Application-Aware ICT Control Technology to Support DX Promotion with Active Use of Beyond 5G, IoT, and AI

TAKAHASHI Eiji , IWAI Takanori , NIHEI Koichi , MORIMOTO Masaharu

Abstract

In recent years, expectations are rising for the realization of an affluent society by promoting digital transformation (DX) and high productivity through Beyond 5G, the Internet of Things (IoT), and artificial intelligence (AI). Against this backdrop, in addition to conventional policies of improving the average quality of service (QoS), there is an increasing need to strengthen policies that precisely adhere to ICT performance requirements per communication session and in real time to enable applications to be used with high performance (work speed, productivity, etc.) in a stable manner. This paper introduces an application-aware ICT control technology that enables the stable use of applications at high-performance levels.

Keywords

Beyond 5G, Internet of Things (IoT), Artificial intelligence (AI), digital transformation (DX), application performance, radio quality, radio access network (RAN), image distribution, edge computing, cloud computing

1. Background

In response to social issues such as the declining workforce due to the falling birthrate and an aging population as well as problems related to technology succession and aging infrastructure, there is a growing need to solve social problems by using machines to do the many tasks that could previously only be done by humans[1]. As a means to achieve this, there are growing expectations to promote digital transformation (DX) by methods such as automation and labor saving through remote monitoring and control using Beyond 5G, the Internet of Things (IoT) and AI. In the field of remote monitoring and control, many use cases require equipment to be mobile and easy to install. This means that wireless communication is essential, and high application performance (such as for the accuracy of the video content analysis of images from security cameras, transport throughput of automated guided vehicles, and safety in autonomous driving) must be guaranteed. Accordingly, in addition to conventional policies to improve communication quality, there is a growing need to strengthen policies that precisely adhere to ICT performance requirements related to communication quality, response performance, etc. per communication session and in real time to enable use with the stable use of high-performance applications. This paper introduces application-aware ICT control technology that enables such stable usage of the aforementioned applications.

2. ICT Performance Requirements for Applications

Section 2 discusses the performance requirements for ICT infrastructure in promoting DX through remote monitoring and control using Beyond 5G, IoT, and AI.

2.1 Responding to the diversification of applications and their requirements

The expansion of the target areas (such as factories, warehouses, construction sites, etc.) for DX promotion through remote monitoring and control requires support for a wide variety of applications and their ICT performance requirements. However, because of the difficulty in securing experts who have a deep understanding of both applications and ICT infrastructure and because the need to optimize ICT infrastructure in real time makes it difficult to manually handle the tasks, functions are required to automatically optimize ICT infrastructure.

2.2 Meeting stringent bi-directional ICT performance requirements

In promoting DX through remote monitoring and control, there is a strong need to ensure that applications are available with stability and high performance, because application performance often directly affects the performance of the core business. To achieve this, strict ICT performance requirements must be met. Furthermore, for example, in the remote control of factory automation and of robots, the bi-directional communication consisting of the status monitoring and control instructions for equipment and robots must be completed within a certain amount of time, so high ICT performance (high reliability, low latency, etc.) must be maintained in both the upstream and downstream directions.

2.3 Supporting a mix of multiple applications

In promoting DX, a wide variety of applications and their requirements must be considered, and the same application may generate several types of traffic with different requirements. For instance, when video distribution that requires high-speed, high-capacity communication and remote control that requires high reliability and low latency are mixed, a wide range of ICT performance requirements must be addressed simultaneously, such as achieving high reliability and low latency while maintaining high-capacity communication.

3. AI-based Radio Quality Analysis

Section 3 describes the technology for learning-based radio quality analysis that enables the visualization and the analysis of radio quality with AI to immediately identify the cause of deterioration in communication quality and to take proper measures[2,3].

3.1 Challenges

In the field of remote monitoring and control where active use is made of Beyond 5G, IoT, and/or AI, communication quality may deteriorate due to fluctuations in the radio wave environment caused by the movement of equipment and people. Because radio waves are invisible, the cause of the degradation is difficult to identify, and analysis requires a great deal of time and effort. As a result, there is a need to automatically identify the causes of poor communication quality and to shorten the time required to take action.

