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UNIT – III
Ubiquitous Internet of Things

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Go, Change the World

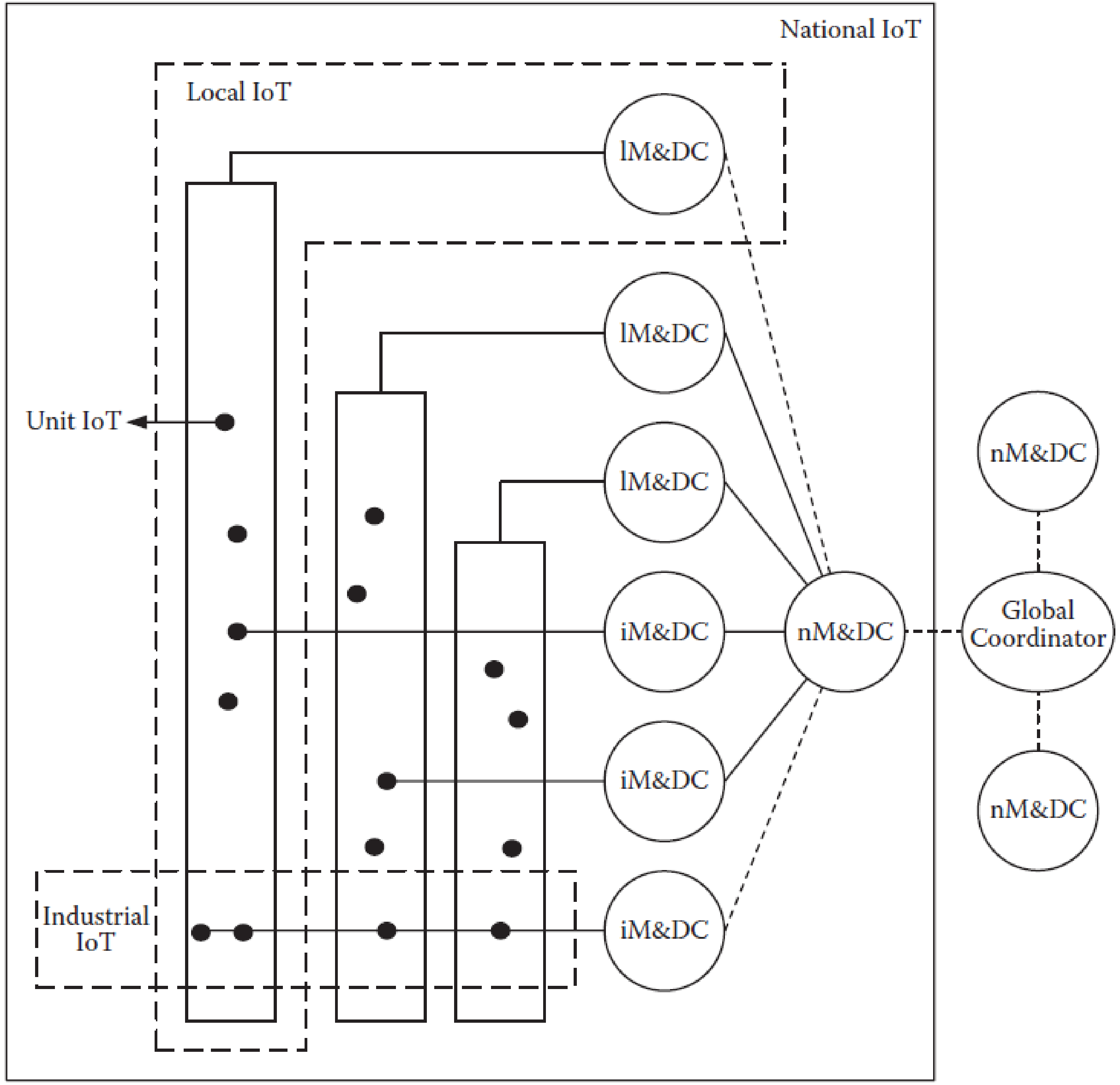
Content

Introduction

- → Ubiquitous Internet of Things (ubiquitous IoT) is the collection of multiple unit IoTs.
- → As an essential paradigm of future IoT with the meanings of network of services, network of networks, and even network of everything, ubiquitous IoT embodies the social attributes of future IoT.
- → Ubiquitous IoT makes it possible for the interaction and cooperation of multiple unit IoTs as well as pervasive management, access, and control of unit IoT resources.
- → According to the architecture of ubiquitous IoT, local IoT, industrial IoT, national IoT, and global application IoT are introduced as typical kinds of ubiquitous IoT.
- → Therefore, local IoT is the integration of multiple unit IoTs within a particular region under the management of a local management and data center (lM&DC).
- → Similarly, industrial IoT is the integration of multiple unit IoTs that belong to a particular industry under the management of an industrial management and data center (iM&DC).
- → Moreover, National IoT refers to all kinds of IoTs within a nation, and national management and data center (nM&DC) acts as the manager of national IoT.
- → It is noteworthy that management politics and regulations play important roles in national IoT

Introduction

Architecture



Local Internet of Things

→ Local IoT (Local IoT = IM&DC + Unit IoT) is composed of IM&DC and the covered unit IoTs in the region (Local IoT is a regional-based relationship that holds the unit IoTs together.) The unit IoTs within the range of local IoT provide the unit services for local IoT.

→ As the head of local IoT, IM&DC acts as the management platform of local IoT and integrates unit IoTs' services to provide higher-level service.

→ Apart from the unit IoTs and IM&DC in a local IoT, the intra/ inter social relationship among unit IoTs is also important.

→ Generally, regional-based relationships in local IoT can be classified into direct relationships and indirect relationships.

- Direct relationships are built when a unit IoT directly interacts with the other ones.
- Indirect relationships refer to the relationships that are built in the process of indirect interaction among unit IoTs.

