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Architecture of the automated information system for monitoring and resources accounting

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Abstract. We solve the problem of minimization of material and time costs on scaling, deployment and expansion of functionality of the distributed automated information system for monitoring and resources accounting (hereinafter–the system), that have been created for experimental research of complicated transition processes in high-voltage circuits of power supply networks (to 25 kV). The solution of this task became possible by developing the new system architecture (software, technological and information support) and functional modules, considering the geographical distribution and heterogeneity of data channels and transmission technologies used to information exchange between the elements of the system.
We explain the features of the new original architecture for systems of this class, considering the logical division into functional levels: measuring, intermediate storage and processing, data representation for users. We have developed mobile information and measuring complexes that allow making a research of continuous dynamic processes in high-voltage circuits using wireless technologies and independent power supplies. A set of solutions is proposed to provide modularity of the architecture for the rapid addition of new devices and functions using intermediate software environment that is actual for a changing infrastructure and variety of interfaces between the parts of the system. The architectural solutions offered in the paper provide a comprehensive analysis and evaluation of power losses due to suboptimal operation of electrical substations and electric rolling stock (high and low voltage, power flows between traction substations, losses in step-down transformers, voltage surges due to recuperation, etc.), as well as the formulating of recommendations for improving the energy efficiency of power supply systems. The system can be adapted to various enterprises needing the account of any production resources and technological parameters that can be synchronously measured in real time for research and operational decision-making.

1. Introduction

The monitoring task is considered and accounting parameters and dynamic characteristics of the process as a continuous process for observation and recording of object parameters. The monitoring result is a plurality of measured values of the parameters obtained in the continuously adjoining time intervals, for which parameter values do not vary significantly. Accordingly, the system for monitoring and recording system is hierarchical multilevel geographically distributed computerized system and makes it possible to control and analyze a variety of technological resources consumption modes, decisions regarding their rational use and aggregated enterprise resource data. The main objective is to obtain reliable information on the embedding amount produced, transmitted, distributed and consumed resources. The need to improve such systems due to the constant rise of a variety of resources indexability of their application and accounting, intensification of modern information technologies in the industry. The system put into operation at the enterprise of the Sverdlovsk Railway, a branch of Russian Railways, is described in [1][2][3]. Consider the basic approaches and architectures used in the modernization of this system.

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2. Analysis of requirements for information systems

The task of designing an automated corporate info-system for monitoring and accounting resources is associated with the need to select and develop a wide range of technical solutions considering the specificity of the automation object. First, it is necessary to carry out research or study of the object, features and modes of its operation, and the dynamics of its processes, to clarify the technical task requirements.

It is necessary to identify the functional tasks associated with the main purpose of the operation of the particular service of the system or the part of it. Wherein, functional tasks can be conditionally subdivided into internal service tasks and user tasks focused on servicing the system user functions. There are often two main levels in corporate informational systems (CIS), that respectively implement the system and application functions (for example, management). The system component of the CIS is a software and hardware base for the application layer operation and it solves the problems of forming a single universal information environment for the transmission, processing and storage of information. The application layer, implemented exclusively in the form of software applications, uses these three main services of the system level.

When developing the automated system architecture, it is necessary to ensure that the requirements of reliability, economy, scalability and configurability are simultaneously fulfilled. The system building solutions must meet the information security requirements and have a margin for expanding the system functionality and its future development.

In most cases, automated systems can be represented as a hierarchical structure, at the top of that are automated workstations, operator stations, various servers and services, whose tasks are integrated throughout the system, centralized collection and comprehensive data analysis, changing the system operating modes of the system as a whole thing. At the same time, the top-level subsystem can be both centralized and distributed, using all modern information technologies, providing different access levels for various categories of personnel working with the system. To transfer information, global or corporate networks can be involved, that can reserve each other.

The greatest complexity, and therefore, greatest interest are distributed systems, in which the automation object consists of a set of local subsystems located at large distances from each other. An example is the power supply system of the railway, which relates to the task of monitoring and technical metering of electricity at the traction substations inputs and railway contact network feeders in order to detect current and power imbalance and to carry out measures to improve the electricity supply system energy efficiency. System peculiarity needs accurate synchronous measurements at objects remotely located from each other.