Fig. 1 AI-based radio quality analysis.

3.2 Solution

The learning-based radio quality analysis technology described in this section uses AI to analyze the characteristics of radio quality fluctuations and automatically identify the causes of degradation in performance per communication session in real time. Specifically, it simulates situations in which multiple causes (distance attenuation, shielding, fading, etc.) affect communication quality, generates time series data of radio quality index values, and uses the simultaneous time series data to learn by using machine learning methods. Then, it automatically identifies the causes of degradation in communication quality in the field from the time series data of the radio quality index values in the actual environment.

3.3 Effectiveness

Experiments have confirmed that AI can identify the causes of degradation in communication quality with high accuracy, even when individual causes of quality degradation occur independently or when multiple causes occur in combination (**Fig. 1**). AI automatically identifies and visualizes the causes of degradation in communication quality and the extent of the impact, making it possible to take prompt action based on that information, and as a result, applications can be used with stability and high performance.

4. Application-Aware RAN Optimization

Section 4 describes a system that automatically optimizes the radio access network (RAN) in accordance with the requirements of each application.

4.1 Challenges

Regardless of how sophisticated the standard specifications of the 5G or Beyond 5G are or how optimized the network slice design/construction is at service launch or

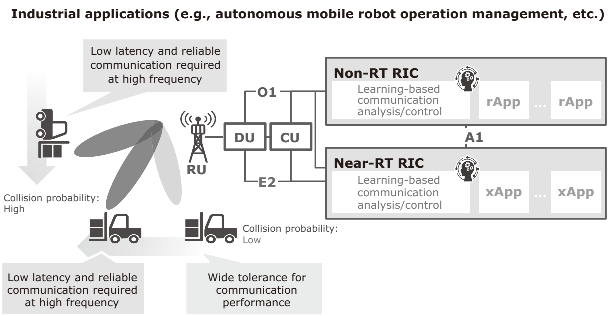

Fig. 2 Application-aware RAN optimization.

how optimized the allocation of computing resources to the RAN is, there is a limit to how well they can respond to dynamically changing communication requirements and ever-changing radio quality. Dynamic, real-time, intelligent RAN optimization is essential to achieve a stable and high application performance in such a fluctuating environment.

4.2 Solution

AI, which understands both the application and the RAN, intelligently and automatically optimizes the RAN to enable a world where applications can be used with stability and high performance without the presence of ICT infrastructure in a transparent and open network architecture that is easy to deploy internationally. AI is incorporated in the RAN Intelligent Controller (RIC) as defined by the O-RAN Alliance[4] to intelligently control the O-RAN central unit (O-CU) and the O-RAN distributed unit (O-DU). By doing so, the features of 5G and Beyond 5G (high speed, high capacity, high reliability, low latency, etc.) can be maximized and applications can be used with stability and high performance (**Fig. 2**).

4.3 Effects

The experiment confirmed that an application's communication requirements can be achieved with high reliability in an environment where the application's ICT performance requirements and radio quality vary in accordance with the field conditions (e.g., movement of equipment, risk of collision between devices, etc.).

5. Remote Monitoring System Using Video Streaming Technology

Section 5 describes a remote vehicle monitoring system using video streaming technology[5)6)].

5.1 Challenges in remote monitoring

A remote vehicle monitoring system must distribute videos through wireless networks. However, because the communication speed of the networks slows down when the radio environment deteriorates, the amount of video data must be reduced to maintain the image quality required for monitoring.

5.2 Solution

NEC has developed a learning-based media transmission control technology that can reduce the amount of video data by learning the regions of interest and the optimal image quality required for image analysis at the monitoring center and by controlling the quality of the transmitted video and has also developed a vehicle remote monitoring system using this technology (**Fig. 3**). This system consists of an integrated monitoring screen that lists the video images of all vehicles to be monitored and a detailed monitoring screen that zooms in on vehicles requiring operator attention or intervention. At the monitoring center, object detection, lane detection, distance estimation, and other functions are performed on the images transmitted from the vehicles. When a person, bicycle, or vehicle enters within a certain distance from the vehicle's lane, the system determines that operator attention is required and displays videos of the vehicle in question on the detailed monitoring screen together with an alert.

