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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet of things and smart cities and communities – Evaluation and assessment

Reference architecture of blockchain-based unified KPI data management for smart sustainable cities

Recommendation ITU-T Y.4907

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Recommendation ITU-T Y.4907

Reference architecture of blockchain-based unified KPI data management for smart sustainable cities

Summary

Recommendation ITU-T Y.4907 provides a reference architecture for blockchain-based unified key performance indicator (KPI) data management for smart sustainable cities (BKDMS). This Recommendation provides the concept, characteristics and high-level requirements of BKDMS. A reference architecture including capabilities of its functional entities is described in detail, and unified structures of KPI data are also introduced to ensure that BKDMS is realizable.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4907	2020-08-29	20	11.1002/1000/14382

Keywords

Blockchain, KPI, reference architecture, smart sustainable city.

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FOREWORD

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Reference architecture of blockchain-based unified KPI data management for smart sustainable cities

1 Scope

This Recommendation introduces the concept of blockchain-based unified key performance indicator data management for smart sustainable cities (BKDMS), analyses its common characteristics and high-level requirements, defines a reference architecture of BKDMS and relevant common capabilities, gives a common data structure of KPIs according to the KPIs definition of the ITU-T Y.4900 series.

The scope of this Recommendation does not include:

- The KPIs definition.
- The KPI data value and scope.
- Specific technical implementation mechanism of blockchain.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 blockchain [b-FG-DPM TR D3.5]: A peer to peer distributed ledger based on a group of technologies for a new generation of transactional applications which may maintain a continuously growing list of cryptographically secured data records hardened against tampering and revision.

NOTE 1 – Blockchains can help establish trust, accountability and transparency while streamlining business processes.

NOTE 2 – Blockchains can be classified as three types (i.e., public, consortium and private) based on the relationship of the participants and the way to provide services.

3.1.3 consensus [b-FG-DPM TR D3.5]: Agreements to confirm the correctness of the blockchain transaction.

3.1.4 smart sustainable city [ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets

the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.

NOTE – City competitiveness refers to policies, institutions, strategies and processes that determine the city's sustainable productivity.

3.1.5 smart city platform (SCP) [b-ITU-T Y.4201]: A city platform that offers direct integration of city platforms and systems, or through open interfaces between city platforms and third parties, in order to offer the urban operation and services supporting the functioning of city services, as well as efficiency, performance, security and scalability.

3.1.6 smart contract [b-FG-DPM TR D3.5]: Embedded logic that encodes the rules for specific types of blockchain transactions. A smart contract can be stored in the blockchain, and can be invoked by specific blockchain applications.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BKDMS	Blockchain-based unified KPI data management for SSC
DPM	Data Processing and Management
GMT	Greenwich Mean Time
GPS	Global Positioning System
ID	Identification
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
KPI	Key Performance Indicator
RFID	Radio Frequency Identification
SSC	Smart Sustainable City

5 Conventions

The following conventions are used in this Recommendation:

– The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

– The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Introduction of BKDMS

BKDMS is a blockchain-based unified key performance indicator (KPI) data management for smart sustainable city (SSC), which adopts a blockchain-based architecture for processing KPI data. Taking the benefits of blockchain, BKDMS ensures KPI data of SSC are tamper-proof and traceable. In this context, BKDMS defines a set of unified data structures for normalization, encryption and storage of KPI data. The unified KPI data is transported in a blockchain platform. BKDMS, by taking advantage of blockchain and encryption technologies, can provide security and reliability to data transport of the unified KPI data of SSC and can guarantee the traceability and verifiability when processing the unified KPI data of SSC.

7 Common characteristics and high-level requirements of the BKDMS

7.1 Common characteristics

This clause describes the common characteristics of BKDMS.

7.1.1 Efficiency for processing KPI data of SSC

BKDMS supports normalization of KPI data of SSC and encapsulation of the normalized KPI data, which render KPI data of SSC to be processed efficiently (such as stored, transported, analysed and utilized) by different entities including sampling sites, smart city platforms and blockchain platforms.