In distributed automated systems, a typical solution is to use an intermediate level—process controllers or industrial computers that collect data and real-time control on local sites of the automation object and perform a time synchronization of all devices in the system. The lower system level consists of single measuring devices and actuators.

Now, there are two main ways that should be used when building the architecture of an automated system: providing full determinism and providing the possibility of system self-organization. In most cases when working with technological objects, self-organization is justified only at the lower system level, while the structure and mode of operation of the upper two levels remains stationary. For example, there is a flexible automated robotic factory or warehouse, on the lower level of which, on the scale of workshops or rooms, individual operations are performed by robots not according to a predetermined algorithm, but in accordance with the constructed object-oriented or event model. Such a system is characterized by the mobility of lower level devices, the use of wireless data transmission technologies, dynamic changes in the data network configuration and parameters.

When inspecting and performing diagnostic activities at automated facilities, it may be necessary to install and dismantle measuring and other low-level technological devices quickly. For example, it is necessary for monitoring and examining the operating modes of devices in a distributed power supply system. In this case, the application of wireless data transmission technologies with the quick self-tuning of the information network possibility will be optimal.

The following general requirements for the information system for monitoring and accounting of resources can be signed out:

- the possibility of expanding the functionality, flexibility and infrastructure controllability, scalability (without stopping the work of the already configured system);
- simple development and configuration; reliability and fault tolerance of the system, which are achieved due to backups and independent redundancy;
- real-time operation of the entire transport and server infrastructure;
- guaranteed transparent access to the information 24 hours a day, 7 days a week, 365 days a year;
- a high degree of the system software components integration. For example, this is achieved using a unified configuration database and the same type of data transfer protocols;
- low response time, adequate bandwidth, no bottlenecks and traffic isolation without additional delays;
- accurate time synchronization on a system-wide scale.

3. General structure of the information system and its features

From the point of view of the main functional tasks, the system for monitoring and accounting of resources should ensure the collection of information from data sources (meters), intermediate information processing and storage, and further centralized storage and provision of information to users of the system. In accordance with this functional tasks set, the structure of the system consists of four main levels (Figure 1).

The lower system level—Data measurement systems (DMS)—provides the measurement and primary transformation of information parameters, their short-term or medium-term storage in memory devices, their necessary processing (averaging, filtering, spectral analysis, event detection) and communication to the next level. In the control systems, this level includes actuators and local control systems. The article [5] describes algorithms that are applied at this level.

The second level is the Local data computing systems (LDCS) and the corresponding data acquisition and transmission devices (DATD). The main device of this level is an industrial controller (which performs the functions of local and coordinated control), or an industrial computer (which collects and stores medium-term or long-term data within a single site). The device can also handle events related to processes generally occurring on the site.

The third level—Data computing system (DCS)—provides centralized data collection from LDCS, long-term storage and data transmission to the next level.

The fourth level (external)—the main users of information—is represented by a variety of clients (automated workplaces) and service servers. The peculiarity of the interaction of this level with the DCS level is the use of standard Internet/Intranet-oriented technologies, tools and protocols for data exchange using a universal web client—browser, which allows the client part to be implemented on various software and hardware platforms. This architecture has a high degree of scalability, stability, availability, universality and unification. The latter characteristics are expanded using a service-oriented architecture (SOA), based on the use of services with standardized interfaces, for example, based on the XML language.

The connection between the first two layers of the system can be based on any available technologies: wired (including fiber-optic) and wireless (Wi-Fi, ZigBee, GSM, GSM-R, UMTS, LTE, etc.). The use of wireless technologies is associated either with the principle of mobility of devices within the local site, or with the need for a rapid deployment of the system. In case the DMS's electricity meters are installed on the railway rolling stock, they can transmit information, either via Wi-Fi or ZigBee technology, to a data concentrator located in locomotive depots (C1, C2, C3 or B1, B2, B3), or using GSM mobile operators' networks (D1, D2, D3) as shown in figure 1. In the latter case, an additional mobile data concentrator installed on the rolling stock may be required, which transmits information to the stationary concentrator located in the depot.

