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*Research Article*

# Decision Support Systems for IoT Based Infrastructures

**Richa Gupta**

Asst. Professor, Department of CSE (Computer sc)

GEHU-Dehradun Campus

**Abstract:** Computation offloading divides enormous computational tasks across numerous computer resources, circumventing hardware limits. Edge computing can employ vast quantities of data, individual preferences, and clever algorithms by offloading smart models to high-performance cloud servers. We propose a getaway-centric IoT system to enable intelligent and autonomous IoT devices at the computer infrastructure's edge. Edge computing manages IoT devices by selecting and applying the best control factor from a pool of intelligent services. The cloud-based intelligent service engine provides intelligent services by offloading intelligence and optimisation algorithms. Thus, the gateway's decision-making model may choose the best alternative. Resource virtualization-based gateway-based device management facilitates user monitoring and visualisation in the proposed IoT system. The gateway evaluates context-based profiles to enable real-time connection with intelligent services and dynamic application of the appropriate control factor to the physical device using the virtual resource. We propose two smart models to learn characteristics of a user's home environment using deep learning and build inference models for the intelligent service engine to optimise energy usage with the recommended IoT system. Inference methods forecast heater energy usage. Heaters set the environment. The decision-making algorithm also lowers the heater setting based on the two use numbers, reducing energy consumption and producing a user-desired environment.

**Keywords** Internet of things, Edge computing, Intelligent systems , Decision-making · Energy management ,Neural networks ,Smart homes

**Introduction**

The Internet of Things (IoT) is a relatively recent endeavour that intends to utilise the Internet to connect together huge resources including equipment, software, and data in order to deliver a wide variety of services across a wide variety of sectors. This initiative is known as the Internet of Things (IoT). The Internet of Things (IoT) is a new engineering paradigm that is inspiring companies to develop self-sufficient, intelligent systems that are built on top of networked devices. Identification, networking of sensors and actuators; cloud and edge computing; big data; stochastic and heuristic approaches; all of these are necessary for the pervasive applications of the Internet of Things [1,2]. Several various kinds of applications for monitoring, control, and security, as well as smart system applications, have been established on the Internet of Things (IoT), and they have been used in many different industrial sectors [3-5]. As Internet of Things (IoT) technologies continue to progress, the number of devices that are linked to the Internet also continues to expand. This enables the provision of ubiquitous and seamless services across a broad variety of industrial sectors, all of which can be operated hands-free, 24 hours a day, seven days a week [6,7]. Uniform Resource Identifiers, or URIs, and Identifiers, or IDs, are used to uniquely identify cyber resources, which are then able to be used to link to the corresponding physical resources in an Internet of Things network [8]. [Note: URI stands for "uniform resource," and ID stands for "identifier." Virtualization allows for the substitution of virtual resources for their physical equivalents on the Internet. This not only increases functionality but also reduces the number of resources that need to be merged in order to give more all-encompassing assistance [9,10]. To manage intricate computation and service situations, however, virtualization of resources in the online world requires a suitable processing and networking infrastructure. The vast majority of IoT devices are constructed for a hardware environment that is severely limited, and as a result, they lack the power, processing capability, storage space, and networking capabilities necessary to fulfil even the most fundamental requirements [11, 12]. Cloud computing is a method of offering apps and databases that can handle the massive volumes of data and service requests that are created by Internet of Things (IoT) devices [14-16]. This enables Internet of Things devices to function in a diverse hardware environment and carry out a variety of complex application scenarios. Although having a short data distribution delay between IoT devices and cloud servers is desired, it is difficult to maintain due to limitations in network capacity and the amount of processing effort that is required [17,18]. Edge computing is the process of extending the cloud to the network's periphery so that it may accommodate processing that is reliant on low-latency connections. This allows the cloud to be placed in close proximity to the limited IoT devices.