→ For example, an indirect relationship between two-unit IoTs is built when both want to serve the same customer. Several typical kinds of direct and indirect relationships among unit IoTs in local IoT are introduced as follows.

Local Internet of Things

→ Some direct relationships:

- Affiliation Relationship: Affiliation relationship indicates that one or more-unit IoTs are owned and controlled by another unit IoT. This kind of relationship is common in a dedicated situation where a unit IoT is designed only for accomplishing a special task.
- Function Calling: Function calling means that one-unit IoT provides services (e.g., command execution, status capturing, environment sensing, etc.) to multiple other unit IoTs.
  - The difference between affiliation and function calling is that affiliation is a one-to-one relationship, while function calling is a one-to-many relationship, which denotes that a unit IoT can be called by more than one other unit IoT.
- Data Interchanging: Data interchanging represents relationships that are built on the process of data exchanging in a peer-to-peer (P2P) mode between two-unit IoTs.

Local Internet of Things

→ Some indirect relationships:

- Coverage Complementation - Coverage complementation indicates that multiple unit IoTs with different coverage areas cooperate with each other to form a local IoT with larger coverage. Due to some reasons (e.g., the limitation of unit IoT coverage, operating cost, and industry pattern), coverage complementation is general in monitoring applications such as air quality monitoring, traffic monitoring, and battlefield surveillance.
- Function Complementation - Since unit IoT is restricted by computing capability, communicating bandwidth, system complexity, energy supply, and other factors, it is better to adopt cooperation of multiple unit IoTs rather than implementing all the functions into a single unit IoT in some cases.
- Service Competition - In local IoT, there may be several competitors (i.e., unit IoTs or a group of unit IoTs) that can provide the same service. In this situation, the relationship among these unit IoTs is service competition. Just like the competition in other fields (e.g., business environment), the competition among unit IoTs contributes to service improvement.
- Resource Competition - Competition exists in resources, such as energy, computing infrastructure, and communicating channel, which are needed by unit IoTs. A resource management strategy should be designed to supervise the resource competition, and to improve energy efficiency, system performance, and system robustness.

Local Internet of Things

Main Characteristics of Local IoT

→ Diversity

- It denotes that one local IoT is generally different from the local IoTs located in other regions.
- Diversity is caused by many factors, such as geographical features (e.g., landscape and climate), cultural characteristics, economic characteristics, policy support, or some demands.
- Local IoT diversity is reflected in various aspects such as scale, function, and structure.
- On the one hand, local IoT diversity makes it possible to integrate regional characteristics into the implementation of local IoT and leads to better performance.
- On the other hand, as the planning and establishment of a local IoT are generally based on the local conditions and particular demands, the development mode is difficult to duplicate among different regions.