7.1.2 Trusted transport and storage of KPI data of SSC

BKDMS provides trusted transport and storage of KPI data of SSC. KPI data of SSC is encrypted and digitally signed when it is transported and stored in a blockchain platform. The blockchain platform maintains KPI data security and protects KPI data privacy. The KPI data in a blockchain platform is tamper-proof.

7.1.3 Traceability of KPI data of SSC

Utilizing the benefits of blockchain, BKDMS ensures that KPI data of SSC are traceable. The smart city platform can trace KPI data of SSC through the blockchain platform.

7.2 High-level requirements

This clause provides high-level requirements of BKDMS.

7.2.1 Requirements for normalization of KPI data of SSC

Requirements and recommendations for normalization of KPI data of SSC are as follows:

– BKDMS is required to support normalization of KPI data of SSC.

– BKDMS is required to support encapsulation of the normalized KPI data of SSC.

– BKDMS is recommended to encrypt the KPI data of SSC after it is normalized.

7.2.2 Requirements for sampling sites

Requirements and recommendations for sampling sites are as follows:

– BKDMS is required to enable sampling sites to collect and normalize KPI data of SSC.

– BKDMS is required to enable sampling sites to encapsulate KPI data of SSC, and to store and transport KPI data of SSC in the corresponding blockchain platform.

– BKDMS is recommended to enable sampling sites to negotiate encryption information with the smart city platform to encrypt and decrypt KPI data of SSC.

– BKDMS is recommended to enable sampling sites to be identified, authenticated and authorized when they transport KPI data of SSC through the corresponding blockchain platform.

7.2.3 Requirements for the smart city platform

Requirements and recommendations for the smart city platform site are as follows:

– BKDMS is required to enable the smart city platform to retrieve and utilize KPI data of SSC through the corresponding blockchain platform.

– BKDMS is required to enable the smart city platform to trace and track KPI data of SSC through the corresponding blockchain platform.

– BKDMS is recommended to enable the smart city platform to negotiate the encryption information with the sampling sites to encrypt and decrypt KPI data of SSC.

– BKDMS is recommended to enable the smart city platform to identify and validate the sampling sites which transport KPI data of SSC through the corresponding blockchain platform.

8 Reference architecture of BKDMS

Figure 8-1 provides a reference architecture of BKDMS, which is in accordance with the SSC IoT architecture described in [b-ITU-T Y.Suppl.37] and the IoT reference model described in [b-ITU-T Y.4000]. BKDMS mainly consists of two logical functional entities. The first is the KPI management module in the service and application support layer and the second is the KPI processing module in the device and sensing layer shown in Figure 8-1. Additionally, BKDMS utilizes the capabilities provided by the entities in the other layers.