The interaction of LDCS and DCS is carried out via a wired datanet or wireless networks (GSM, GSM-R, UMTS, LTE) in the coverage area. Similar technologies and networks can also be used to implement the interaction between the DCS and the fourth level.

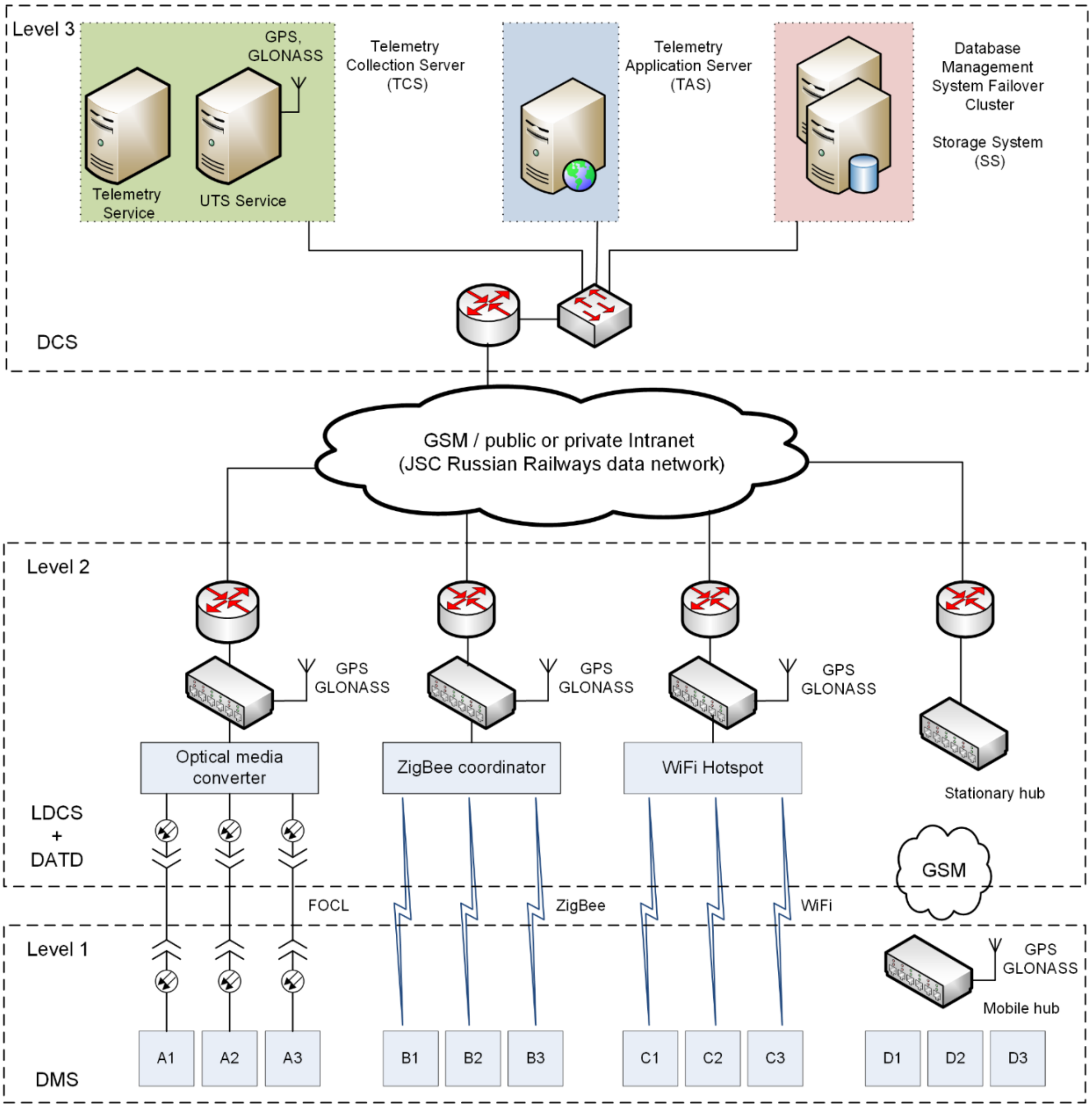

Figure 1. The distributed corporate information system structure.