Local Internet of Things

Main Characteristics of Local IoT

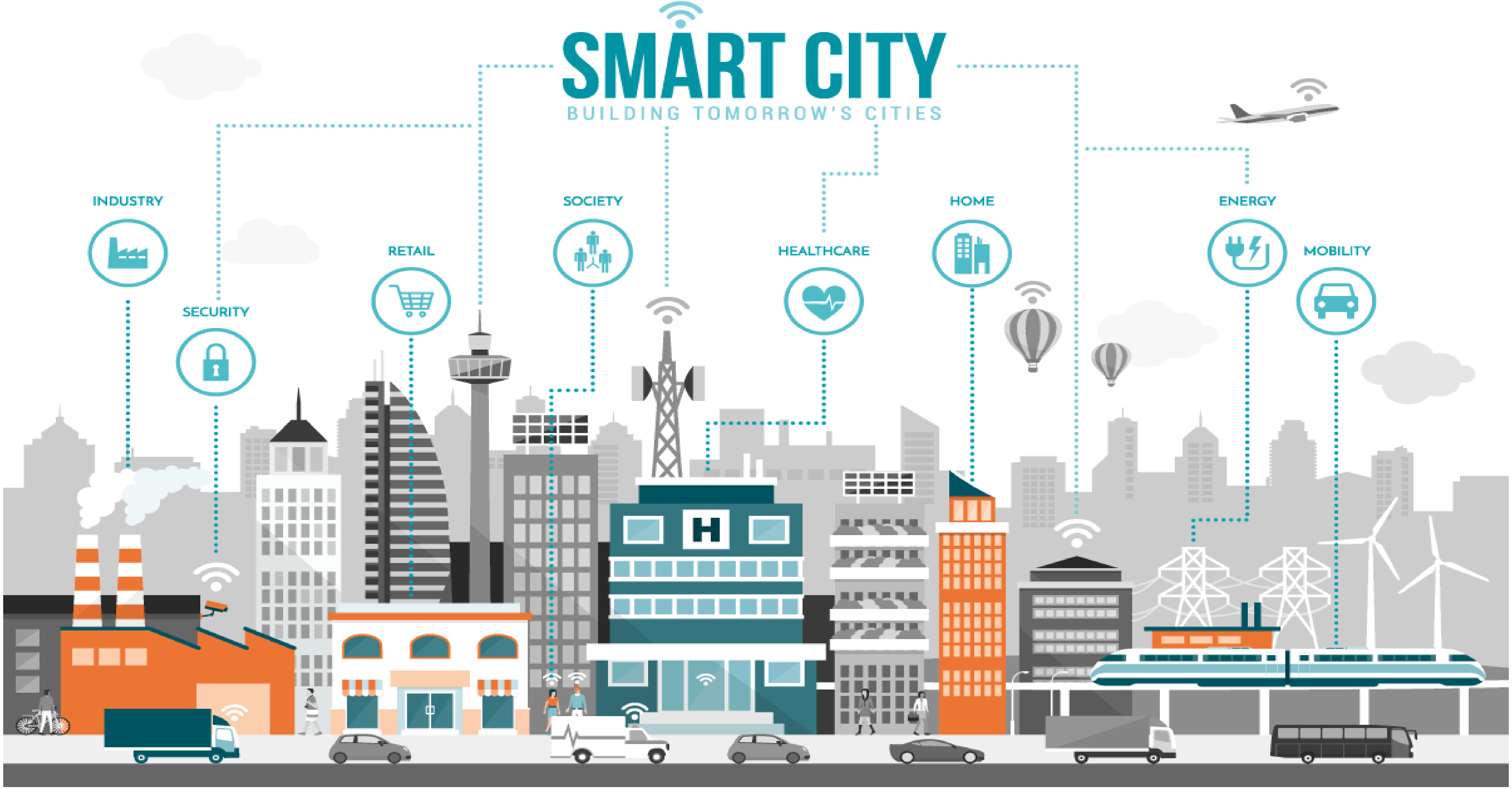
→ Regional Fusion Effect

- It refers to the covered unit IoTs being deeply fused by some core values to provide better services.
- For example, in a future smart city, the sustainable development concept will fusion the unit IoTs in the city to promote energy efficiency.
- The unit IoTs will cooperate as much as possible to provide optimized solutions to citizens.
- The regional fusion effect is the basis for achieving *intelligent local IoT*. Here, intelligent local IoT includes two aspects:
  - local IoT should obtain the ability to monitor and react to situations rationally, and
  - local IoT should be able to predict future trends and make early preparations for upcoming events in it.
- Intelligent local IoT cannot be accomplished without information sharing and cooperation among unit IoTs, which are the preconditions of regional fusion

Case Study: Smart City

- → With the development of urbanization around the world, the scale and population of urban cities have been a magnificent miracle in human history during a fast and increasing period.
- → Currently, many people live in urban cities, and this amount is climbing at a high speed
- → The fast growth of city populations and scales has made cities overloaded, and has done great damage to the environment, making it uncomfortable to live in urban cities.
- → Fortunately, the wide adoption of information and communication technology (ICT) has brought new solutions to these problems.
- → More exciting, IoT is promising to bring attractive changes to current city status, making cities greener and better.

Case Study: Smart City



Case Study: Smart City

→ Smart city focuses on the utilization of IoT technologies such as ubiquitous sensing, communication, and computing to realize the mapping between the cyber world and physical world as shown in Figure

→ In the physical world, things are controlled by time and space, causing the limitation of functions/ services.

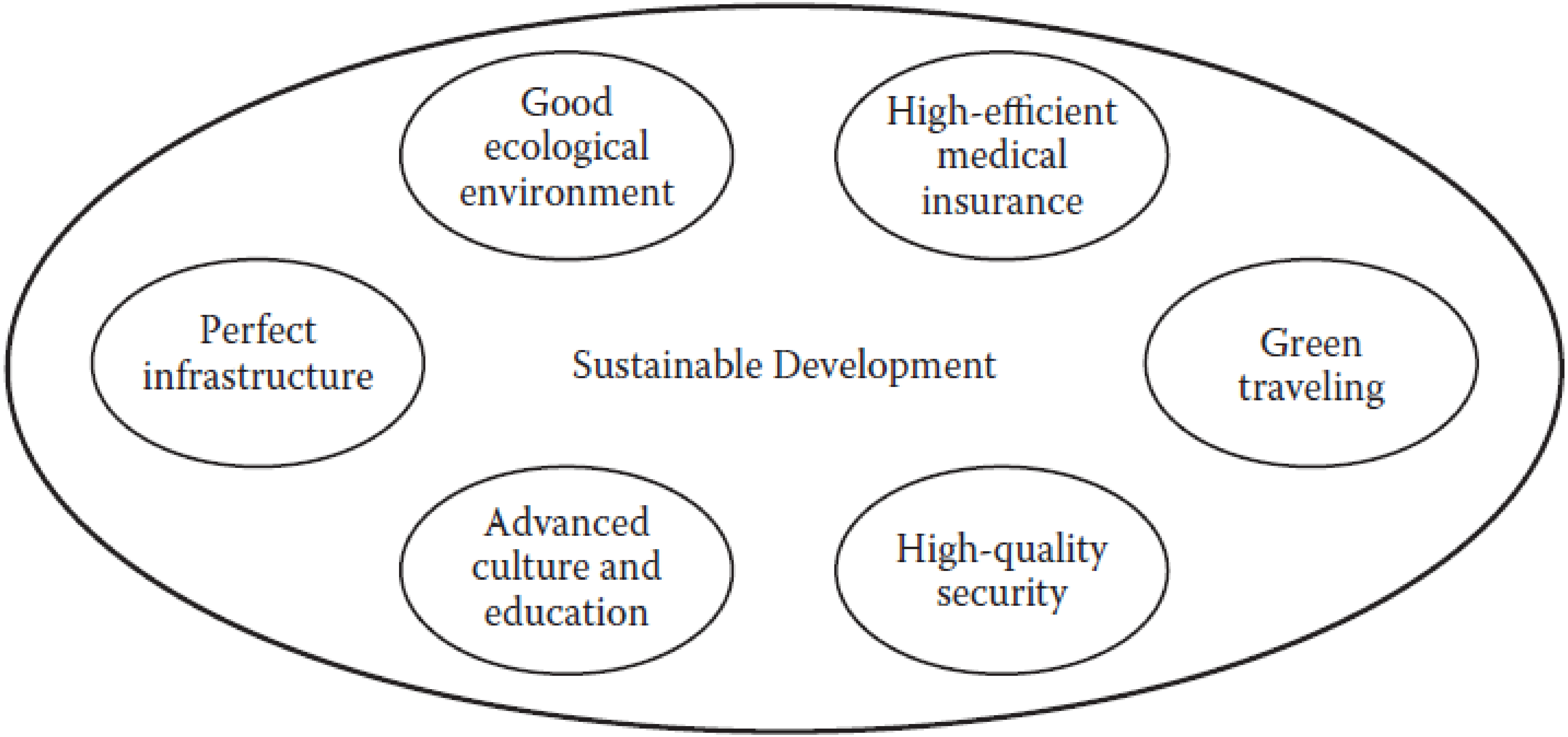
→ However, in the cyber world, many limitations can be overcome and services/ functions with much better user experience can be implemented.

