PowerSystem based computing framework

Eepsita Shridevi
College of Engineering Bhubaneswar, Odisha, India

Abstract: The study and application of the edge computing framework-based power distribution area automation system is presented in this publication. It starts out by talking about the difficulties in managing and operating electricity distribution zones. The general framework—that is, the cloud-edge-device architecture built upon the edge computing framework—is then explained. Key technologies such as the cloud master station, edge computing node, end node, and cloud-edge synergy protocol stack and paradigm are also explained. Lastly, the paper presents the power distribution area automation system's engineering practice outcome and technological development path.

1 Introduction

Power distribution areas are critical to power distribution networks, which directly connect power users and the power supply company. As a great number of new energy sources and loads are connected to medium- and low-voltage power distribution networks, new challenges have emerged in the operation of power distribution areas, such as the power flow of the networks from unidirectional to bidirectional caused by new energy sources. In addition, there are a huge number of devices in power distribution areas, which are distributed across urban and rural areas. Consequently, device access and operation and maintenance (O&M) are difficult.

The architecture of traditional power distribution automation systems cannot effectively solve the preceding problems. First, the distribution automation systems use a monolith service-oriented architecture (SOA) [1], which cannot meet the requirements for the quick and flexible rollout of application services or accessing tens of millions of monitoring devices. Second, lightweight systems, protocols, and models are required to cope with the limited computing and network resources of monitoring devices in power distribution areas. Third, the IEC 61850 and the IEC 61968 model systems are inconsistent. As a result, information exchange between the monitoring devices and the master station has to use protocols such as IEC 104, which is poor in self-descriptiveness of device information, causing heavy workload in verifying consistency and interoperability of information. Fourth, the master station is ineffective to manage monitoring devices in power distribution areas. Plug-and-play [2] cannot be implemented between monitoring devices in power distribution areas and the master station.

2 Methodology

This document focuses on how to build a system that solves the preceding issues and implements autonomous operation of power distribution areas. The system is built on the basis of the edge computing framework, using the cloud, internet of things (IoT), edge computing, and microservices.

System architecture

As shown in Fig. 1, the system consists of a cloud master station and one or more edge computing nodes and end nodes [3]. The edge computing framework enables the edge to collaborate with the cloud and end nodes.

Edge computing nodes collaborate with the cloud master station through the management channel (for resources, information models, and AI models) and the service channel (for data and applications). The management channel uses NetConf protocol [4] and yet another next generation (YANG) data modeling language [5] to ensure that the cloud master station can completely mirror the functions of the edge computing node. The service channel uses the message queuing telemetry transport (MQTT) protocol and IEC 61970/61968 Common Information Model (IEC CIM) model in JavaScript object notation (JSON) format to ensure the model consistency between the cloud master station and edge computing nodes while avoiding the large number of resources required for XML compilation.

Edge computing nodes collaborate with end nodes also through the management channel (for information models) and the service channel (for data and applications, using software development kits (SDKs). As end nodes have limited communications and computing capabilities, the management and service channels use the lightweight protocol constrained application protocol (CoAP) and the type-length-value (TLV) format model. Cloud-edge CIM models are mapped to the TLV format, and measurement names are encoded in ASN.1 BER format with fixed lengths. In this way, the models can be kept consistent and effective collaboration among the cloud, edge, and end is established.

Cloud master station

By leveraging cloud technologies, the cloud master station supports elastic scaling of computing, storage, and network resources, allowing access to millions of devices. The cloud master station uses the microservice architecture for the fast development of applications. In addition, management and service functions are separated and a management channel is added for edge devices to realise remote edge device O&M, such as running status monitoring, resource and application management, and program upgrades. All these implement services and management collaboration between the cloud and edge.

