deliver the proper remote radio heads. The self-priority dynamics will identify the high or low-priority intrinsic traffic types and will support isolation and manage the excitation packets. From the wireless or optical point of view, the statistical multiplexing feature will manage the IP QoS scenario by shedding importance. In the end, the bandwidth scheduling and IP QoS will fulfill the energy per bit of operation consumption, representing an economic opportunity for the next optical generation. Because a key aspect of this network and technology is to improve spectral and energy efficiency, as much spectrum as possible must be allocated to support the increasing traffic. The different aspects of spectrum and networking support that are required to improve spectral efficiency are reviewed.

The network will interconnect a variety of heterogeneous, generalized, and diversified equipment and systems that will work together towards the future network and technology evolution. The Electrical Engineering and Computer Information Science approaches played a significant role in revolutionizing high-speed communication systems and can also address other critical elements such as very low complexity, robust design, and ultra-low-power communication systems. Generally, the increasing demand for high global network capacity can be supplied by increasing the frequency spectrum at the radio interface, increasing the data transmission rates through optimization of the physical and network layers, and by optimization of a wide range of network technologies that are expected to support the massive number of connected devices in the future. Some enabling technologies, including beamforming, polarization multiplexing dynamic spectrum, and improved WLAN and backhauled CWDM/NGDMA, can guarantee the performance required for both indoor high-multipoint connectivity and outdoor encryption-free communication. In line with emerging technologies, the combination of a location-based identity, demand, and interaction management that supports hierarchically distributed service resource opportunity makes RF-photonic networks great candidates for emerging smart scenarios.

6. Secure Network Architectures

In the context of mobile and intelligent computing, as well as cloud and fog computing, architectures and related systems need to ensure secure and dependable networking. The need for a common model for network architecture that would later be transformed into a reference model, serving the industry and society, has long been known. This chapter presents an initial proposal for secure network architecture to create standards and research. This includes approaches to identity management, security policy management, and modeling network behavior.

This document proposes a network architecture standard that takes an approach to identify controls for network elements at Layer 2 and Layer 3 and that allows the formation of shared security policy rules between network profiles for different organizations. With this process, it is possible to ensure that uniform security policies are maintained, ensuring that this is necessary. This chapter also suggests a methodology for the analysis of the characteristics of switches through operational models, the implementation of the state variables and traffic states into a model, the realization of the network behavior via simulation, and the comparison between both analytical and simulated behavior. Its purpose is to assist in the identification of the most common security vulnerabilities and to verify how current commercial products behave according to certain proposed security policies, as well as to measure their performance.

6.1. Cybersecurity Challenges

There has been interesting research underway in the context of smart transportation, healthcare, and the electricity grid on the use of off-the-shelf smartphone cameras to deduce activities, biomedical health, and downstream transmission and distribution grid status, respectively, and process the visual data in the cloud. This could reduce the availability, time latency, and energy cost benefits of streaming this visual data across existing wired and wireless network infrastructure that services the devices in the field. For instance, a rerouting decision in light of a sensed downed electricity distribution cable segment could be better handled if it could be reliably confirmed by a camera processing the real-time footage of the observed damaged location and conditions, and sending a text message similar to what is conventionally reported from a smart glass or glass-like device rather than streaming the visual data over low-power communication to the processing unit in the cloud. However, this immediate visual data processing could also open new cybersecurity attack surfaces for the deployed system, where the processing unit and cloud infrastructure along the intended connection path could be manipulated to misinterpret the visual data by the compromised system and infrastructure.

An even more acute cybersecurity challenge comes from the need for secure data analytics over private data when the data owner is unwilling to share and fully trust her data with the data processor. We argue that a framework that tries to endow trustworthy properties on the often inevitable single aggregating/processing unit that processes the disaggregated/divided data from multiple owners to derive actionable knowledge that summarizes the raw data cannot hope to simultaneously minimize adverse privacy and energy collateral damage from the data bulk and processing sum. A powerful combination of comprehensively protected properties and assumptions at the inter-and-intra owner data transmission network and the eventual disconnecting or non-existence of any equivalent processor concurrency that otherwise can demonstrably yield significant damage towards the aggregate data privacy; a newer disincentivizing approach entails the submission of multiple equivalent answers to limit forward damage. In the process, new safeguards are not only necessary at the individual data item level that we carefully explore through an abstract example of net income and tax liability bracket-level interest, and that we explore through more concrete electricity sector applications in PEV plug-in events, HRIM hourly residential building consumption, and DG diesel generator activity, but also repurposing the preferred storage computations with end applications of the derived knowledge.