→ The main purpose of the smart city is to reduce city costs and improve efficiencies and quality of life by considering sustainable and environment-friendly development.

→ The function requirements and themes of the future smart city may vary prominently in different regions due to the regional diversity of local IoT.

→ Due to the bright future of smart city, many smart city projects have been launched to bring it into reality.

Case Study: Smart City



Case Study: Smart City

→ Lee et al. proposed an Integrated Service Management Platform for a Ubiquitous City (ISMP-UC) that is equivalent to a smart city to overcome the limitations of stovepipe systems and enable synergistic service collaboration.

→ The ISMP-UC has three aspects

- The first aspect includes sensors, actuators, and other devices
- The second aspect is service-oriented middleware in which context information data are stored and processed for service integration
- The third aspect includes the services

→ Based on the regional characteristics of smart city, it makes sense to model smart city as a local IoT that consists of IM&DC and multiple unit IoTs within the city.

→ Unit IoTs in local IoT provide the services that satisfy the requirements of the smart city (e.g., intelligent transportation, energy management, and air quality monitoring).

→ IM&DC manages unit IoTs within the city and provides interfaces for external IoTs.

Industrial Internet of Things

→ Industrial IoT includes the unit IoTs that belong to a specific industry (e.g., logistic, agriculture, and smart grid), as well as management platforms to manage them (i.e., iM&DC).

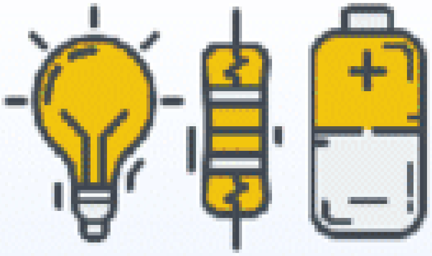
→ The industrial M&DC (iM&DC) is responsible for the management and integration of the involved unit IoTs and other functions, such as policy making, event monitoring, and security protecting.

→ The function requirements and system components of industrial IoT are based on the characteristics of the industry, which are significant factors for the development of industrial IoT.

Industrial Internet of Things

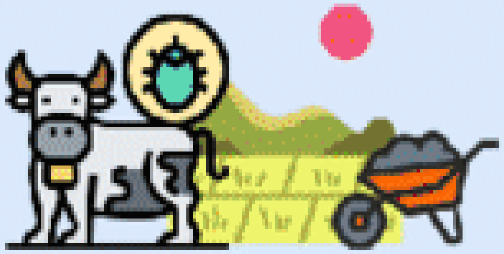
Water Utilities

- IoT sensors can be used to track the condition of water and put alerts as contaminant level increases.



Electric Utility

- Identify electricity stolen, smart metering, and take restorative action.
- Efficiently manage power distribution process



Smart Agriculture

- Soil condition monitoring, crop protection from pesticides, and automated water irrigation.
- Experienced guess to a technology-driven approach.

Coal Mining

- Cost optimization and ensure the safety of people by monitoring mining equipment.
- Mining 4.0 improves production benefits.

Industrial Internet of Things

Main Characteristics of IIoT

→ Geographical Dispersion

- Different from local IoT, industrial IoT shows a strong geographic dispersion characteristic.
- For an industry, its functions are radiated to different areas. For example, in the manufacturing industry, two vital measures to achieve high profit are reducing cost and improving efficiency in each industrial link.
- The key approach to achieve low cost and high efficiency is making full use of the geographically dispersed resources (e.g., raw materials, labor resources, and information technologies).
- In addition, the market distribution may also disperse throughout the nation and even all over the world.

Industrial Internet of Things

Main Characteristics of IIoT

→ Multi-user Orientation

- Multiuser orientation denotes that industrial IoT has diverse orientations according to different users.
- For example, on the one hand, food industrial IoT tends to provide services that can lead to the promotion of productivity and efficiency for this industry. On the other hand, it is also responsible for providing security and qualified services to customers.
- A further discussion on the multi-oriented characteristics of industrial IoT is given from the government, industry, and customer perspectives.

→ Government Orientation

- For government, the information used to make national industrial decisions and plans can be collected by industrial IoT.
- The government's policy and support are important for industry development, especially in an international trade environment. Currently, some national regulation and control policies from the government lag behind the industrial developing trends

Industrial Internet of Things

Main Characteristics of IIoT

- Moreover, the response time and regulation efficiency are criteria are used to evaluate the government's performance.
- Industrial IoT gives the government with the capability to analyze information and make an optimized management strategy and plan.
- It is noteworthy that industrial IoT can strengthen the government's industrial emergency response capability due to its real-time monitoring and intelligence.
- Industrial IoT can also help governments revise local industrial policies

→ Self-Orientation

- It is obvious that industrial IoT can bring many advantages to the industry's operation and management, such as promoting production efficiency, reducing production cost, optimizing resource utilization, and standardizing production and management.
- For example, in the agriculture industry, great product promotion and cost reduction can be achieved by applying IoT technologies to a greenhouse environmental monitoring and controlling system.

An Example: A Smart Grid

→A smart grid applies IoT technologies and other innovative technologies such as distributed generation into a traditional power grid.

→It can realize the optimized scheduling of electric power through bidirectional information and electric networks.