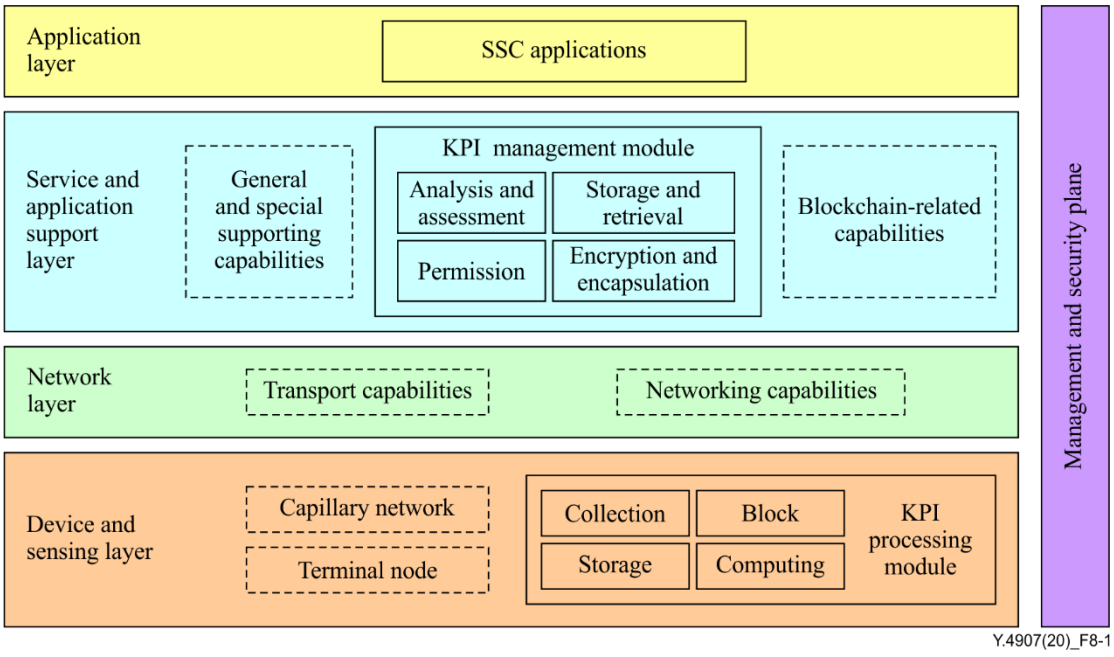

Figure 8-1 – Reference architecture diagram of BKDMS

8.1 Device and sensing layer

The device and sensing layer consists of terminal nodes and capillary networks. Terminal nodes (such as sensors, transducers, actuators, cameras, RFID readers, barcode symbols, GPS trackers) sense the physical world. They provide the "environment-detecting" ability and intelligence for monitoring and controlling the physical infrastructures within the city.

A KPI processing module of BKDMS is deployed to collect city indicators data from local databases and processes them into unified KPI data of SSC. KPI data of SSC should be encrypted, encapsulated and routed to the blockchain platform.

KPI processing module of BKDMS provides the following capabilities:

– Collection
  - Extracting and/or receiving input city indicators data from a database of sampling sites or from the smart city platform.

– Storage
  - Temporary gathering of various data including intermediate results generated during the collection and computing processes.

– Computing
  - Filtering the city indicators data, forming KPI data of SSC according to the set of normalization algorithms.
  - Executing the data consolidation and calculation according to the policies and instructions from the upper layers.

– Block
  - Supporting the interactions with the network and the blockchain platforms, cooperating with the KPI management module to perform the following functions:
    – Executing encryption and decryption of data.
    – Performing identification and authentication to the sampling sites and accessing the blockchain platform.
    – Encapsulating and uploading the normalized KPI data of SSC to the blockchain platform.
    – Storing local public and private keys.
    – Decrypting encrypted data packets extracted from the blockchain platform.
    – Performing traceability and verification of KPI data of SSC.

8.2 Network layer

BKDMS utilizes the capabilities provided by the entities in the network layer to perform the communications among the sampling sites, the smart city platform and the blockchain platform.

8.3 Service and application support layer

For this layer, [b-ITU-T Y.4000] provides descriptions of two groups of capabilities: generic support capabilities and specific support capabilities. Blockchain-related capabilities of the blockchain platform are also provided in this layer. A group of capabilities provided in this layer can be utilized to support the SSC applications.

KPI management module of BKDMS is deployed in the smart city platform in this layer. The KPI management module of BKDMS provides the following capabilities:

– Encryption and encapsulation
  - Defining and adjusting the data structures, and encapsulating KPI data of SSC for transportation and storage.
  - Creating and managing the private and public keys, providing encryption algorithms, encrypting and decrypting KPI data of SSC.

– Permission
  - Managing authentication information in the blockchain platform, executing validity verification of the access requests from the KPI processing modules, and creating an access to the blockchain platform.
– Storage and retrieval
  - Extracting KPI data of SSC from the blockchain platform and storing them in the smart city platform.
– Analysis and assessments
  - Evaluating the quality and availability of KPI data of SSC, providing the algorithms, models, tools and policies for analysis and assessment, and providing the analysis and assessment results to the applications of SSC.

8.4 Application layer

The application layer includes various applications that perform SSC services. Some of the functionalities of the smart city platform can be deployed in the application layer.