Entities in this layer exist between devices and the cloud and link Internet of Things devices to Internet-connected entities such as web servers and clients. They are responsible for message translation, the offloading of computing work, and the administration of linked devices. An edge gateway is often installed at the network's outermost border in order to allow communication between Internet of Things (IoT) devices and other Internet-connected entities. The edge gateway is vital because it enables complex computation and service scenarios close to a constrained environment. This is required for improving the computing and storage capabilities of IoT devices so that improved services can be provided. However, cloud servers may be utilised for the remote execution of activities that need a significant amount of computing power, which can assist fulfil the ever-increasing demand for data processing. In order to get over this limitation, computation offloading enables for enormous amounts of computing work to be split up and done on a number of different machines. Edge computing, which makes use of cloud computing, may offload artificial intelligence algorithms to high-performance servers in the cloud in order to handle vast volumes of data. This would enable edge computing to apply both large-scale and customised data. An artificial intelligence may be developed by using a stochastic method known as Machine Learning (ML), which analyses samples of data in order to make predictions or judgements. First, the learning model generates an inference model by using a machine learning algorithm and training data. This model serves as the foundation for the ML-based intelligent approach that is offered. After the appropriate input parameters have been gathered, an inference model may then be utilised to produce predictions about the ecosystem that is around the area.

In addition, online machine learning offers a way through which the existing inference model's knowledge may be enhanced by continuous incoming input. This is made possible by online machine learning. While the intelligent service is provided based on the currently employed inference model, the operation for upgrading the model to make use of more recent training data may be carried out concurrently in the cloud. When paired with cloud-based artificial intelligence deployment and web service provisioning for edge computing, edge gateways may thereby allow the intelligent operation of IoT devices in customised contexts. We propose a getaway-centric Internet of Things system in order to promote the intelligent and autonomous functioning of IoT devices. This will be accomplished by providing a foundation for decision-making that is based on a number of intelligent services that are given at the edge of the network. The proposed Internet of Things system has an IoT client, an ASP, an ISE, an EG, and an IoT device. These components work together to offload the smart models that are stored in the ISE and give the smart service to end users. The Intelligent Systems Environment (ISE) employs smart models to generate intelligent and optimal control variables, which are then utilised to fuel the service offerings made by the platform. Edge computing enables the construction of models based on deep learning with user-specific data, making it possible to provide intelligent services that are specifically suited to each unique user. The EG will dynamically activate intelligent services based on its interpretation of the scenario profile that has been deployed, and the decision model will utilise the outcomes of the intelligent services to decide the best potential controlling variable to employ. Developing a smart IoT device operating scenario on the basis of the recommended IoT architecture is required in order to identify the ideal value for the heater's energy consumption while it is functioning in the edge computing environment that has been presented. In order for the Intelligent Service Environment (ISE) to be able to provide users intelligent services, two intelligent models need to be developed and installed in the user's house utilising deep learning methods. The models are used to compute the amount of energy required for the heater to operate, and this information is then included into the process of altering the environment's characteristics to match the user's chosen setpoints. The model for decision-making can pick a lower value from the ISE services to be fed to the heater in order to execute the suggested energy optimisation for operating the IoT devices in edge computing. This will result in a decrease in the amount of energy that is used while also providing an environment that is desired by the user.

**Literature Review**

**Joseph Rahme Youssef et.al (2017)** The organisation does not do a good job of tracking and managing its routine operations. The majority of companies have chosen to use ERP or other data orchestration support systems [4], but this may restrict their capacity for expansion due to the top-down, "enclosing" nature of the solution. In this paper, a preliminary proposal is made for an Enterprise Operating System (EOS) as an alternative to ERP and as a prerequisite to the future Enterprise 4.0 that will be based on the Internet of Things (IoT) and the Cyber Physical System principle. This will be accomplished by establishing loosely coupled connections between the software of the enterprise with only one simplified central orchestrator component using the Decentralised Decision Support method. This will allow the enterprise to make decisions without the need for centralised decision-making. Interoperability, seamless handoffs, and an ecosystem that is ever growing are all things that need some degree of "on-the-fly" tolerance and modification on the part of the parties involved. The objectives and reasons for creating this paper are described in the very first section. After that, a survey of relevant previous initiatives is mapped onto the requirements. After that, the significance of EOS within the framework of Industry 4.0 is broken down using DDS as an example. We present an example of the usage of EOS, as well as a description of the intended designs for it. The last part presents some concluding remarks while also looking forward.

**Mohammad Mahdi Kashef et.al (2016)** This research recommends the use of a decision support tool as a means of assisting Internet of Things service providers in determining where to deploy virtual machines (VMs) across clouds in order to achieve the lowest possible overall cost. The software package includes both a strategy for optimising performance as well as a cost estimation methodology. Our instrument for making decisions is put through its paces by simulating a variety of scenarios, and the results provide insight into how well it operates in the real world.