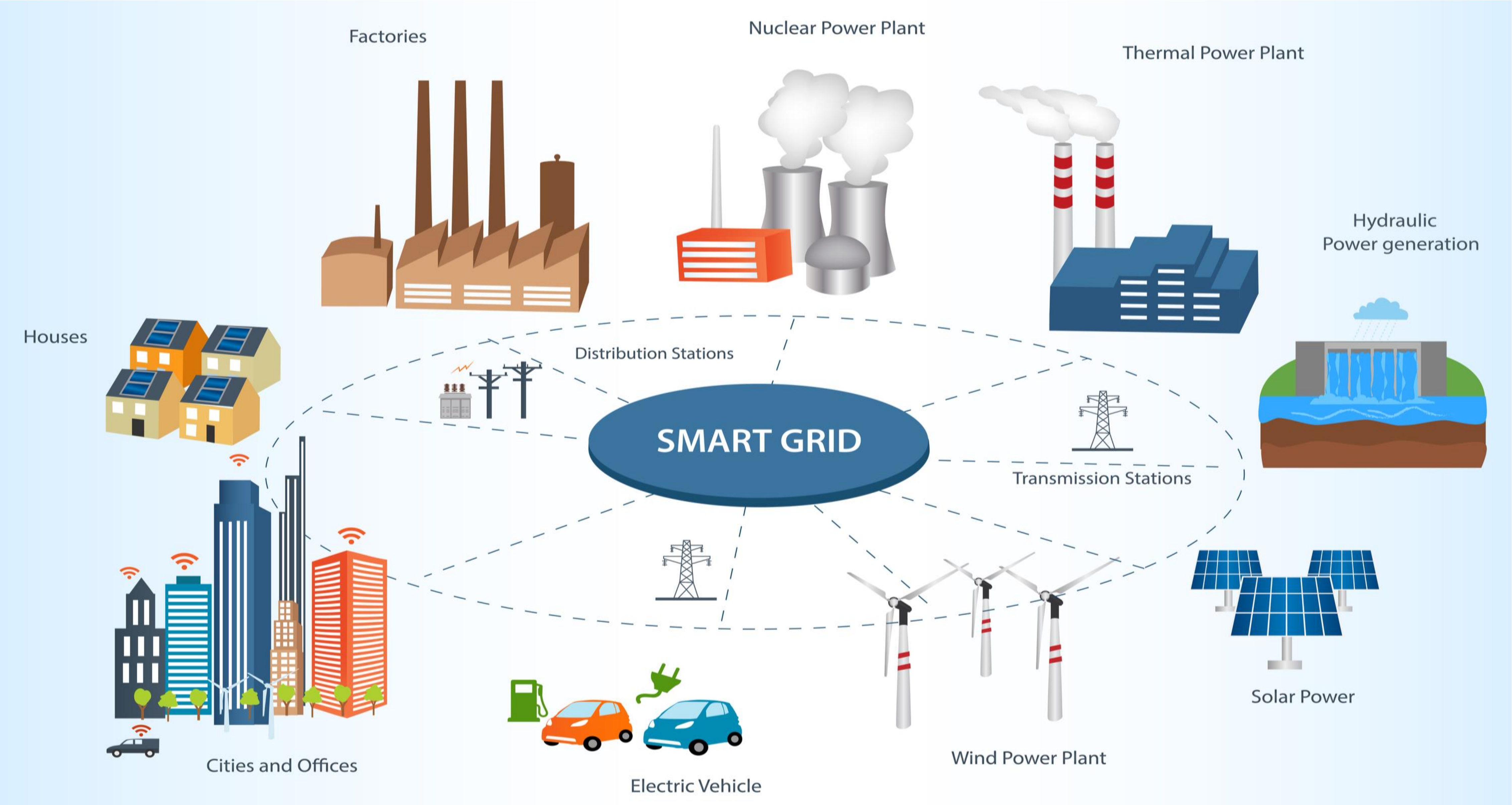
→The functions and scales of a smart grid depend on the specific situation in the nation.

→For example, in China, due to the vast territorial area, the smart grid is on great scale and complexity.

→Meanwhile, due to the unbalanced distribution of energy sources and energy demand (the distribution of energy sources is mainly scattered across the southwest, northwest, and north regions of China; however, the energy consumers are concentrated in eastern and southeastern China)

→The smart grid in China aims to increase the proportion of renewable energy access, improve transmission efficiency, reduce energy consumption, and maintain a good balance of energy demand and supply

An Example: A Smart Grid



An Example: A Smart Grid

- →Due to common problems (e.g., resource depletion and environmental pollution), more and more renewable energy sources (e.g., wind and solar) need to be connected into the power grid.
- →Another obvious trend of the smart grid is the adoption of smart meters that can be used to achieve optimized energy efficiency through real-time grid-user interaction.
- →A smart grid is an industrial IoT that aims at providing reliable and green energy flow to the customers.
- →It is composed of multiple unit IoTs in different links from electricity generation to utilization with various functions (e.g., generation controlling, load sensing, transmission parameter monitoring, marketing, etc.).
- →The iM&DC monitors and manages all the covered unit IoTs and provides interfaces to other external IoTs.

National Internet of Things

- → National IoT Concept: To achieve the ubiquitous characteristics of future IoT, local IoT and industrial IoT should be further integrated and extended to support more comprehensive applications.
- → A larger scale of IoT is needed to realize more powerful services, including nationwide access and management of services.
- → National IoT is the collection of unit IoTs in a specific nation and provides the corresponding management/regulation/strategy mechanisms.
- → nM&DC is the head of national IoT and It manages the corresponding nationwide unit IoTs, and controls iM&DC and lM&DC in the nation
- → The nM&DC also supports other functions, such as multinational cooperation, data backup, arbitration, and macroeconomic regulation and control.
- → In a word, nM&DC's main functions are to manage local and industrial IoTs' operation and development, and to manage transnational cooperation among IoTs.

National Internet of Things

National Development Planning

→ National policies and strategies are the key factors influencing IoT development, which generally needs the cooperation of government, industry, and other nations.