8.5 Management and security plane

This plane provides the operation, administration, maintenance, provisioning, and security functions for the ICT systems of SSC. BKDMS utilizes the capabilities of this plane to provide security and privacy protection for KPI data of SSC.

9 Major work procedure of BKDMS

As shown in Figure 9-1, sampling sites collect, store, encrypt, encapsulate and normalize KPI data of SSC and upload the unified KPI data of SSC to the blockchain platform. The smart city platform extracts, processes, and analyses the unified KPI data of SSC from the blockchain platform.

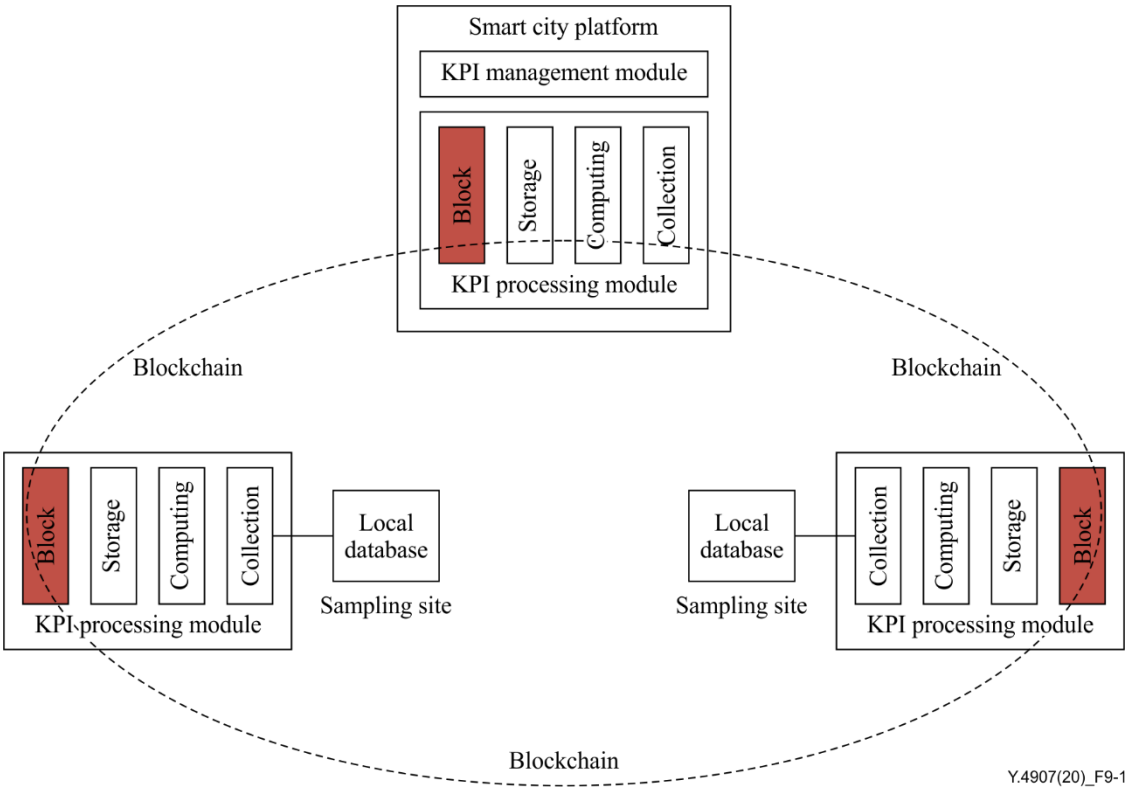

Figure 9-1 – Main building blocks of BKDMS

The main work procedure to process KPI data of SSC include the following steps:

– Normalization of KPI data of SSC

KPI processing modules in sampling sites implement extraction, calculation, storage and screening of various city indicators data, form the KPI data of SSC after normalization according to the unified KPI data structure (see Table 10-1), and implement the identity binding between KPI data packet and KPI processing module.