6.2. Blockchain for Secure Transactions

Blockchain enables a ledger that is independent, neutral, transparent, reliable, and secured by employing the decentralized algorithmic model to report and exchange the ownership of a token electronically. Despite the potential capability of blockchain technology to provide a trustworthy decentralized platform, latency and scalability remain persistent in conventional blockchain technology. Owing to the stringent constraints of smart city real-time capacity allocation and privacy issues, the viability of financial transactions using blockchain technology within the context of a smart city is doubtful. Here we present a novel blockchain electronic record, denoted as the privacy-preserving zero-knowledge proof-based blockchain credo, to overcome the two stringent constraints of latency and complexity by avoiding public key infrastructure setup for the users and proofs generated by the receiver. A set of results is derived to demonstrate the computational cost of the proposed record, and an extended signature scheme that supports ownership transfer of embedded electronic transactions is illustrated to show that blockchain can be complementarity leveraged to facilitate the development of smart cities.

Electronic financial transactions that are mediated through the existing system of financial services involve third-party registration and arbitration, which result in additional costs and delays. The financial corporate sector is responsible for the intermediation role. This responsibility increases the cost and reduces the refund that would have been possible if direct electronic financial transactions could be carried out among individuals. Financial transactions can be managed more smartly, resulting in the decentralized management of the economy and a selfregulatory mechanism for the financial system. By disintermediating the existing financial system and managing financial transactions more smartly, these transactions could be managed via smart contracts that are stipulated in a script, and transactions are automatically processed when the conditions are met. The noteworthy enabling technology to change the current system stems from the utilization of blockchain technology. Blockchain, as a transformative technology for business and social entities, has the potential to decentralize and disintermediate transactions and impose no intermediaries. In this section, we illustrate the challenges and applications in lightweight and anonymous blockchain electronic financial transactions.

6.3. AI in Network Security

Network security is of paramount importance to protect private data and ensure both user and economic security in the world of AI. To this end, researchers have proposed applying AI to network security to facilitate the detection and classification of abnormal network behaviors. AI-based network security consists of two paradigms: defective network data classification using AI and intrusion prevention/detection using AI. The former classifies potential network data deficiencies to detect and address these deficiencies promptly. The latter uses AI methods to strengthen the detection, classification, and mapping of network intrusions, focusing on reducing the time needed to expose an intruder.

Current solutions lag in practice and do not meet the required levels of protection. Deployed methods such as machine learning and deep learning quickly reach bottlenecks, as training data are inevitably incomplete compared to original training data, prone to large prediction delays, and produce expensive false detections. We survey the existing approaches and possible solutions at different phases of the research. The intersection of network security and AI research, insight, and application will help people understand past work and potential ideas in these two areas. Let's call for extra protection in AI-based network security deployments to resist the temptation of applying shallow detection systems. AI has the potential to facilitate superior network detection. The question is when.

7. Intelligent Manufacturing

Intelligent manufacturing is making transformations from pure data-based human labor assisting environments to a combination of big data-driven and artificial intelligence (AI)-driven self-adaptive collaboration mechanisms of flexible production systems. The two core features of intelligent manufacturing are that it is data-driven and flexible. Intelligent manufacturing is the micro-level technology application of Industry 4.0, and it is a transformation of the manufacturing industry driven by big data and AI. Emerging technologies are growing rapidly, and their commercial and industry applications have already exceeded the research and development explorations. The growing transformation of those emerging technologies, boosted by manufacturing industries, is providing a great opportunity to develop the next generation of intelligent manufacturing.