→ For national IoT development planning, some aspects should be considered by the national IoT management authorities to propel the construction of national IoT:

- Strategy and planning
- Policy support
- Financial support
- Project and technologies support
- Public service platform construction
- Industry chain and ecological environmental construction
- Standards construction
- International cooperation promotion

National Internet of Things

→ The development model of national IoT includes different patterns according to the national IoT development strategy plan.

→ For example, national IoT may be designed in a systematic view.

→ It is important to perform comprehensive studies (e.g., architecture, basic theory, and key technologies), and to guarantee the rationality and scalability of national IoT.

→ This means that this systematic view aims to create mature prerequisites for national IoT.

→ Additionally, national IoT can also be designed in a demand-oriented pattern, in which national IoT is led by the practical application demands.

→ For this pattern, IoT development is closely related to specific applications such as smart grid, intelligent medical, smart home, and environmental monitoring.

→ It is hard to determine which development pattern is better, and national IoT should be designed according to the practical situations.

→ In terms of the status, the latter development pattern is more realistic, as IoT development is driven by demands, and many key issues in IoT will be addressed by practice in the process of IoT exploration

Management of National IoT

→ The management of national IoT focuses on the management of all the IoTs within the nation.

→ Generally, the scales of national IoT may be different according to the nation’s territory area, national development level, and other factors.

→ For example, in nations such as the United States and China, it is not easy to manage national IoT due to the vast territorial area and complexity of national industrial structures

→ In national IoT, there are two topology-based management schemes

- Region-based management scheme.
- Industry-based management scheme

Management of National IoT

→ **Region-based management scheme**

- In this scheme, unit IoTs distributed around the nation are incorporated into local IoTs, which are established based on geographical features.
- Unit IoTs located in an area are managed by one lM&DC, and the lM&DCs across the nation are under the management of nM&DC.
- For a regional-based management scheme, the rational partition plan for the local IoTs is important to achieve high management efficiency.

→ **Industry-based management scheme**

- In this scheme, unit IoTs are managed based on vertical industries in the nation. For example, all the aviation-related IoTs are managed by the aviation iM&DC.
- The aviation iM&DCs and other iM&DCs are managed by nM&DC.

→ Due to the high complexity of national IoT management, nM&DC should be armed with high-level intelligence, powerful computing capability, huge storage space, and strong communication ability.

→ In addition to technological support, regulations and laws are also crucial in national IoT management.

Transnational Internet of Things Application

→ With the development of transnational cooperation and commercial trade among multiple nations, transnational IoT is introduced to realize the cooperation of IoTs from different nations.

→ Transnational IoT is efficient for solving international issues.

→ For example, in the cross-border water quality monitoring application, transnational IoT is established by mutual cooperation among different nations to complete the monitoring task.

→ In the following, a case study on the transnational logistics IoT in the Association of Southeast Asia Nations and China Free Trade Area (ACFTA) is discussed to introduce transnational IoT.

An Example: Transnational Logistics IoT in ACFTA

→ The China-ASEAN Free Trade Area (CAFTA), also known as ASEAN-China Free Trade Area (ACFTA), is a free trade area among China and includes the 10 members of the Association of Southeast Asian Nations (ASEAN).

→ The initial framework agreement was signed in 2002 in Cambodia, with the intent of establishing a free trade area among the 11 nations by 2010.

→ CAFTA is the largest free trade area in terms of population, which is about 1.9 billion, and the third largest in terms of nominal GDP.

→ However, there are some difficulties for development, such as the low efficiency of traditional logistics and transportation systems.

→ A transnational logistics IoT with different languages is promising to break the bottleneck and promote the overall development level.

An Example: Transnational Logistics IoT in ACFTA

→ The main significant aspects of the transnational logistics IoT in this area are as follows:

Overcome the linguistic obstacles

→ CAFTA covers 11 nations, which leads to many different languages (i.e., Chinese, Thai, Malay, English, France, Indonesian, Laotian, Burmese, Filipino, and Vietnamese) used in this trade area.

→ The language barrier is one of the most important obstacles for further trade development.

→ It can be solved by the automatic language conversion services provided by transnational logistics IoT.

Provide supply chain management and efficient logistics

→ With the development of transnational trade, supply chain management brings challenges to traditional logistics.

→ A typical challenge is the promotion of services quality and efficiency.

An Example: Transnational Logistics IoT in ACFTA

→ Transnational logistics IoT is promising to address the above challenge through real-time and ubiquitous monitoring and intelligent decision support.

Provide a reference for Government

→ Transnational logistics IoT can provide a platform for governments to obtain trade information and serve as a reference for governments to develop policy and strategy this area.

→ Transnational logistics IoT can also promote the development of CAFTA from other aspects, such as providing multi billing and electronic payments, and so forth

Global Application IoT and a Typical Example

- → Along with the intensification of globalization, the world turns into a global village, and some global application IoTs appear to provide global services or solve some worldwide issues (e.g., environmental protection, ocean protection, and energy crisis).
- → Global application IoT is composed of the IoTs that are needed to accomplish a specific task across the world and the global coordinator, whose responsibility is coordinating the different participants around the globe.
- → Global application IoT will benefit optimized resources allocation in the global range.
- → The main function of global logistics include multiple aspects, such as security transportation, warehousing, inventory, and management of freight from the source to the destination in the global range.
- → A significant revolution in global logistics is the adoption of information technology to promote efficiency and reduce costs, such as electronic data interchange (EDI) and computer-based freight management. In recent years, IoT-related technologies, such as ubiquitous sensing (e.g., RFID and global positioning system), ubiquitous and high-bandwidth communicating, and intelligent information processing, have brought a huge upgrade in performance and efficiency to global logistics.