5.3 Effectiveness

After conducting a demonstration experiment in which two vehicles were monitored, operators evaluated the

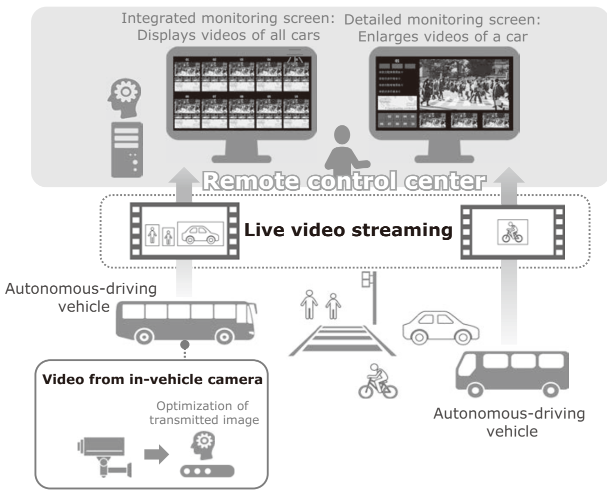

Fig. 3 Remote vehicle monitoring system.

system as less burdensome and capable of monitoring multiple vehicles compared to the existing system.

6. Edge-Cloud Processing Optimization

Section 6 describes the technology for optimally sharing AI video analysis tasks in a distributed edge cloud computing environment that is connected by wireless networks.

6.1 Challenges in inference processing of video analysis

In video analysis such as for behavior recognition, the processing load fluctuates in accordance with the number of objects in the video frame. This is dealt with, for example, by transferring the processing tasks that cannot be accommodated in the edge to the cloud. This method, however, results in a loss of data or a degradation in accuracy unless an optimal task distribution method is selected that takes into consideration the variations of the wireless network performance.

6.2 Solution

To solve this problem, NEC has developed a technology for edge-cloud processing optimization that transfers the processing for the AI video analysis from the edge to the cloud by considering variations in the wireless network performance between the edge and the cloud (**Fig. 4**). This technology predicts fluctuations in processing load and performance of wireless networks. It then calculates and selects the optimal processing pipeline based on these constraints, thereby achieving dynamic changes in the allocation of processing.

6.3 Effectiveness

An experiment using video from a construction site and AI-based behavior recognition has confirmed that accuracy degradation can be reduced by selecting the optimum allocation in accordance with the number of objects in the video frames and fluctuations in wireless network performances.

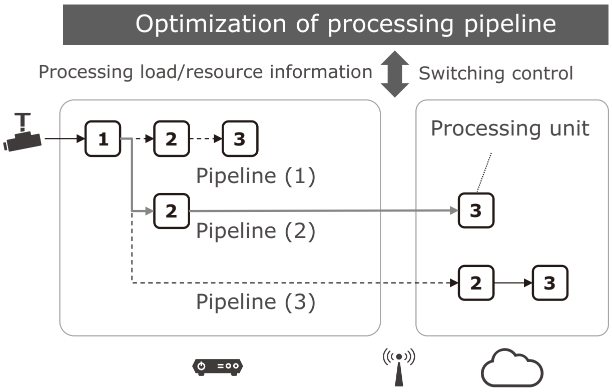

Fig. 4 Edge-cloud processing optimization.

7. Conclusion

In this paper, we described application-aware ICT control technologies that enable applications to be used in a stable manner with high performance. As specific examples, we introduced a technology for radio quality analysis based on the active use of AI, a technology for application-aware RAN optimization, remote monitoring systems using video distribution technology, and a technology for edge-cloud processing optimization. By using these technologies in accordance with the ICT performance requirements of applications and by effectively utilizing network and computing resources, we can achieve high performance for a wide variety of applications.

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Authors' Profiles

TAKAHASHI Eiji
Senior Research Architect
Secure System Platform Research Laboratories

IWAI Takanori
Director
Secure System Platform Research Laboratories

NIHEI Koichi
Principal Researcher
Secure System Platform Research Laboratories

MORIMOTO Masaharu
Principal Researcher
Secure System Platform Research Laboratories

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