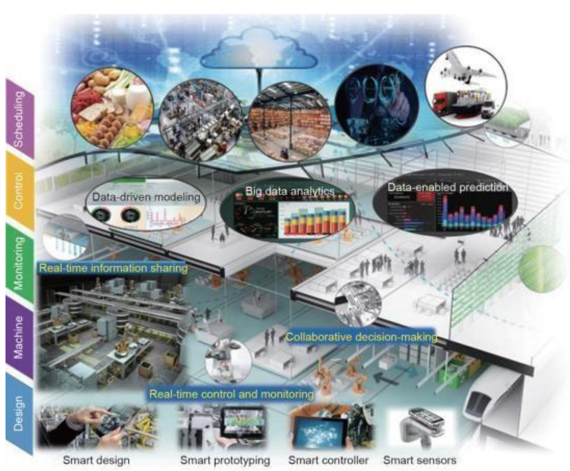

Fig 4 : Intelligent Manufacturing in the Context of Industry 4.0

7.1. Industry 4.0 Principles

The fourth industrial revolution assimilates the merger of the physical, biological, and digital worlds with the rapid proliferation of cyber-physical systems, where the physical systems are connected, interact, and cooperate both with humans and with other types of systems in real-time through the industrial internet. Industry 4.0 encompasses cutting-edge concepts of the Internet of Things, cloud computing, the Internet of Services, and the Internet of People. With the advent of the Industrial Internet of Things and Industry 4.0, the fourth industrial revolution is anticipated to substantially enhance the performance of manufacturing systems and to accomplish the objective of mass customization at costs, an ultimate ambition that is yet to be achieved. It is imperative to drive manufacturing systems toward flexible, predictable, and energy-efficient systems to realize the ambition of Industry 4.0. Transformative evolution in technology disrupts the orthodox structure of manufacturing systems and partakes tremendous capability to adjust it in real-time to the trends of the volatile market by intelligent adaptable manufacturability. Consequently, smarter systems will allow dealing with the real-time data associated with huge variations and accelerating output requirements. The interconnectedness of communication across technologies based on Industry 4.0 has a significant impact on technical pillars for sustainability in procedures of the company. Progress in network innovation leads to the integration of information technology, context-driven computing with low-cost sensors and other resources of business moving towards integrated smart systems for real-time data-efficient decision-making. Successfully evolved businesses could capitalize on these innovative technologies to differentiate in emerging market scenarios by expanding flexibility, competency, and knowledge exchange efficiently. A majority of business sectors extensively attempt to encounter a wide variety of industrial requirements through active participation in these simple technologies. The broader idea of Industry 4.0's capabilities could be accessed through the incorporation of systems to increase connectivity for corporations across business boundaries with transaction protocols with other company procedures. Small firms that do not get direct benefits from high-level information systems could benefit from this literature, which summarizes the efforts of Industry 4.0 technologies into five key aspects supporting intelligent computing that is related to the industry. There are some limitations in assessing Industry 4.0 capabilities that are recognized in making business, economic, and industry-based decisions. These limitations encompass identifying the adequacy and ability of infrastructure for information technology and obstacles associated with related postulated expenses. Businesses also apprehend the human resources abilities of modern digital technologies for Industry 4.0. These HR skills could be explained as a moderating factor that is important for understanding the operative capacities of modern innovative breakthroughs. There are still a few main obstacles. First, it is not simple to include all the participants of the industry with different systems, as noted earlier. Second, the protection of technology is another major issue because most of the business's technologies are connected to the internet. Lastly, a final barrier is the absence of a clear understanding of the opportunities management has in the business for a manufacturing system. As a result, the business must take on exploratory procedures to handle the comprehensive challenges, both internal and external, associated with market innovation, particularly those including technological application.

7.2. Automation and Robotics

Under the contemporary move toward automation of processes and work in many domains, more and more robotic systems are being put in place to provide assistance or execute portions of highly structured tasks usually executed by humans. While entirely autonomous robotic systems that can replace human performance in a near nonspecific skill domain, universally execute any decision, and achieve the broad range of decision dynamics of human professionals may still be regarded as science fiction, a growing variety of unmanned devices are already finding a place in the workplace, being able to execute tasks independently, collaborate with human workers in safety assistance roles, or operate under remote supervision and control. Robotic systems execute a variety of processes in a deterministic way and do not meet the perception-interpretation and action-response features performed by humans.

Robotics in the workplace generally focuses on intelligent systems documentation and identification of the appropriate structure type for the task, given the goal and task constraints, interaction with humans, learning of vocabularies representing the environment about decision-making under uncertainty, performance assessment of structures under human types of supervision, and management in various decision paradigms. This chapter discusses these features in the context of human-robot interaction models, frameworks used to identify relevant attributes for successful collaboration and the decision processes associated with various types of work in which robots and humans are engaged cost-effectively and stably. The most common work paradigms either provide autonomous robots that perform tasks in a self-scheduled or pre-scheduled manner without human intervention or provide robots with humans in the loop. Safety is the first consideration of human interaction, including the safety of the robot itself as well as the safety of the human operators, the formation of trust, and robustness when they intervene. The subject matter falls within the broader domain of intelligent systems, which includes other types of control systems coordinated by learning, acting, reasoning, manipulating, and assimilating ambient information, whether directed to humans, structures, vehicles, data manipulation, finance, or other system functions.

