Creating Smart Cities through Digital Twins

Ippei Shake and Chihiro Yamamoto

Abstract

We describe our initiatives in creating smart cities using digital twin (DT) technology. In these Feature Articles on Urban DTC for Creating Optimized Smart Cities Attentive to the Individual, we first outline the concept of a totally optimized smart city. We then describe a variety of services that use digitalized data and artificial intelligence (AI), an integrated platform that achieves total optimization by interlinking those services, examples of services that link areas over a wide region, and the AI value platform that makes it easy to provide such cross-domain services.

Keywords: digital twin, AI, smart city

1. Introduction

There are many problems in modern society that need to be solved in a variety of areas including health, education, disaster management, poverty, population, and climate change. To this end, the Sustainable Development Goals were proposed by the United Nations as goals that mankind should strive to achieve. In Japan, the future form of society that should be targeted has been defined as "Society 5.0." There is also demand for the provision of new services as lifestyles change in the wake of the COVID-19 pandemic and user needs diversify. Under these conditions, the value provided by each industry is changing greatly from what has been considered common sense up to now and is taking on the form of cross-field services that go beyond individual industries. In short, services are becoming increasingly complex.

Against this background, NTT Smart Data Science Center (Smart Data Science Research Project, NTT Computer and Data Science Laboratories) is working to transform society through the use of digital twins (DTs). Our aim is to develop industry and solve social problems through the creation of new services that use data and artificial intelligence (AI). In these Feature Articles on Urban DTC for Creating Optimized Smart Cities Attentive to the Individual, we introduce our initiatives toward smart cities. The direction of our study flows from (a) optimization in units of residential and building districts to (b) urban optimization spanning multiple districts and (c) optimization that includes supply and demand on a national scale (**Fig. 1**).

2. Initiatives toward smart cities

We wish to provide the following two types of value as our ultimate goal.

(1) Totally optimized smart cities integrating society and people: Mutual optimization of value among individuals and communities and among a variety of industries extending as far as the global environment. In the future, smart cities will take on wide-area features in both spatial and virtual terms, and a sense of well-being and prosperity will be sustained by capitalizing on the features of each district (Social Well-Being and Flourishing Society).

(2) Smart cities that respond to diversifying needs by optimizing value for the individual: Making people's lives even better in a natural way that is attentive to latent and constantly changing individual needs (Personalized Well-Being City).