4. Application the concept of intermediate software environment

The system implements the intermediate software environment (middleware) concept, which primarily provides a unified and independent mechanism for intercomponent messaging and functional tasks execution. In addition, tasks are solved such as component authentication and authorization, protection of data transferred between components, ensuring data integrity, load balancing and detection of remote components. The architecture that implements the intermediate software environment concept is shown in figure 2.

The system uses several intermediate media, that leads to the formation of a heterogeneous medium. This makes it possible to simplify the level interaction implementation considering the transport level specifics and the geographical distance of the components of different levels of the system relative to each other.

Figure 3 shows a typical system architecture with an intermediate software environment, which is implemented at each system level.

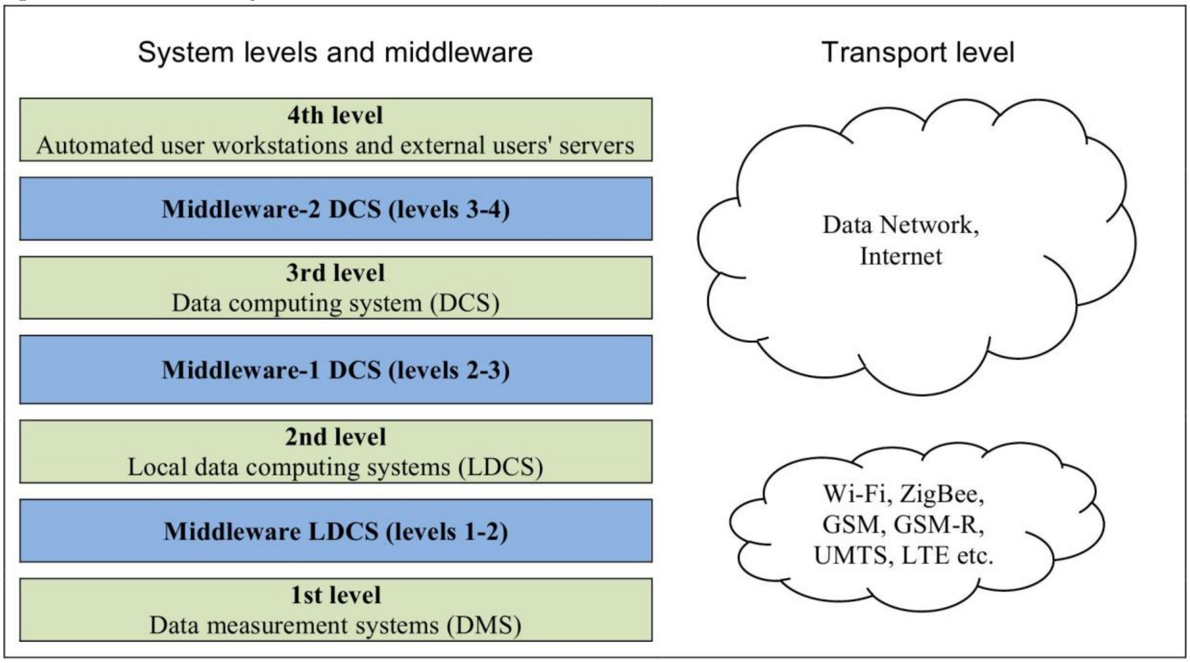

Figure 2. The architecture of a heterogeneous distributed system with intermediate software environments.