7.3. Supply Chain Optimization

Optimization of a supply chain has attracted much attention in recent years to reduce complexity, and cost, and to ensure the movement of goods is as smooth and efficient as possible from manufacturers and suppliers through distribution and logistics entities. A supply chain consists of various integrated components working together to move products from an idea through the various production stages and finally to the hands of the end customer or consumer. The primary purpose of a supply chain is to fulfill customer demand as quickly as possible while minimizing the total cost. It is not an easy task to synchronize all components to consistently meet this demand. A supply chain typically includes suppliers, materials, production facilities, distribution centers, logistics networks, retailers, wholesalers, and finally the end consumer. Each entity in this chain should interact and communicate effectively to ensure the smooth flow of necessities.

Given the increasing speed of changes in industrial environments and consumer needs, a section of this chapter is devoted to the study concerning the supply chain. In collaboration with machine learning and data science, a wide spectrum of tools have been proposed to centralize and simplify the logistics scenario. They specifically deal with the prediction, management, and monitoring of goods and other related services provided to the daily needs of citizens. Their performances are continuously improved due to the never-ending request for increasingly precise, fast, and efficient delivery. The unprecedented volumes of data in digital knowledge, along with the spectacular advancements in AI and machine learning algorithms, have a remarkable impact on supply chain optimization.

8. Interdisciplinary Approaches

The scope of the presented review work is the identification of emerging, novel technologies that generate the creation of a smarter, more sustainable, and more efficient future, focusing mainly on intelligent systems, novel mobile devices, and IT applications used in vehicles, energy saving, and reduction of emissions, optimal infrastructure reliability, and greater personal safety and security. In some cases, the traditional concept of data and information transmission and processing, mostly related to speed and clarity, needs to be revised in more general terms as pattern recognition and human-like decisions. Multidisciplinary approaches and the novel technological advances presented certainly generate important progress in all reviewed applications, which are core themes in a Smart City concept. All presented solutions greatly impact mankind's welfare and quality of life and contribute to a smarter, more sustainable, and more efficient city concept. Emphasized technologies are closely related to the research fields of electrical engineering, electronics, and information technologies.

8.1. Collaboration between Sectors

Collaboration between sectors is transforming the global economy, from energy production and use to transport, connectivity, and IT. Sectors we consider critically include smart computing, smart cities, energy, and mobility. New technologies and approaches, including artificial intelligence agents, the Internet of Things, robotics, autonomous vehicles, blockchain, and distributed computing, will underpin rapid, ongoing transformation in these sectors. Despite many uncertainties, private, public, and not-for-profit sector organizations can employ strategic planning to achieve significant benefits. Significant contributions can be made through changes to policy making, legislation, standardization, and regulation. We introduce these technologies and forecast changes likely to take place, suggest future political measures and goals for these sectors, and identify principal policy, legislation, and regulation challenges that must be addressed through close collaboration between sectors to facilitate global economic and social benefits.

Research collaboration between academia and industry, focusing on talented, well-trained graduates, the nature of research projects, and translating research results from academia to industry, is considered critical for rapid progress in the future application and realization of the benefits of these technologies. Researchers themselves must also be prepared to initiate and support collaborations. Positive, synergistic collaboration within interlinked sectors will enable faster deployment of new solutions and contribute to the development of improved products and services for the benefit of society as a whole. We invite industrial and academic leaders to engage with society to open discussions about the technologies and challenges we describe, and to advance future joint strategies that will lead to their successful realization and practical vision.

8.2. Policy and Regulatory Considerations

Policy and regulatory frameworks play a vital role in the development, deployment, and coordination of smart computing, sustainable energy systems, and next-generation mobility across multiple and complex levels. Importantly, these frameworks will greatly influence how this suite of technologies will shape and be shaped by broader trends, such as the green and digital transformations and structural changes in the economy and labor market. Several important preliminary insights can be drawn from existing regulatory reforms while acknowledging the dynamic and context-dependent nature of policy-making in these areas and the need for long-term transition paths that can embrace the co-evolution of emerging digital technologies with sustainability goals. Broader goals around sustainable development, digital inclusion, and overall social welfare within and across countries must be paramount in the process of designing, implementing, and periodically reviewing the policy and regulatory frameworks for the transition.

