Research on Architecture of Smart Urban Rail Transit System

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Abstract. By conducting a comprehensive review of domestic and international research findings, this study examines the data collection and utilization of smart city rail transit systems. It identifies the essential functional modules necessary for the overall architecture of such systems. The study also elucidates the establishment of processes within the perception and data collection layer, the data processing and analysis layer, and the control and management layer. Furthermore, it investigates the interrelationships among system components and the internal flow of information. The establishment of smart city rail transit system architecture helps to sort out and coordinate all kinds of information and data of the rail transit system, improve the efficiency of information collection and conversion, enhance the overall smoothness and safety of rail transit, and promote the establishment of a complete urban rail transit travel service system.

Keywords: Urban rail transit, architecture, big data, information technology, smart transportation.

1. Introduction

Based on the development of a new generation of information technology, such as the Internet, Internet of Things, big data, cloud computing, artificial intelligence, etc., has given rise to many new concepts similar to the development of "Smart Earth", "Smart City" [1], smart urban rail transit has become a hot spot and trend of development in the field of rail transit. A "smart city" is a metropolis where innovative technologies, such as high-speed rail and trendy eateries, are integrated into everyday life. The term "smart city" refers to a city where the government uses modern information and communication technologies, such as the Internet and the Internet of Things, to intelligently perceive, analyze, and integrate the running conditions of the environment, resources, infrastructure, public safety, urban services, public welfare, and ci to exercise the functions of economic regulation, market supervision, social management, and public service in the process of urban development [2].

Smart urban rail transit system generates a large amount of spatial and temporal data information such as train operation and passenger travel, and this information is generated and transmitted at all levels of the system. How to integrate the system information resources and monitor, analyze, and process the information to coordinate the orderly operation of each functional module, guarantee the safe, reliable, and efficient operation of the urban rail transit system, and provide intelligent services for users is a great challenge for operation managers [3].

2. Smart Rail Transit Overview

"Intelligent transportation" is the specific embodiment of the concept of "smart city" in the transportation industry, and "smart rail transit" is the specific embodiment of "intelligent transportation" in the field of rail transit (such as railways, city subways, magnetic levitation trains, etc.). "Intelligent transportation" is the specific embodiment of the concept of "smart city" in the transportation industry, and "smart rail transportation" is the specific embodiment of "smart transportation" in the field of rail transportation (such as railroads, city subways, magnetic levitation trains, etc.) [4].

Smart rail transit is the ideal goal of human future society, guided by the human (related) wisdom of informatization, guided by the concepts and theories of planning and design, construction, operation, control, and management of rail transit, and guided by the Internet of Things (IoT), which integrates "people, things and objects", as the basic support platform for information collection, exchange, and service; with intelligent informatization decision-making and processing technologies, it is the concrete embodiment of "smart transportation" in the field of rail transit (such as railway, urban subway, and magnetic levitation train, etc.). Taking intelligent informatization decision-making and processing technology as the basic means, through sorting, filtering, mining, and utilizing the massive rail transportation information, it integrates human and human intelligence, physical network of rail transportation, and related information to build a modern rail transportation system that is "highly efficient, convenient, safe, visible, predictable and environmentally friendly" [5].

3. Key Technologies for Smart City Rail Transit Systems

3.1. Internet of Things (IoT)

The Internet of Things (IoT) is crucial to the success of any plan to build a high-tech rail transit system for a smart city. This system allows for the continuous monitoring of traffic infrastructure and railway operations. Using sensors and the Internet of Things connectivity, this is possible. To facilitate intelligent identification and administration, "The Internet of Things" was first proposed in 1999 and defined as the practice of connecting diverse items to the Internet through radio frequency identification and other information sensing devices. On November 17, 2005, during the World Summit on the Information Society (WSIS) in Tunis, the International Telecommunication Union (ITU) publicly announced the notion of the Internet of Things (IoT). This happened after the publication of the ITU Internet Report 2005: IoT. There has been extensive coverage and investigation of the "Internet of Things" in scholarly journals [6].