Edge computing node

An edge computing node is a software-defined device that runs real-time operating system (RTOS) (an operating system for edge computing) and implements functions through apps. Its functions can be customised on demand. Edge computing nodes

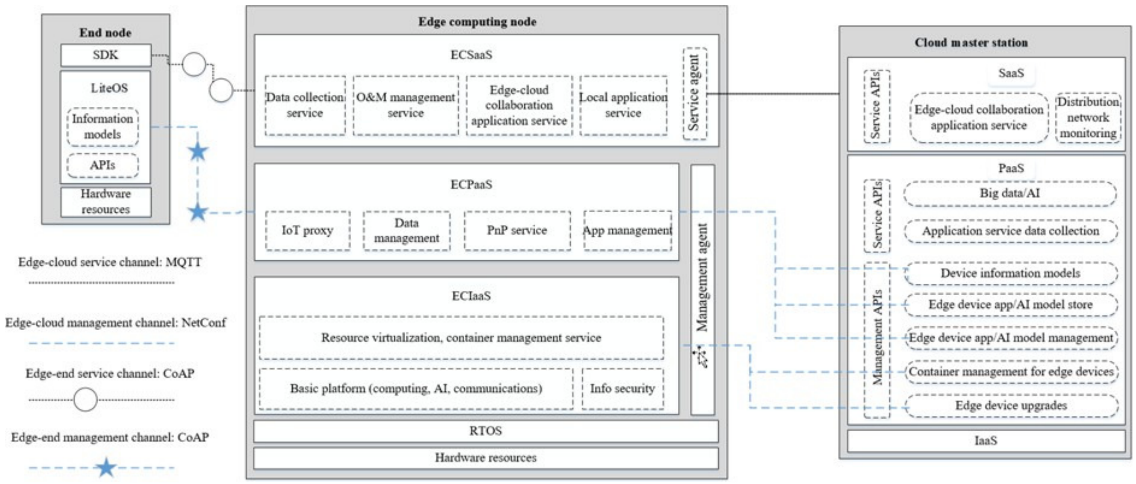

Fig. 1 *Architecture of the power distribution area automation system*

communicate with the cloud main station through agents. The management agent is used to implement resource and model collaboration, and the service agent is used to implement application and service data collaboration.

End node

As the computing and storage resources of end nodes are limited, end nodes are designed to intelligently collaborate with edge computing nodes by using the CoAP protocol and model embedded in LiteOS for data collection and analysis, using SDKs for application/service management.

Protocol stack

To achieve plug-and-play for devices, different communications protocols are used in the service channel and management channel, as shown in Fig. 2.

The management channel uses NetConf to ensure that the functions of edge computing nodes can be mirrored on the cloud master station. In this way, the cloud master station can remotely manage resources and models and monitor the running status of edge computing nodes.

Protocol stack for edge-end communications: End nodes have limited computing and communications capabilities. To ensure edge-end communications efficiency, CoAP is used for the management and service channels, and the IP-based PLC and RF-mesh networking are adopted to achieve cabling-free and plug-and-play functionality, avoiding independent node deployment in the power distribution area near-field communications network.

Information model

Information model of edge computing nodes: To ensure service data consistency between the cloud master station and edge computing nodes, the IEC CIM modelling rules of the cloud master station are applied to the edge computing node information model. In addition, data is encoded using JSON format to cope with the limited computing capabilities of edge computing nodes. The service data information model is as flatten and lightweight as IoT models, which is shown in Fig. 3.

The major YANG modules, configuration and operational data declarations and action (RPC) and notification declarations, correspond to the typical data and operations involved in

Stack	Cloud-Edge service channel protocol stack	Cloud-Edge management channel protocol stack	Edge-End communication protocol stack	
Application	MQTT ISO/IEC PRF 20922; TLS RFC 5246; Https RFC2818; SSH RFC4255	NetConf RFC 6241; NetConf over SSH RFC 6242; YANG RFC 6020	CoAP RFC 7252	
Transport	TCP RFC 793; UDP RFC 768	TCP RFC 793	UDP RFC 768	
Network	IPV4 RFC 791; IPv6 RFC 2460	IPV4 RFC 791; IPv6 RFC 2460	RPL RFC 6550	ND RFC 4861
			IPv6 RFC 2460	
Data Link	Ethernet II / IEEE 802.3 RFC894 3GPP 2G/3G/4G/5G/NB-IoT	Ethernet II / IEEE 802.3 RFC894 3GPP 2G/3G/4G/5G/NB-IoT	IEEE 1901.1	6LoWAPN RFC 6282; IEEE 802.15.4
Physical	Ethernet II / IEEE 802.3 RFC894 3GPP 2G/3G/4G/5G/NB-IoT	Ethernet II / IEEE 802.3 RFC894 3GPP 2G/3G/4G/5G/NB-IoT	IEEE 1901.1	IEEE 802.15.4g