Renewables and sustainability. Smart computing relies on data centers to function accurately and efficiently. Data centers consume vast amounts of electricity, contribute significantly to greenhouse gas emissions, and are expected to continue to grow as our digital footprint expands. Energy and environmental policies need to grapple with these concerns by advancing energy-efficiency measures and sustainable, low-carbon energy supplies for data centers. In addition, the growth in a computing-intensive society and digital economy requires a rapid scaling up of data center services to accommodate the data storage and cloud computing requirements of societies and businesses. This in turn requires not only highly efficient data centers but also strategies for data center owners and operators to use clean energy to optimize their operations. An additional sustainability concern lies in the power and environmental footprints of the underlying technological progress made possible by the convergence of smart computing with other emerging technologies, such as artificial intelligence, manufacturing, and materials. The technology development itself must be directed toward more absolute and equitable sustainability, energy, and environmental goals. Finally, new business models in the digital economy enable social practices that can be detrimental to human welfare, particularly concerning social inequalities, privacy, security, the digital divide, and compliance with basic ethical values. Regulatory approaches for digital sustainability must address these issues in an integrated manner with efforts in technological research, international standardization, and industry self-regulation.

8.3. Research and Development Initiatives

In June 2011, the Ministry of National Development encouraged interested Singapore entities such as companies or research and development institutions to form consortiums to jointly submit proposals under the Electric Vehicle Skirting Scheme. These consortiums will work together on projects that involve the research and development of electric vehicles or their various components. Very little experience exists in the Asia-Pacific region for such systems. This cooperative research and development will deliver front-end competitive projects that will help to pull forward the commercialization of electric vehicles and contribute to the growth and vibrancy of the electric vehicle industry in Singapore. The projects submitted need to be able to demonstrate integrated solutions in the areas of smart charging systems, energy storage systems, safety, and power electronic technologies. Consortia which includes the collaboration of multinational companies or international research institutes and has strong technology components, regional impacts, and the ability to foster the growth of the electric vehicle core competence, knowledge, and technology in Singapore will benefit from additional support.

In the recent national budget, an innovation grant was introduced to promote electric vehicle adoption that was technology and innovation-neutral. Support will be extended for research and development and the demonstration of innovative electric vehicle behaviors and attributes, including their safety, reliability, and performance. The grant will cater to electric vehicle charging infrastructure, other related supporting services, and data applications such as diagnostics, forecasting, optimization, vehicle-to-grid, and vehicle-to-home. This innovation grant comes on top of the current funding support for active players in the research and development and pilot adoption of electric vehicles. These active players can tap into a range of existing government initiatives, which are focused on reducing the high incremental technology cost and other barriers to scalable, mass-market electric vehicle deployment. Participants selected for the Electric Vehicle Skirting Scheme will be able to work on demand, supply, and regulatory issues and develop new business models and revenue streams for electric vehicles in Singapore. The breadth and scope of these many government initiatives are such that a diverse range of research and development work is needed to accelerate electric vehicle adoption.

9. Case Studies

This chapter includes several smaller case studies regarding the successful application of emerging technologies from science and engineering, such as artificial intelligence, machine learning, smart computing, sustainable energy, and next-generation mobility. Our internal natural language processing platform, which has a plug-and-play architecture, is very important for both technology transfer and knowledge dissemination. As an AI research platform, we have a process that includes mainly the collection, filtering, and deep learning reflected information publishing in formats such as paper and book. Especially, in this book, an internal K-means algorithm for deciding the happiest statements and an internal joint enrichment algorithm for providing complementary information given the number of clusters and location of new documents are employed for dataset summarization.

The widespread use of plug-in electric and hybrid-electric vehicles is important for achieving a more sustainable transportation system. Battery aging and non-ideal environmental conditions can lead to decreased performance. When a battery no longer meets its operational needs, it has to be replaced, but degraded batteries can be reused, for example, to store electric energy in connection with photovoltaic systems. In this chapter, we show some analysis and a case study regarding battery aging in a normal automotive situation, including reference curves for NMC111 and LFP chemistry cells, and also an example of cooperation between the grid and electric vehicles using dynamic reward shaping.

9.1. Successful Implementations in Smart Computing

Intelligent and flexible computing is both a necessity and a driving force in modern society. Developing smart computing through the fusion of advanced analytics with emerging technologies that are more sustainable or will soon be widely deployed is no longer an option. It has gradually become a historical inevitability. This chapter reviews several innovative and successful implementations in key areas that include the integration of big data, the security of cloud computing, multimedia big data, mobile big data, mobile computing and the Internet of things, edge computing, next-generation computing systems, machine learning revolution, brain-inspired computing, cognitive computing, and neuromorphic computing. Intelligent and flexible computing is both a necessity and a driving force in our society. With the digital generation moving into an information society, intelligent adaptable computing is the development trend of modern society. In this trend, the interconnected technology space of matter, energy, life, body, information, and cognition is the foundation space for intelligent, flexible, and adaptive computing. In the next ten years, intelligent big data, intelligent cloud, intelligent network, intelligent display, intelligent adaptability, and other areas will be derived from several trillion-dollar industries and smart innovative products.