The "Internet of Things" (IoT) is a system that enables various devices and items to connect and share data via the internet. This system is referred to by its acronym. This communication is made possible through the utilization of a variety of information-sensing tools, including radio frequency identification, infrared sensors, global positioning systems, laser scanners, and others. These devices adhere to preset protocols, which make it possible for data and messages to be transferred. The Internet of Things supports the development of technologies that enable networked objects to be intelligently identified, localized, tracked, monitored and managed. For monitoring and control, sensors are installed in a wide variety of systems and objects, including but not limited to electric grids, trains, bridges, tunnels, highways, buildings, water supply systems, dams, and oil and gas pipelines. The Internet of Things is a massive network that is made up of numerous sensors that are networked together [7].

3.2. Big Data

Since "big data" refers to a massive amount of information, the concept it communicates is necessarily nebulous. Many people, however, clearly cannot tell the difference between "big data" and older words like "massive data" or "very large data." It's important to remember that to qualify as "big data," volume, diversity, and velocity must all be met. The concept of Big Data encompasses three essential features, namely volume, variety, and velocity. Furthermore, an additional definition of 4V exists, aiming to introduce a novel attribute to the existing three V's. About the fourth V, it is worth noting that there is a lack of consistency, as recognized by the International Data Corporation (IDC). The IDC posits that Big Data should encompass value, which is frequently characterized by its sparsity. According to the description provided by Wikipedia, big data pertains to the use of widely employed software tools to capture, manage, and process data that exceeds the acceptable timeframe of the given dataset [8].

3.3. Artificial Intelligence(AI)

The phenomenon of intellect that arises through the process of natural evolution is commonly referred to as natural intelligence. In contrast, artificial intelligence pertains to the intelligence that is created by people, specifically the intelligence exhibited by robots. Human intelligence encompasses the cognitive abilities employed by individuals to enhance their survival and progress. Through the acquisition and application of information, humans engage in a process of problem identification, problem definition (comprehending the intricacies of the environment), and problem-solving (facilitating transformative changes in the world) [9].

The objective of study in the field of artificial intelligence is to develop computers that possess a specific degree of intelligence by comprehending natural intelligence, particularly human intelligence. Hence, whether in the domain of natural intelligence or artificial intelligence, both areas of study delve into the enigmatic nature of cognition. Such research is characterized by its depth and intricate nature, necessitating the utilization of methodological frameworks [10].

3.4. Cloud Computing

Cloud computing is a form of computing that is built around the Internet model. It represents an advancement and expansion of distributed computing and grid computing and has emerged as a result of the evolving distribution of Internet resources. The advancement of virtualization-based cloud computing has liberated computer interactive services from hardware constraints. This breakthrough has enabled software and interactive services to operate independently of specific hardware, eliminating the need for hardware maintenance [11].

Cloud computing centers facilitate the socialization, intensification, and specialization of information services by optimizing and reconstructing the service process. This is achieved through the reuse and flexible reorganization of software, resulting in an improved usage rate. Cloud computing enables the consolidation of resources, the exchange of information, and the facilitation of collaborative work among software systems, resulting in the establishment of service-oriented computing. Cloud computing facilitates the expeditious processing of vast volumes of data from many geographical locations and the concurrent provision of services to a large user base [12].

4. Smart City Rail Transit System Architecture

Take a process-oriented approach informed by the relevant literature, both domestic and international, and design a rail transit system fit for a smart city. The operation of the system is described from a data flow perspective, and the smart urban rail transit system is organized via a top-down, step-by-step decomposition. Rail transit data flows seamlessly inside the framework, and the data is organized to offer relevant functional modules. Services, logic, hardware, and a generic tech platform make up the bulk of the smart city rail transit system's structure.

4.1. Smart City Rail Transit System Functional Modules

4.1.1. Passenger information management module

The Passenger Information Management module is accountable for gathering and overseeing data on passenger travel, such as inbound card information and ticket particulars, to present precise passenger mobility information and travel amenities.

4.1.2. Train operation controlling module

The Train Operation Controlling Module employs intelligent scheduling and control algorithms which are fed by real-time operation data, with the aim of elevating the efficiency and safety of train operation.

4.1.3. Safety monitoring module

The Safety Monitoring Module is tasked with the real-time monitoring of train operation status and station conditions via the video monitoring system and safety sensors, alerting and taking appropriate measures promptly upon detection of anomalies.