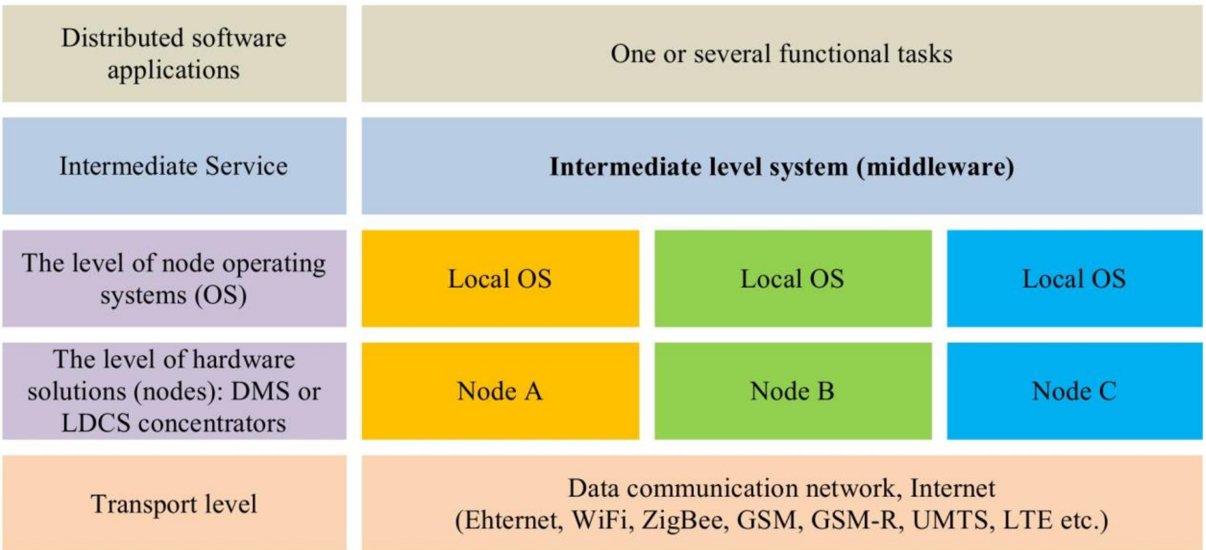

Figure 3. The architecture of a system with an intermediate software environment.

5. Technological features of the implementation the information system

During the technological architecture of the system and the DATD development, the following general principles for the data transmission channels organization were taken into account:

- transport subnets of data transmission are logically divided at the LDCS level;

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- the wireless network and the core package network may have different addressing schemes. Note that the functions of the wireless network or the core package network can be physically implemented in one equipment;
- control of the availability and routing of wireless network nodes is entirely entrusted to the wireless network itself;
- the functional separation of the wireless network interfaces must have several possible options;
- interfaces should be based on the logical model of the block controlled by this interface;
- one physical network element can contain several logical blocks.

The technological architecture provides the following basic transport functions:

- transmission of information and diagnostic messages to a higher level;
- receiving command messages (control information) from a higher level;
- detection of errors in messages;
- discarding corrupted messages;
- retransmission of messages;
- information protection, including management of encryption keys;
- quality of service management.

The following specific transport functions are assigned to the LDCS level:

- sending command messages (control information) to a lower level;
- transit of command messages (control information) from a higher to a lower level;
- re-connection at the DMS-LDCS, LDCS-DCS levels;
- installation, configuration, adjustment of the wireless network.

The specific transport functions of the DCS level are:

- sending command messages (control information) to a lower level;
- obtaining control information from external administrative systems.

The basis for building transport communications of remote system elements is the OSI / ISO open systems interaction model and the TCP / IP protocol stack, which is a standard, cross-platform, low-level data exchange service. At the same time, all elements of the system have a network component of operating systems based on the socket interface, which provide low-level primitives for the byte stream direct exchange between software processes. Of the two most popular concepts for the software components interaction (messaging and procedure calling or the remote component object methods), the first one has been applied. At that, the asynchronous variant of interaction with the message queue is used. In this case, the mediator—the message queue manager is used. The program component sends a message to one of the manager queues, after which it can continue its work. Later, the receiving part will extract the message from the manager queue and begin its processing.