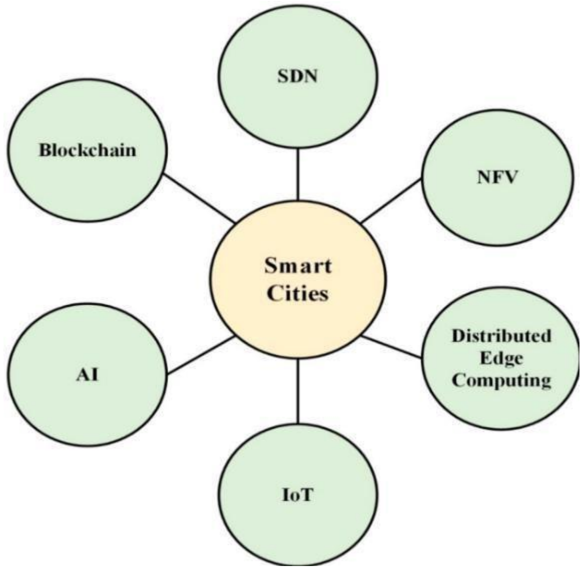

Fig 5 : Enabling Technologies for Next-Generation Smart Cities

The above phrases are used to describe the integration and innovation of advanced analytics with structured, unstructured, and semi-structured data plus a variety of commercially available, tailored, and newly developed enabling technologies to fully realize the potential future value of emerging technologies in the smart and computing space. The concept of intelligent big data is defined as technologies that tap into machine learning, artificial intelligence, cognitive computing, genetic algorithms, future and neuromorphic computing, autonomous agents, multimodal neural fusion and alignment, machine vision, visual analytics, speech and audio processing, natural language processing, computational linguistics, intelligent smart robotics, planning and scheduling, multiple criteria search, and IoT technologies sensors and actuators to support the accomplishments of objectives. A part of the above sentence enhances the use of cognitive and neuromorphic computing in intelligent big data.

9.2. Innovations in Sustainable Energy

Global warming is a well-recognized issue that has led to significant worldwide interest in affordable and sustainable green energy. The global energy challenge must be addressed by a combination of conservation, increased use of renewable, sustainable supplies, energy efficiency, and national security. In this section, we highlight some of the recent advances in the related fields of sustainable green energy, photovoltaic devices, fuel cells, and hydrogen storage. Hybrid core-shell nanostructures have been synthesized by a facile approach. The transmission electron microscopy images indicate that the layer has a thickness of about 5-10 nm on the hollow microspheres. The photodiode was fabricated using these novel hybrid core-shell nanostructures as the organic layer.

The results show that the photodiode with the hybrid core-shell nanostructures exhibited a high power conversion efficiency and high photoresponse sensitivity. These results suggest that the hybrid core-shell nanostructures have potential applications in organic photovoltaic cells. In addition, this work uses a simple process to manufacture hybrid core-shell nanostructures supporting the large-scale preparation of organic photovoltaic cells. The fabrication of organic solar cells is significant. Since most conductive polymers exhibit good absorption at visible wavelengths, the photovoltaic devices based on the bulk heterojunction structure can be fabricated with a much thinner active layer than crystalline silicon solar cells, thereby decreasing the weight of the solar module with the same power or enhancing the power output while keeping the standard thickness, which has greater potential commercial prospects for bulk heterojunction solar cells.

9.3. Advancements in Mobility Solutions

In the future, vehicles will be required to work more actively with each other as part of an intelligent traffic system, as opposed to just relying on the traffic infrastructure, such as road signage or signals. In the new paradigm, automotive technologies must move from isolated systems to part of an integrated traffic environment - Vehicle-to-Everything (V2X). The diversity of communication systems that will be required to support the V2X environment, promoting traffic safety, driver convenience, energy efficiency, and the optimization of traffic flow on urban, suburban, and rural roads, has been recognized as a significant issue.

At the same time as the need for cooperative and intelligent vehicular systems is being discussed, other services such as infotainment, as well as the need for other parties to work with the automotive community, are also important. Ultimately, it may make sense for these diverse requirements to be supported simultaneously by the same set of wireless communication resources. However, none of the communication technologies available today satisfy either the V2X requirements, the coexistence requirements, or the requirements of the other interested parties. The needs for V2X include low latency, robustness to rapidly changing channel conditions, operation in high mobility scenarios, and long-range communications, and these conflict with both the requirements of deployment and the need for fixed-mobile coexistence. This chapter provides an overview of how the next generation of mobile communications technologies can be designed to meet these conflicting requirements in a manner that enables road safety, localized traffic optimization, and the potential reduction in journey time that is seen.