– Encryption of KPI data of SSC

KPI processing modules in sampling sites implement the encryption of the KPI data by using the public key of the smart city platform and the encryption of the KPI data digest by using the private key of the sampling site. The encrypted KPI data and its digest are packaged in accordance with the unified structure to form the KPI data packet (see Table 10-2).

– Processing of KPI data of SSC in blockchain platform

KPI processing modules in sampling sites initiate access requests to the blockchain platform and the validity verification is executed by the blockchain platform. Encrypted KPI data packets sent by the KPI processing modules are routed to the corresponding consensus accounting node of the blockchain platform. According to its own consensus mechanism, the blockchain platform merges the received data packets of KPI data of SSC into the data block according to the processing time period, and completes the update of the blockchain platform.

– Processing of KPI data of SSC in the smart city platform

The KPI processing module in the smart city platform extracts KPI data packets from the blockchain platform. The KPI management module verifies the credibility and consistency of the KPI data of SSC.

The extracted encrypted KPI data of SSC and its encrypted digest, together with its other relevant information are encapsulated in a unified data structure (see Table 10-3) and stored in the database of the smart city platform.

– Decryption and application of KPI data of SSC

The KPI management module of the smart city platform decrypts of the encrypted KPI data of SSC by using the private key of the smart city platform, and it decrypts the encrypted data digest by using the public key of the relevant sampling site.

KPI data is verified by its digest for the use of various SSC applications supported by the smart city platform.

10 Reference common structures of KPI data of SSC

KPI is the basis of comprehensive evaluation of SSC. Due to the various forms of data in collection, the data collected may be in the form of electronic documents, or derived from the original data of the data collecting devices, or can be from manually constructed tables on paper. A unified data structure of the KPI data of SSC is needed for comprehensive assessment and analysis of the status of SSCs by digital means.

10.1 Unified KPI data structure

The collected KPI data of SSC should be normalized according to the definition in [b-ITU-T Y.4903]. As shown in Table 10-1, the unified KPI data structure is specified to unify different forms of KPI data of SSC. Binary encoding is used to represent the value of each part in the data structure.

Table 10-1 – Unified KPI data structure

Country/region	City	Site ID	Time	KPI data	Length	Extending

The main parts of the unified KPI data structure include:

– Country/region: Country/region coding, according to the international common country/region coding standard;

– City: City coding, according to the national city coding standard;

– Site ID: IPv4/IPv6 address of data collecting equipment;

– Time: Data collecting time (GMT);

– KPI data: KPI of each data collecting site, according to the definition in [b-ITU-T Y.4903];

– Length: Length of extending data part;

– Extending: Data of extending part.

The KPI data part is recommended to be designed according to the definition in [b-ITU-T Y.4903].

10.2 Encryption of unified KPI data

The network environment in which the equipment is located does not always meet its security requirement for the city indicator data collection and transmission. The KPI data of SSC should be encrypted for transportation and storage.

Table 10-2 – Encrypted unified KPI data packet

Encrypted KPI data	Encrypted digest

Table 10-2 specifies the structure of encrypted unified KPI data packet as follows:

– Encrypted KPI data: Encrypted KPI data of SSC with the unified KPI data structure;

– Encrypted digest: Encrypted hash result of KPI data of SSC with the unified KPI data structure.

The encryption methods could be chosen and adopted according to the application needs. The encrypted unified KPI data packet is transported from the KPI processing module to the blockchain platform, and accessed and added to the blockchain platform through its operating consensus mechanism.

10.3 KPI data structure of storage

The encrypted KPI data of SSC is extracted from the blockchain platform and encapsulated in a KPI management module. The KPI data of SSC should be stored in the database of the smart city platform in the data structure for KPI storage given in Table 10-3. With the support of the blockchain platform, the KPI data of SSC is more trustworthy and traceable. The KPI data of SSC is decrypted for processing in different applications.