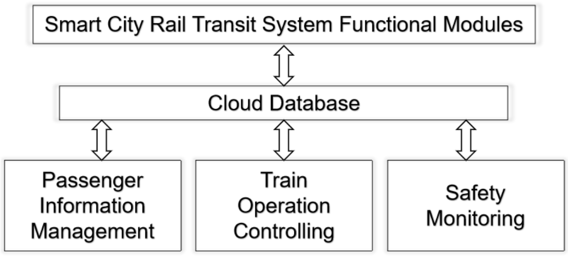

Figure 1. Schematic diagram of the functional modules of the Smart City Rail Transit System (Picture credit: Original)

4.2. Smart City Rail Transit System Architecture Hierarchy

The overall architecture of a smart city rail transit system includes three main parts: hardware equipment, software system, and data center. Hardware equipment includes trains, signaling equipment, station equipment, etc.; software system includes passenger information management system, train operation control system, safety monitoring system, etc.; the data center is responsible for data storage, analysis, and processing.

4.2.1. Sensing and data acquisition layer

The sensing and data acquisition layer is the foundation of the smart city rail transit system, which uses IoT technology and sensor devices to sense and collect information in real-time, such as train operation status, station traffic flow, environmental monitoring data, and other information, and transmits it to the data center for processing.

4.2.2. Data processing and analysis layer

The primary function of the data processing and analysis layer involves the processing and analysis of data received from the sensing and data acquisition layer. This is achieved through the utilization of big data technology and artificial intelligence algorithms. The objective is to extract significant information from the data and offer decision support for operations management.

4.2.3. Control and management layer

The control and management layer includes train operation control, passenger information management, safety monitoring, and other subsystems to ensure the normal operation of the railway transportation system and the safe travel of passengers through real-time monitoring and control of train operation status, passenger information management, and safety protection.

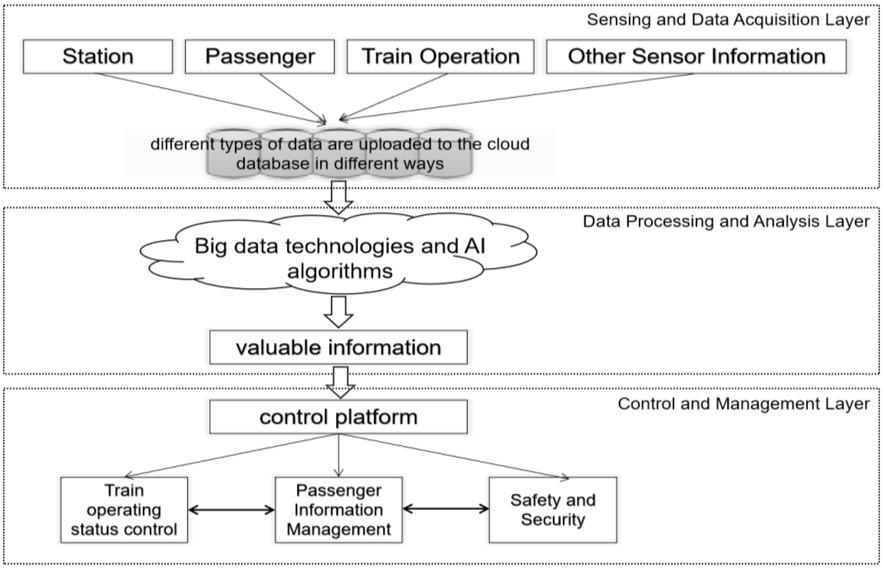

Figure 2. Schematic Diagram of the Structure Level of Smart City Rail Transportation System (Picture credit: Original)

5. Conclusion

More thorough perception, wider interconnection, and deeper intelligent processing capability are the basic features of intelligent rail transit. This system is supported by artificial intelligence technology, intelligent information processing technology, Internet of Things technology, and sensing technology. It builds and demonstrates an efficient, convenient, safe, predictable, environmentally friendly, intelligent high-tech, modern, and extensive rail transit system. It presents a rail transit system that is efficient, convenient, safe, visible, predictable, environmentally friendly, and intelligent. However, due to space limitations, this paper does not address supporting technologies in detail, which will be covered in future articles.

An intelligent rail transportation system is presented in this study, along with its three-tiered architecture: the "perception and data acquisition layer," the "data processing and analysis layer," and the "control and management layer." An intelligent rail transportation system's suggested three-layer architecture consists of the "perception and data acquisition layer," "data processing and analysis layer," and "control and management layer." This paper is an early attempt to define and broadly categorize the technical elements that make up an intelligent rail transit system. The authors of this piece hope to hear back from experts, academics, and rail transit colleagues in the form of criticism and amendments.

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