Equation 3 : Intelligent Mobility Efficiency Model

$$M_e = \frac{D_t}{E_c}$$

where

M_e = Mobility efficiency (distance per energy unit),

D_t = Total travel distance (km),

E_c = Energy consumption (kWh).

10. Future Directions

This monograph detailed diverse technologies about computing, electronics, energy, cybersecurity, telecom, IoT, mobility, and societal concerns among others. Even though the majority of the technologies have already been researched and applied to varied applications, the interest in these technologies is intensifying because of the challenges posed and the benefits meted out. Future efforts could be directed at novel research cross-pollinated among the various covered technological areas. For instance, smart sensors and smart computing can be integrated to better control home and office energy usage while ensuring comforts originally debated more from the energy and smart comfort aspects. Similar cooperative research across technology fields will be fruitful. Research would extend didactically to political science, regulatory laws, and economic aspects and the multi-faceted human responses. Several start-ups are envisioned to be created; hence, a guide on entrepreneurial and business aspects is highly called for. Technology education covering the subjects at all stages can be developed using this monograph as a resource. Topics in this monograph are also well-suited for the continued development of summer and winter programs for high schools and colleges and the in-servicing of practicing professionals. Finally, human responses in the form of migration and privacy concerns need to be transparently addressed in the research efforts and while applying these technologies.

10.1. Emerging Trends to Watch

Smart computing devices and systems are increasing at an accelerating pace in the modern era. The emerging trends of smart computing are expected to exhibit great potential for workplace needs. A paradigm of smart computing was addressed and introduced based on fundamental knowledge and potential impact. From smart desks to tools for sustainable societies, not only is the enhancement of processing power and innovation in materials expected but also the development of co-design to optimize power and performance is anticipated. Because of the unique attributes of advanced technology, modern issues in a diverse range of fundamental fields in the domain of sustainable energy have emerged. The prevalent endeavors in the familiar living environment contribute to sustainable energy pathways, technology and policy, and systematic strategies. The results of a substantial increase in the reliance of society on transportation have increasingly adverse impacts.

The integration of a wide range of advanced technologies, such as intelligent transportation systems, infotainment and transportation communication, and rail and traffic surveillance, can effectively enhance the safety, comfort, and capacity of the transportation system. However, the trends in everyday life, business, and transportation-related technology have been evolving at relentless speeds. Not only are sustainable transportation challenges, strategies, and solutions emerging, but next-generation mobility is becoming real. A rich family of solutions according to different settings and design principles in a well-known smart environment mainly explores the distribution system, geographic mining, grid topography, intelligent building, monitoring, privacy, security, and social benefits. A general guiding principle is the maximization of the utilization of smart computing, renewable, and sustainable features according to energy. The combination of smart computing services with emerging technologies can be expected to leverage their advantages. To deliver underperforming solutions with reduced costs and environmental impacts, smart computing, integrating sustainable energy and next-generation mobility, has promised roadmaps and outlines for societal benefit.

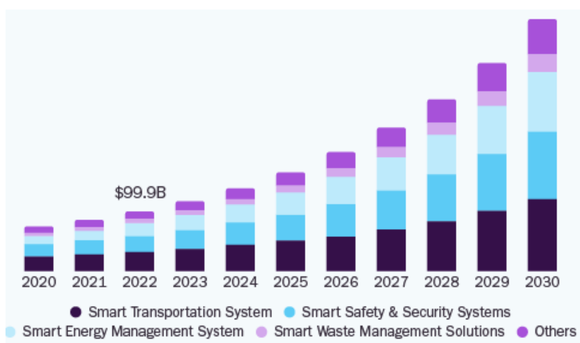

Fig 6 : Smart Infrastructure Market Size

10.2. Potential Disruptive Technologies

In the last decade, smart computing, sustainable energy, and mobility have been transformed by digital and communication technologies. Artificial intelligence, deep learning, and cloud computing have played a pivotal role in accelerating the realization of smart finance, smart commerce, and smart manufacturing. Renewable energy, energy storage, and carbon capture not only provide the technological foundation for smart energy but also decouple the linkage between economic growth and greenhouse gas emissions. The success of electric vehicles, intelligent transportation, and advanced air traffic control has far surpassed the expectations of the public, the government, and the industry. This chapter outlines the crucial roles of emerging technologies in smart computing, sustainable energy, and next-generation mobility. In the next three decades, several potentially disruptive technologies will almost certainly impact these three critical sectors and trigger endogenous growth in disruptive smart computing, disruptive sustainable energy, and disruptive next-generation mobility. First and foremost, the next two generations of computing paradigms will augment and amplify the smart technologies of the current deep learning and cloud computing models. Digital and brain computing technologies may not only address unsupervised and reinforcement learning but also engineer artificial general intelligence in computers. The symbiosis between human brains and machine learning facilitates access to competing knowledge algorithms, and sort of knowledge epidemics, and transfers the futuristic economy's cognitive aptitude advantages quantitatively into qualitative breakthroughs in social sciences and humanities.