Table 10-3 – The data structure for KPI data storage

Data recorder	Block recorder	City data	Chain ID	Tracing code	Check code

The main parts of the data structure for the KPI data storage include:

– Data recorder: Indicates the length and the offset of encrypted KPI packet;
– Block recorder: Indicates the length and the offset of the block in the blockchain platform;
– City data: The encrypted KPI data of SSC;
– Chain ID: The URL address of the blockchain platform;
– Tracing code: Code used to backtrack the KPI data of SSC;
– Check Code: Code used to check the consistency of the KPI data of SSC.

11 Security considerations

The sampling sites and the smart city platform are usually deployed in different domains and may reside in untrusted environments. BKDMS is required to provide security mechanisms to support the sampling sites and the smart city platform to identify, authenticate and authorize each other.

Additionally, the security mechanisms should support security transport technologies such as transport layer security when the KPI data of SSC is transported between the sampling sites, the blockchain platform, and the smart city platform.

Appendix I

Use case of the BKDMS

(This appendix does not form an integral part of this Recommendation.)

This appendix provides a use case to illustrate the concept of the BKDMS.

I.1 Use case: Enhancing traceability and auditability of KPI data of SSC

This use case shows a smart city platform trace and audit for the KPI data of SSC through BKDMS (see Figure I.1). Prior to its operation, the smart city platform deploys smart contracts on the blockchain platform, with which the blockchain platform can identify and authenticate the sampling sites, and then accept and store the KPI data of SSC uploaded by the authorized sampling sites.

Sampling sites collect and upload the KPI data of SSC to the blockchain platform. When the KPI data of SSC from an authorized sampling site is stored, it is also bound to the identities of the sampling site which uploaded the KPI data of SSC. The blockchain platform can keep the stored KPI data of SSC and the bound information to avoid tampering with the data.

The smart city platform discovers and extracts the KPI data of SSC and the bound information from the blockchain platform. The smart city platform can utilize the bound information of the KPI data of SSC to trace and audit the KPI data of SSC at any time in due course.

With the inherent properties of the blockchain (such as transparency, data unchangeability, data security), BKDMS can enable the smart city platform to receive, trace and audit the unified KPI data of SSC.

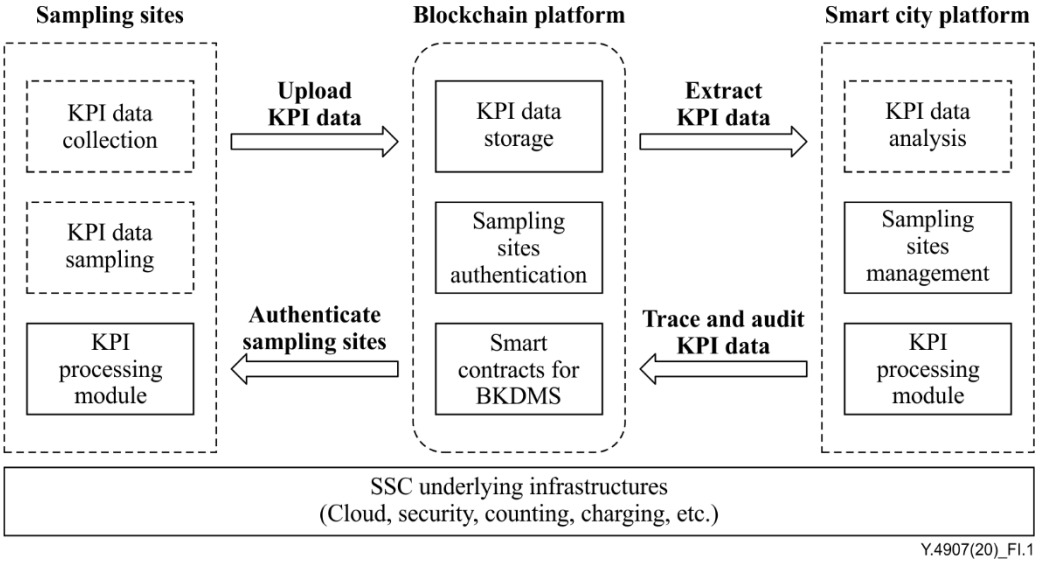

Figure I.1 – Enhancing traceability and auditability of the KPI data of SSC

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