We are moving forward on initiatives for presenting

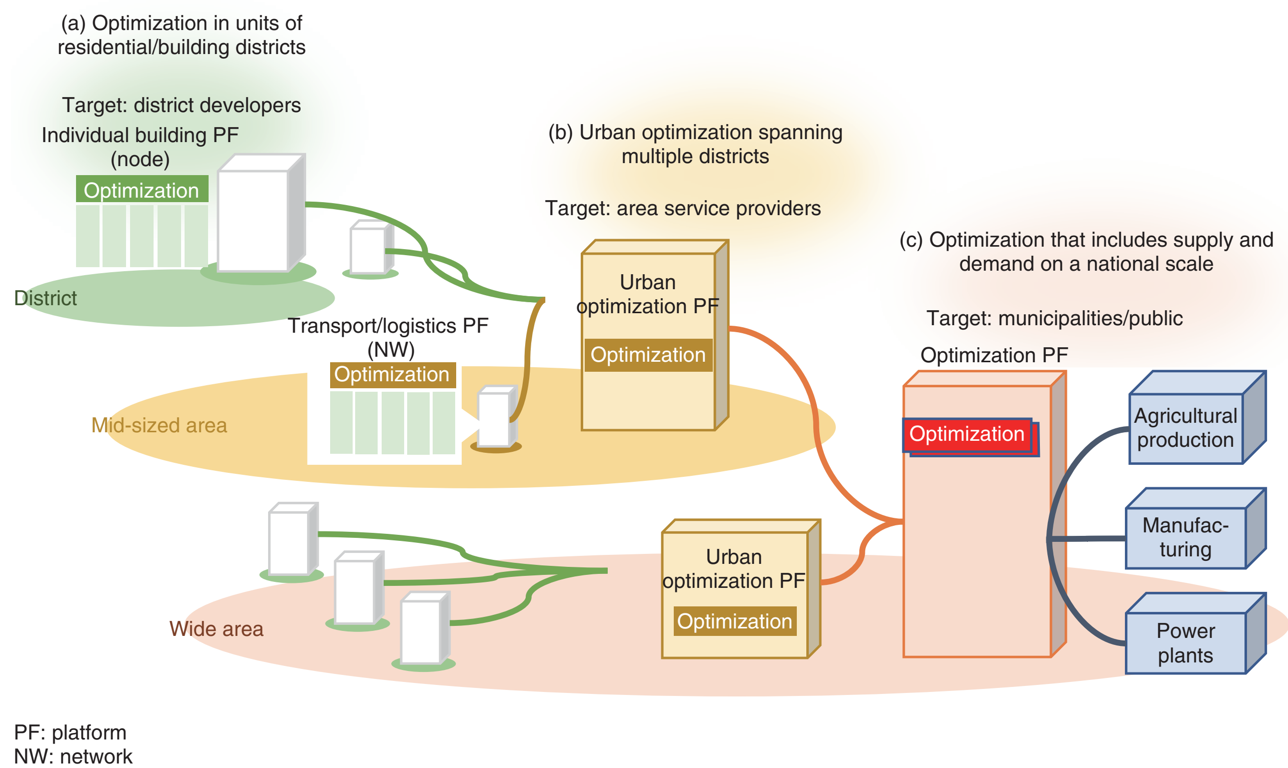

Fig. 1. Embodying optimization through inter-AI linking.

mechanisms and concrete services for the smart cities described above. All these mechanisms and services use DT technology that models and reproduces states in the real world in cyber space and that feeds back value to the real world by simulating a variety of state changes.

Building districts and areas covering multiple districts as in study items (a) and (b) above constitute a field that provides value across multiple and overlapping industry domains such as energy, retail (stores and eating/drinking establishments), real estate (building management, offices, and residences), and mobility. Therefore, configuring an entire city/area/district as a single DT is not very realistic, so the approach that we take is to configure a DT for each industry domain and link the simulations of each DT to configure DTs in units of districts. Thus, various types of value can be provided simultaneously to shop owners and managers within a district and social problems can be solved, such as by optimizing energy consumption and facility usage and reducing food loss while providing services that make the day-to-day life and activities of individuals more comfortable. When setting out to accomplish this, however, there are difficulties that must be faced since a variety of elements, such as the behavior and state of each individual within a district, state inside of each building (stores, offices, etc.), and social environment (energy, etc.), are all intertwined.

For example, focusing on energy savings can reduce personal comfort, and aiming to reduce food loss at a store, such as by limiting the amount of stocked goods to reduce the risk of unsold items, may prevent customers from purchasing desired items. In other words, identifying and optimizing a single need can lead to conditions in which other needs are not satisfied. A district is a space in which services for a variety of stakeholders exist and multiple needs become intertwined in a complex manner. There is a separate optimization index, or key performance indicator, for each service, but the individual behavior of people can influence each service and the external environment, which can influence other people and other services. If we could take a bird's-eye view of this entire situation and optimize it, we might be able to provide a pleasant environment and make life easier, ideally for anyone.

Our goal is to achieve total optimization of multiple services in an urban district through Digital Twin Computing (DTC). We call this initiative "urban DTC." To take into account the mutual effects (linking) among multiple services, urban DTC uses predictions of behavior in units of individuals, predictions of changes in the environment and things brought about by that behavior, and predictions of the mutual influence among things that have also been influenced. We can make a broad concept of DT of a district more specific by first envisioning various types of future services and defining in detail the value that they can provide in a district. This value includes not only the user experience (UX) of visitors to the district, the people who work there, and the people who live there but also support services that enable building owners, district managers, and tenants of stores and offices to provide an even better experience for their customers (district visitors) and employees at all times. If we broadly define all such provided value as UX, we can think of "data-driven urban development" more precisely as "UX-driven urban development," which makes it important to begin with the design of future UX.

Turning now to optimization over a wide area that expands to the entire nation as described in study item (c) above, it is necessary to focus on industry domains that influence each other's supply and demand over a wide area. For example, we can consider that domains that are in close contact with people's lives and behavior (energy use, retail, real estate, mobility, etc.) would benefit from optimization executed from a demand standpoint. When such domains execute optimization with a focus on convenience and comfort, it is not so important to think from a perspective of a wide area on a national scale. However, there are also industries that would execute optimization by supply-and-demand matching by considering supply and logistics (quantity and type, timing, production location, etc.), that is, industries such as manufacturing, agriculture, and electric power and energy that must take into account the entire supply chain. In these industries, problems arise in the optimization of quantities, types, delivery routes, etc. between consumers and supply sources such as factories, production regions, and power plants. For this reason, we are developing a supply-chain optimization platform using DTs for each industry.

3. Conclusion

In our work on (a) optimization in units of residential and building districts, we have thus far achieved individual services such as air-conditioning optimization for common areas in buildings and zero-food-loss stores using DTs. In these Feature Articles, we outline a personalized air-conditioning service [1], store-management optimization and one-to-one marketing stores [2], a robot delivery service based on mobile orders [3], and hospitality services using a DT integrated platform and integrated app that achieve total optimization by linking such services [4]. Regarding our work on (c) optimization that includes supply and demand on a national scale, we introduce a virtual market for agricultural logistics [5] and optimization of power supply and demand [6]. We have successfully developed multiple AI models and an inter-AI linking mechanism for diverse domains and extracted and solved associated problems toward their provision as services. On the basis of this achievement, we outline our development of the AI value platform embodying the knowledge gained from a bird's eye view of cross-domain services [7].

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