10.3. Long-term Sustainability Goals

In addition to the potential for short-term shared savings with energy management and the cost-effectiveness of technologies to the user, the service provider must ensure that emerging technologies coexist with and support long-term sustainability goals by adhering to sustainability best practices. These goals include sustainable cities, sustainable economies, and environmental betterment. Lowering energy consumption and grid peak demand, leveraging renewable energy sources, reducing greenhouse gas emissions, preserving important fossil resources, minimizing waste and transportation impacts, and delivering real environmental benefits through energy-efficient technologies are necessary. Support urbanization and the economic richness of the Smart Cities concept. The Smart Cities concept could be considered an advanced application of Information and Communication Technologies in a more traditional urban context and would use urban resources in the most economically efficient and environmentally sustainable way. It should strive to ensure that technology obeys the principles to ensure the quality of life in its various aspects, such as economic, environmental, and social.

This business sector needs to consider the environmental impact of using ICT to promote long-term business sustainability goals. It should stimulate and support the growth and proliferation of eco-friendly and socially responsible companies and products. It should also consider the ecological and social impact of allowing consumer electronic devices such as tablets, mobile phones, and laptops to operate whenever and wherever they please. It should provide services and sharing without considering the energy, transportation, or industrial costs or the light exposure that consumers face. Market leaders will be those who support sustainable development, corporate social responsibility, and product stewardship. As an example, companies should try to reduce, reuse, and recycle as environmental best practices. Finally, technological solutions need to be scalable to improve energy efficiency and lower power consumption to be environmentally sustainable. The Smart Cities concept emphasizes knowledge sharing and collaboration with ICT business ecosystems contributing to environmental, social, and sustainable urban cultures. The use of ICT in Smart Cities can help avoid the shortcomings of past urbanization processes by ensuring a high level of eco-sustainable sensitivity in urban processes by promoting new models of urban governance.

One of the vexing tasks facing humanity is how to achieve a high level of sustained development that ensures a high quality of life for everyone while simultaneously increasing resource efficiency and minimizing energy consumption, pollution, and transportation emissions. The main drivers for a Smart City operational model are goals, actors, and enabling technological advances in a wide range of urban functions such as intelligent energy management, sustainable transportation, and ubiquitous information. Improvement in the quality of life and sensible business strategies, and perhaps also the pursuit of happiness, may be advanced through innovative business models that promote the development of smarter awareness and use of urban resources. Modern cities have a high level of complexity to analyze and develop solutions. The cities of the future, the so-called smart cities, will be organized around the paradigm of creative, intelligent, and socially sustainable interactions. These city systems are complex, distributed systems subject to forces of integration but also dictated by strong self-organizing forces. Their behavior is determined by a continuous exchange of digital and physical resources, data, services, and information, operated by a variety of actors and constituting complex networks.

11. Conclusion

This chapter provided snapshots of some of the emerging technologies and their applications in the fields of smart computing and machine learning, sustainable energies, and next-generation mobility. The presented works leveraged different machine learning techniques and validation methods to address the encountered challenges. Several empirical studies were conducted to confirm the suitability and efficiency with which the methods can handle large-scale and diverse data types. Additionally, we presented representative innovative works in transportation systems at different levels, i.e., routing, traffic management, energy management, and maintenance, causing a fundamental impact on the field of transportation, with ripples extending far beyond academic research and into the public interest and policy-making.

They also showed that for complex real-world problems to be handled effectively, these techniques need to be built upon fundamental advances in the application of traditional machine learning techniques, e.g., exploiting hierarchical relationships for multimodal learning, dual learning, global and local optimization, etc., and innovations in formulating new types of machine learning problems that naturally occur in different stages of energy and infrastructure systems. The studies and results presented in this chapter are only a stepping stone in building deeper AI research where the problems of studying transportation systems can potentially serve as an interdisciplinary platform for leveraging machine learning techniques to solve complex real-world problems while simultaneously advancing the theory of machine learning. At the moment, it appears that the bounds are being pushed by real-world transportation problems with accurate benchmarks and varied data modes, complementing the methodological advances.

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