Fig. 2 *Cloud-edge-end protocol stack*

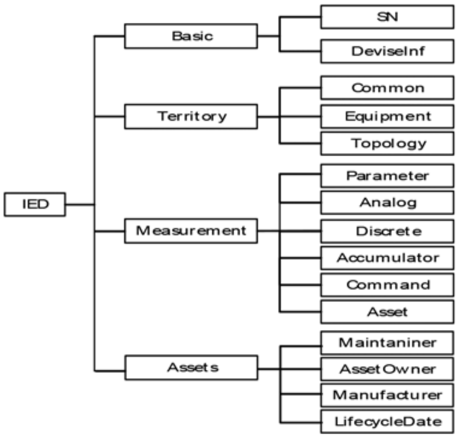

Fig. 3 *Service data information model framework*

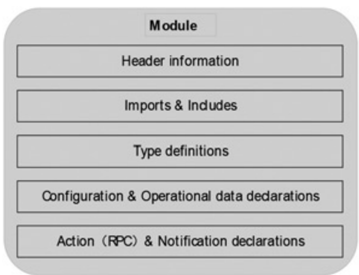

Fig. 4 *YANG module structure*

Table 1 Mapping between edge and end node models

Measurement	Unique ID (JSON)	TLV Tag (Hex)	Unit
A phase voltage	PhV_phsA	DFC98000	V
B phase voltage	PhV_phsB	DFC98001	V
C phase voltage	PhV_phsC	DFC98002	V

the interactions between the cloud master station and edge computing nodes, that is, configuration data, status data, RPCs, and notification.

Information model of end nodes: Due to the limited computing resources of end nodes, the information model of end nodes uses the TLV format, and tags are encoded in the ASN.1 BER format with a fixed length (4 bytes). According to this encoding rule, the first byte 0xDF indicates that the code is an enterprise private type.

.

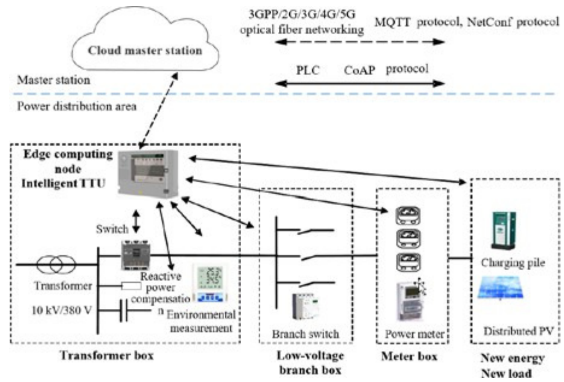

Fig. 5 *Site deployment and networking*

3 Results

The entire system has been deployed in branch companies of SGCC in six provinces including Shandong and Jiangsu. The branch company in Shandong has connected >20,000 intelligent transformer terminal units (TTUs) and >60,000 access node devices. Fig. 5 shows the site deployment and device networking.

4 Conclusion

Compared with the traditional systems for power distribution automation, this system has obvious advantages. First, the cloud-edge-device architecture based on edge computing framework enables collaboration of resources, data, models, and application services, reducing the workload in information consistency verification and facilitating remote O&M of onsitedevices. Second, the unified IEC CIM architecture with different coding methods ensures the consistency and interoperability of models. Third, the protocols used in management and service channels support self-description and plug-and-play of devices and communication networks.

In the future, it will try to use MQTT in the cloud-edge management channel to simplify the protocol stack.

5 References

1 Dong, W., Liu, R., Yi, Y., *et al.*: 'Research and practice of the D-Iot system'. CIGRE D2 Colloquium 2019, Helsinki Finland, June 2019, PS3-P-11

2 Jun, Y., Yueming, C., Mingxiang, L., *et al.*: 'Adaptive access method of low voltage intelligent terminal for distribution internet of things', *Autom. Electr. Power Syst.*, 2020, *44*, (2), pp. 22–27

3 Jun, L., Wenpeng, L., Riliang, L., *et al.*: 'Architecture of distribution internet of things based on widespread sensing &software defined technology', *Power Syst. Technol.*, 2018, *42*, (10), pp. 3108–3115

4 RFC6020: 'YANG - A data modeling language for the network configuration protocol (NETCONF)', 2010

5 RFC4741: 'NETCONF configuration protocol', 2006