**Hesham H. Aly et.al (2015)** The prevalence of Manhole Cover (MC) failure has been on the rise as of late, which has far-reaching repercussions for public health and safety as well as the economy. Because of this, it is very necessary to have a monitoring system that is fully automated. The development of Smart Cities (SC) and the Internet of Things (IOT), both of which involve automated monitoring of MC, is required for modern administrations in order to achieve their aim of managing and monitoring the resources of a city in order to achieve the goal of monitoring and regulating those resources. This article gives a complete overview of MC problems, defining and assessing them in terms of their effect on the environment, as well as outlining the different monitoring systems that are currently in use. It evaluates the efficiency with which automated and non-automatic monitoring systems function, the extent to which the underground has an effect on the MC, and how effectively the systems function as a whole. The research reveals that present automated monitoring systems do not handle all MC issues, and that the majority of such systems fail to account for all of them. As a result, the data that these systems create may include the chance of false positives. The classification that is provided in this research is the first step towards the building of a fully automated monitoring system for MC. Keeping in mind the advancements that have been made in SC and IOT solutions was important for this.

**Proposed gateway-centric IoT system based on edge computing**

The proposed Internet of Things system consists of an IoT client, an application service provider (ASP), an intelligent service environment (ISE), an enterprise gateway (EG), and IoT devices. These components work together to enable device administration, visualisation, and intelligent services. The proposed architecture for the Internet of Things enables several entities to be installed on a single IoT node. A swarm of Internet of

Things nodes may be connected by an EG, which functions as a hub at the network's edge. In Figure 1, an illustration of the Internet of Things system being suggested is shown in the form of a hierarchical architecture with four levels. The hierarchical structure is composed of four different tiers: the Client, the Cloud, the Edge, and the Device. IoT devices at the device layer have the potential to supply IoT services. They do this by collecting data from the surrounding environment via actuators and sensors, respectively. In order to support either an interior or an outdoor environment, Internet of Things devices may be deployed in a cluster. IoT devices are only provided with a minimum amount of processing resources since the environment is so constrained. Because of this, the computing has been distributed between the edge and the cloud.Edge gateway controllers, also known as EGs, and Internet of Things (IoT) devices are connected to the cloud layer via the use of the edge layer. IoT devices may connect to the network via EGs, which are located on the outside of the network. An EG might be used by a collection of Internet of Things devices in order to transmit registration, sensing, and status data to an Application Service Provider (ASP) and to receive command data from the ASP. In order to boost up energy

An optimisation based on smart services may be accomplished by applying a profile to an EG and then using that profile in a service scenario. This is done in order to attain this goal. Based on the current state of the service, the EG engages in two-way communication with the intelligent layer and the Internet of Things devices. In EG, we make use of a model that involves decision-making in order to deduce the operational component for Internet of Things devices. The supply of intelligent service-based reference elements by the ISE is essential to the functioning of the model. The cloud layer is composed of servers that have high-performance computing units as well as sufficient storage capacity for the processing and storing of data..

Both a service layer and an intelligence layer are made available by the servers, but which one is used is determined by the requirements of the end users. The APS is a service provider that assists businesses in communicating information to end-users and in communicating with Internet of Things devices. The receivers of these services include things like ISEs and IoT clients, which are both found on the client layer. The ISEs are utilised to collect data from the APS, which is then put to use to power intelligent solutions. at addition, the registration service for Internet of Things (IoT) devices is made accessible at the edge layer of the protocol stack. At the intelligence layer, the lairises that offer intelligent services for the Internet of Things (IoT) ecosystem are called intelligence layer lairises. Intelligent service engines, also known as ISEs, are online service providers that provide AI-powered services by installing supporting algorithms that are themselves based on previously-trained models. These online service providers are also known as intelligent service platforms. ISEs presented by a wide range of service providers have the potential to provide solutions to issues that arise in a wide variety of industrial sectors. As a result, ISEs provide customers a number of different alternatives to choose from in order to resolve their problems. The client layer is composed of users who have IoT clients and who access the cloud layer to use various services. Through the usage of user interfaces that include various visualisation approaches, the services are used to provide data to customers through the customers' respective client devices.It is necessary to have an online client device in order to access the services that the proposed IoT system provides. The information generated by a device connected to the Internet of Things that may be kept in a database and sent directly to consumers connected to the Internet of Things. The user interfaces of an Internet of Things (IoT) client, which may be a mobile device, desktop computer, or online front-end client, enable administration, control, and data collection on an application's interaction with Internet of Things (IoT) devices and the smart space. This interaction may take place on a mobile device, desktop computer, or web front-end client.