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Global Application IoT and a Typical Example

Case Study: Global Logistics IoT

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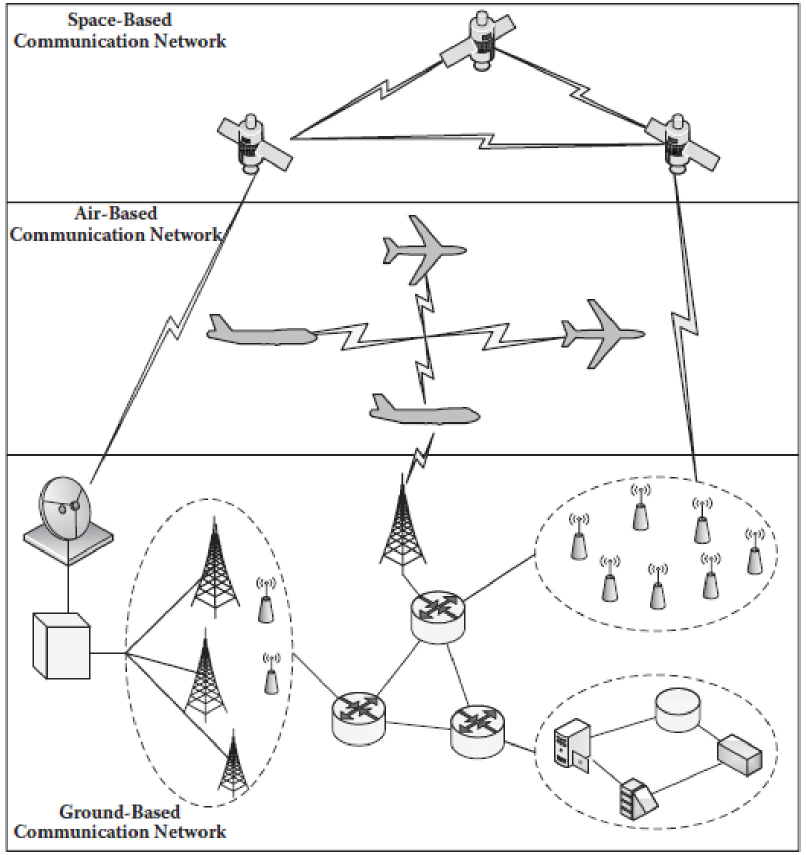
→ Due to the investment cost and economic gap in different nations, global logistics confronts great challenges, including the following aspects:

- Basic infrastructure is insufficient
- Growing problem of unbalanced container scheduling
- Low efficiency in global logistics chain
- Lag behind the development of new technology

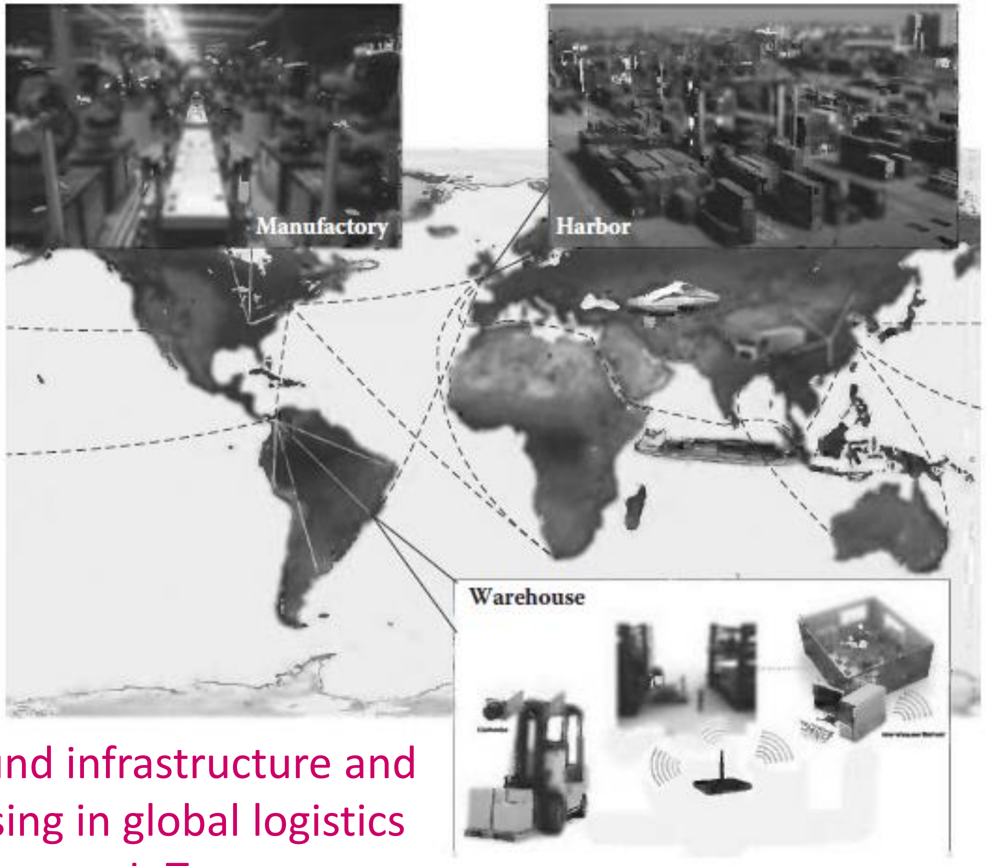
Global Application IoT and a Typical Example

→ A low-cost and green global logistics IoT can help to overcome the above challenges, but it requires cooperation from different nations.

→ The schematic of global logistics IoT can be regarded in three hierarchies: global infrastructure and sensing, an air-space-ground–based network, and multiple transportation platforms



The air-space-ground–based networks in global logistics IoT.



Ground infrastructure and sensing in global logistics IoT.

Global Application IoT and a Typical Example

→ The first hierarchy is ground infrastructure and sensing, including all the infrastructures (e.g., seaports, airports, railway stations, highway facilities, and warehouses), transportation tools (e.g., ships, airplanes, trains, and trucks), and sensing devices (GPS, RFID, and other sensors).