Figure 2 depicts, in the form of a network architecture, the interaction that occurs between the various components of the Internet of Things system that is being suggested. At the cloud layer, application service providers (ASPs) and Internet service providers (ISEs) are located to provide public network access. An Edge network, which provides service to private areas like as households, businesses, and other buildings, is supported by EGs and other Internet of Things devices, which act as the network's backbone. The application service provider makes available a comprehensive selection of services, which may be used by a broad spectrum of hardware, software, and user profiles (such as beginners, experts, and system administrators). Through client devices, users may access Internet of Things services on the cloud network. These services include administration, visualisation, control, and smart services. The central portion of the Internet as well as the outside of the network are both served by ASP resources. Users make a request for the ASP so that they may access data that has been previously saved or data that has been recently produced, and so that they can also send instructions to the system, which may include Internet of Things devices. A web client is included into the ASP, and this client is responsible for communicating with an EG in order to pass along a request for a service profile to be implemented on the edge network. The registration service is used by Internet of Things devices that are situated on the edge network in order to issue a request to send their device profiles and sensing data in the form of EGs. The placement of intelligent service environments (ISEs) on the internet enables them to provide intelligent services in specialist domains, private areas, or collaborative service scenarios.ISEs are what make it feasible to provide support for a wide variety of intelligent functions. An intelligent function that has already been established for an ISE and is based on data analysis in a specific domain or environment. This function is utilised to allow sophisticated solutions such as prediction and decision-making. In order to provide intelligent services, ISEs must connect with the ASP in order to get the required information from the database. The findings of the intelligent functions are used to determine which data should be transmitted to the edge of the network in order to regulate activities.

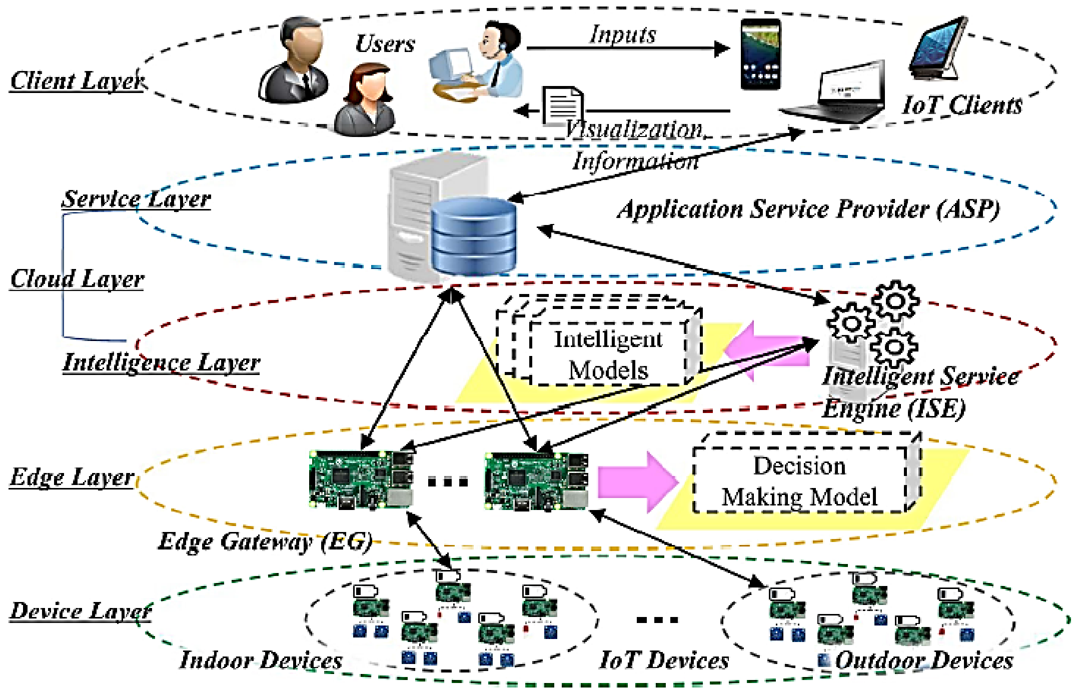


**Figure. 1 Proposed IoT system hierarchical architecture**

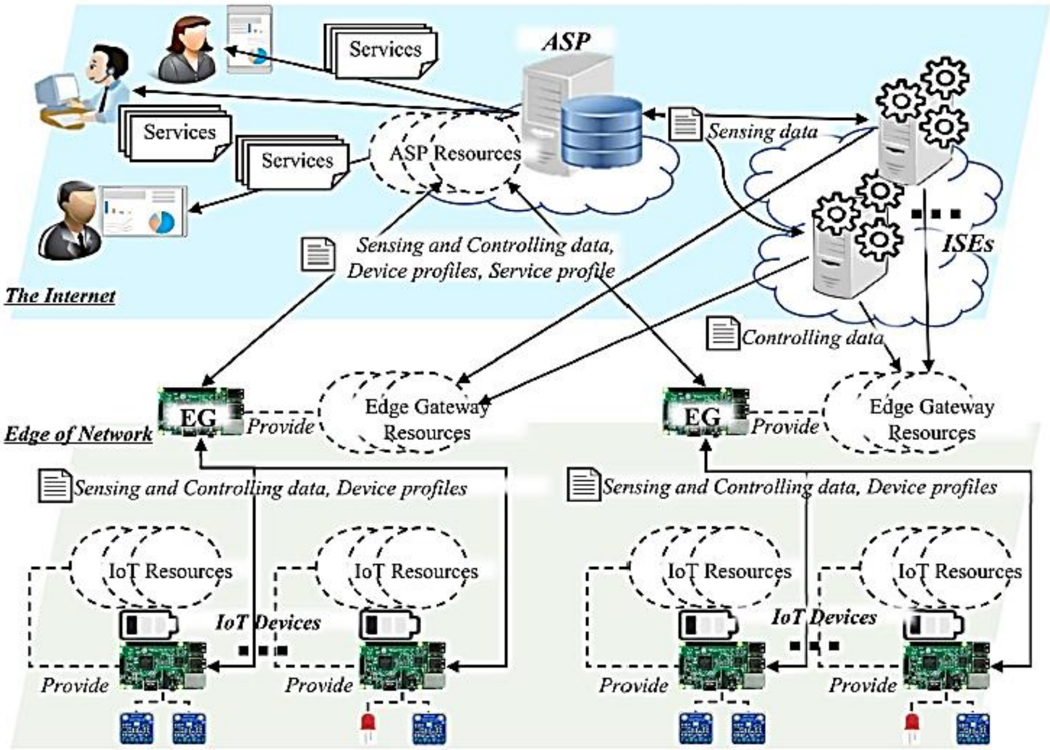


**Figure. 2 Gateway-centric IoT architecture for intelligent edge computing**

**Implementation details and results**

A number of different frameworks and libraries are offered for the purpose of constructing each individual component of the intelligent edge computing that is suggested. There are a number of published frameworks and platforms that may be used to develop IoT and edge computing. These frameworks and platforms can be used to manage information, offer services, process and store data, safeguard users' data and privacy, and process and store data. The proposed system places a significant amount of reliance on OCF in order to carry out the IoT management and communication, as is seen from Table 1. OCF makes use of the IoTivity framework, which is composed of EG and IoT devices, in order to simplify the process of device registration and the transmission of commands. ASP and ISE are installed on the high-performance system that is running the 64-bit version of Windows 10 Pro. The Spring Framework, version 4.3.3, is used as the foundation for the ASP server application that was developed. The management of MySQL databases inside ASP is taken care of by MyBatis 3.4.2. Commons File Upload 1.3.1, Apache HTTP Client 4.5.3, Fasterxml JSON 2.8.5, and ORG JSON 20160810 are the libraries that were used in the process of implementing the ASP functionality. The libraries Jquery 3.1.1 and Bootstrap v3.3.7 were used in the development of the web client in order to bring the client functionality and interface to life. Spring Boot 2.1.0 is used in the construction of ISE for service implementation, while Apache HTTP Client 4.5.3 is used for EG request processing. Both the REO and PCO inference models are executed by the server programme, which makes use of the org.tensorflow:tensorflow:1.8.0 library.When constructing the REO and PCO model using user input, the Python 3 environment makes use of TensorFlow 1.10.0 and Numpy 1.15.1. Both of these packages are used to manipulate and analyse data. An Android-based IoTivity-powered EG and IoT device is installed because of the restricted space available. The EG server application utilises Jetty to deliver requests from application service providers (ASPs) and Internet of Things devices.