→ The second hierarchy consists of the air-space-ground–based networks that cover the global range.

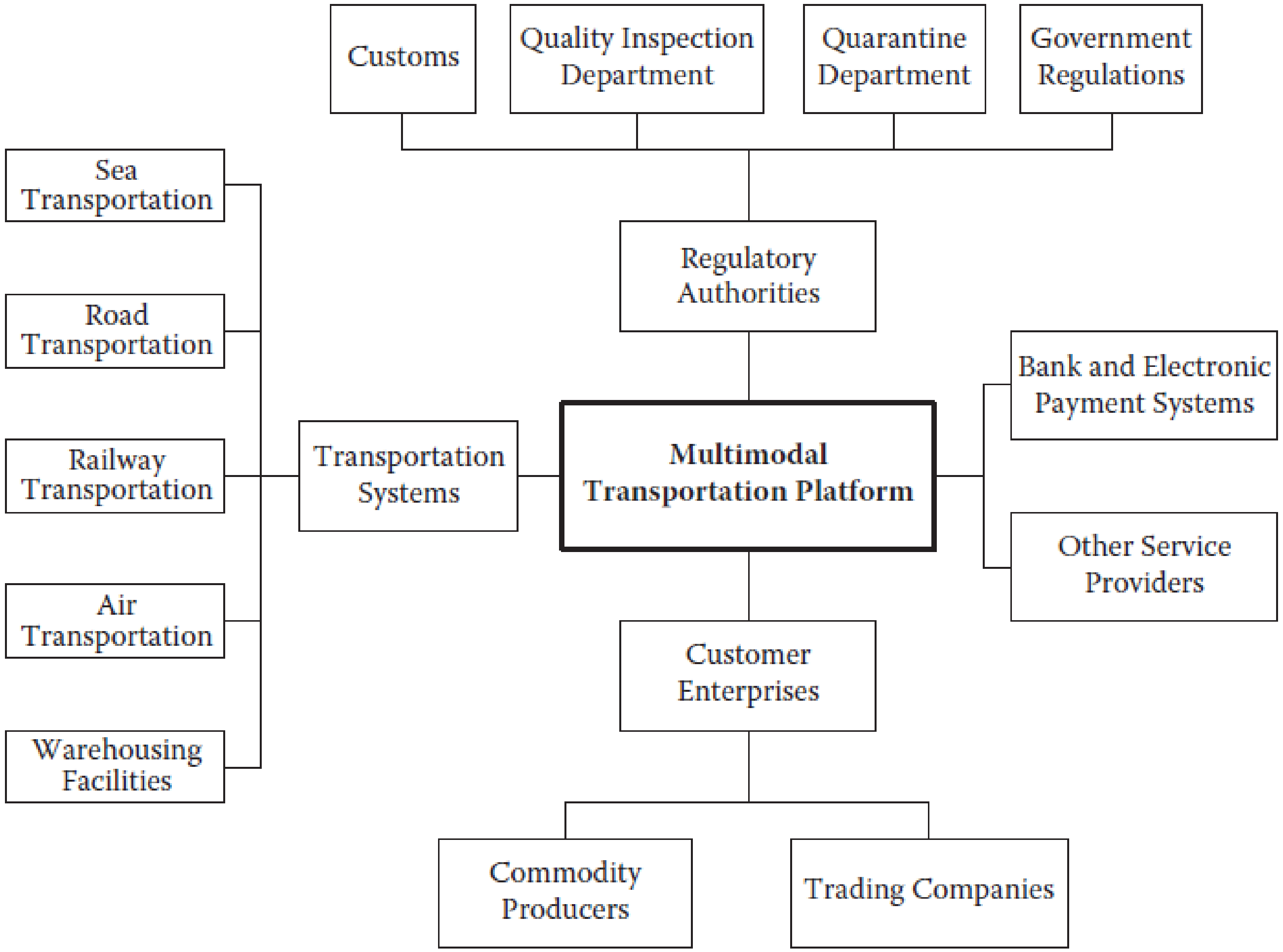
→ Global logistics IoT is based on communication networks that cover every corner of the globe.

→ Air-space-ground–based networks are integrated by space-based (i.e., satellite), air-based (i.e., airplane), and ground-based (i.e., Internet) communication networks.

Global Application IoT and a Typical Example

→ The selection of different kinds of networks can be decided by specific application scenarios and cost.

→ There are several key aspects involved in global logistics multimodal transportation platforms transportation systems (air-based transportation, sea-based transportation, and road/railway-based transportation systems), customer enterprises, regulatory authorities (customs, quality inspection departments, quarantine departments, and other government regulation departments), and other functions, such as bank and payment systems.



Global Application IoT and a Typical Example

→ The multimodal transportation platform includes road, railway, air transport, and ocean shipping across the world to form a uniform global transportation network.

→ Moreover, other related organizations (e.g., warehouses, agents, enterprises, customs, and inspection/quarantine departments) also participate in global logistics IoT to share information services.

→ The global logistics IoT coordinator manages the coordination among the different participants.

→ Some core services in global logistics IoT listed as follows, can be used to solve the four challenges that global logistics confronts

Global logistics infrastructure layout and planning decision support

→ The services provided to help global logistics infrastructure design and establishment, for example, road, railway, airport, port, warehouse, and information system construction.

→ They can promote the effectiveness of the logistics infrastructure as well as reduce the investment.

Global Application IoT and a Typical Example

Global transportation management

→ The service of managing the transportation process of freight to realize green, low-cost, and efficient targets (e.g., short delivery time, low transportation cost, low carbon emissions, empty rate, etc.)

Intelligent supply chain management

→ It plays an increasingly important role in the process of economic and production globalization, and it penetrates into every link of the commodity life cycle, from material purchasing, intermediate product producing, and product assembling to commodity dispatching for global trade.

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