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**Table 1** Development environment

| Components | Platform | Frameworks and Library |
|---|---|---|
| ASP | Windows 10 Pro 64 bit | Spring Framework 4.3.3, MyBatis 3.4.2, Commons File Upload 1.3.1, Apache HTTP Client 4.5.3, Fasterxml JSON 2.8.6, ORG JSON 20160810, Jquery 3.1.1, Bootstrap v3.3.7 |
| ISE | Windows 10 Pro 64 bit | Spring Boot 2.1.0, Apache HTTP Client 4.5.3, org.tensorflow:tensorflow:1.8.0, TensorFlow 1.10.0, Numpy 1.15.1 |
| EG | Android Things 1.0, SDK API Level 28 | Jetty 9.1.0.v20131115, slf4j- 1.7.21, Volley 1.1.0, Fasterxml JSON 2.9.7, IoTivity 1.3.1 |
| IoT device emulator | Android 7.0, SDK API Level 24 | IoTivity 1.3.1, Volley 1.1.0, Fasterxml JSON 2.9.7 |
| Environment emulator | Windows 10 Pro 64 bit | Spring Boot 2.1.0, org.tensorflow:tensorflow:1.8.0 |

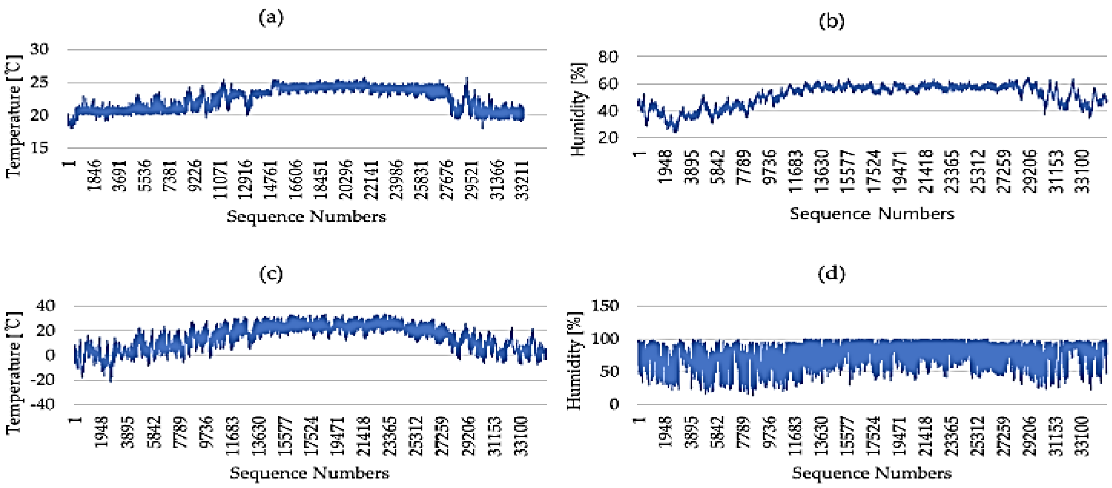


**Figure.3 Environmental data for experimental environment: a user-desired indoor temperature. b User-desired indoor humidity. c Outdoor temperature.d Outdoor humidity**

## Conclusions

An EG-based Internet of Things system was provided by us in order to facilitate the operation of intelligent and self-sufficient Internet of Things devices. Building inference models on the basis of a deep learning method allows for the provision of intelligent services by the ISE. This, in turn, enables improved energy optimisation via the use of the decision-making strategy found in the EG. After that, the EG may interact with the appropriate intelligent services in order to identify which component will have the most influence on the operation of the IoT device. We aim to offload new deep learning approaches to the ISE so that it can speed up the delivery of intelligent services from a number of perspectives. In the meanwhile, the process that the EG uses to make decisions has to take into account a variety of considerations before arriving at the most suitable option. In addition, the method of making decisions makes it possible to conduct intricate analyses of a variety of control elements.

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