6. Organization of data storage

According to the domain approach [6] to describing the information systems architecture, the system under consideration belongs to the class of information management systems (IMS), which implements the process of collecting data coming from various sources, in particular from meters. The data is processed, and a variety of reports intended for different categories of users are generated on their basis. Reports can be considered when deciding on the effectiveness of the automation object.

Figure 4 presents the architecture of distributed storage, processing and presentation of information in the context of IMS, which contains the following main components:

- data sources (DS)—DMS meters;
- a database for storing intermediate results (DBSIR) for processing time-synchronized measurement data from the DS ("raw data");
- a data processing subsystem (PS), which processes the measurement results and prepares them for storing and report generation;
- the main database (MDB), which provides storage of monitoring and accounting data in the form suitable for report generation;
- subsystem of report generation (RG)—provides information representation in a user-friendly form;
- a set of software man-machine interfaces—provides access to reports on a regular basis, or in case of exceptional situations. In general, interfaces are used to implement operational, tactical and strategic management.

Data sources are implemented at the first level of the system, DBSIR and PS—partially on the second and third levels. The main database, the report generation subsystem and a set of software man-machine interfaces are implemented on the third and fourth levels of the system.

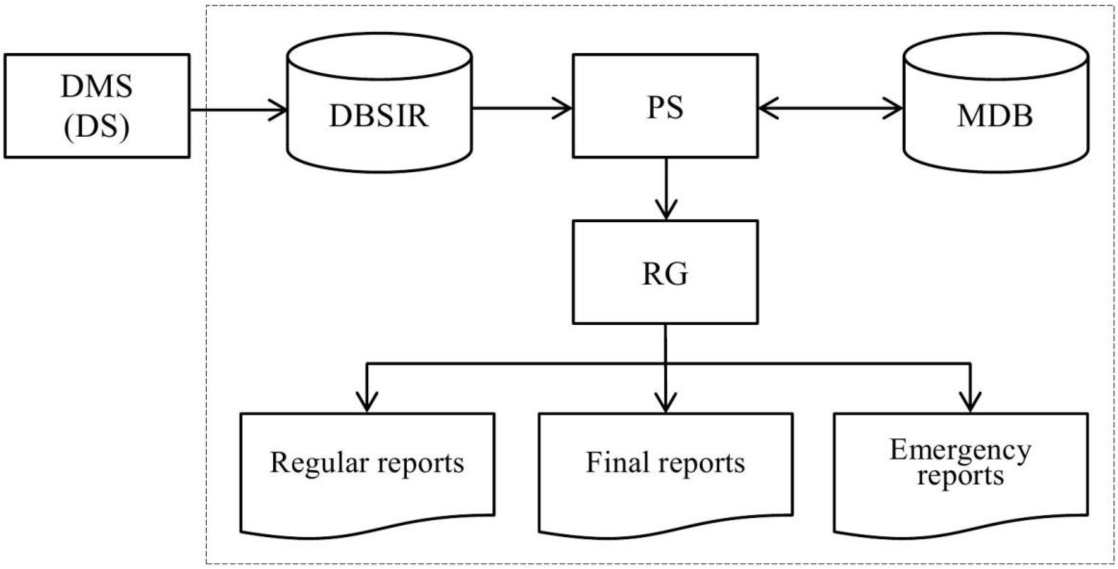

Figure 4. The architecture of distributed storage, processing and presentation of information.

DBSIR and MDB are the elements of a data architecture that includes logical and physical data stores and data management tools. The software architecture is implemented in the data processing subsystem, the report generation subsystem and the software man-machine interfaces. The techno-logical architecture, which characterizes hardware and system software, is implemented in server equipment and DATD.

7. Decomposition of functional tasks of the data computing level

Let’s consider the architectural solutions implemented at the third level of the system. Figure 5 presents the three-tier architecture of the information and computing complex, in accordance to which the functions of the DCS are divided into three layers (levels): presentation layer, business logic, data access layer. These functions are implemented in full or in part on different elements of the DCS. So a

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set of software man-machine interfaces is fully implemented on the clients of the DCS, and data storage is located on database management system (DBMS) servers and in the data storage system.

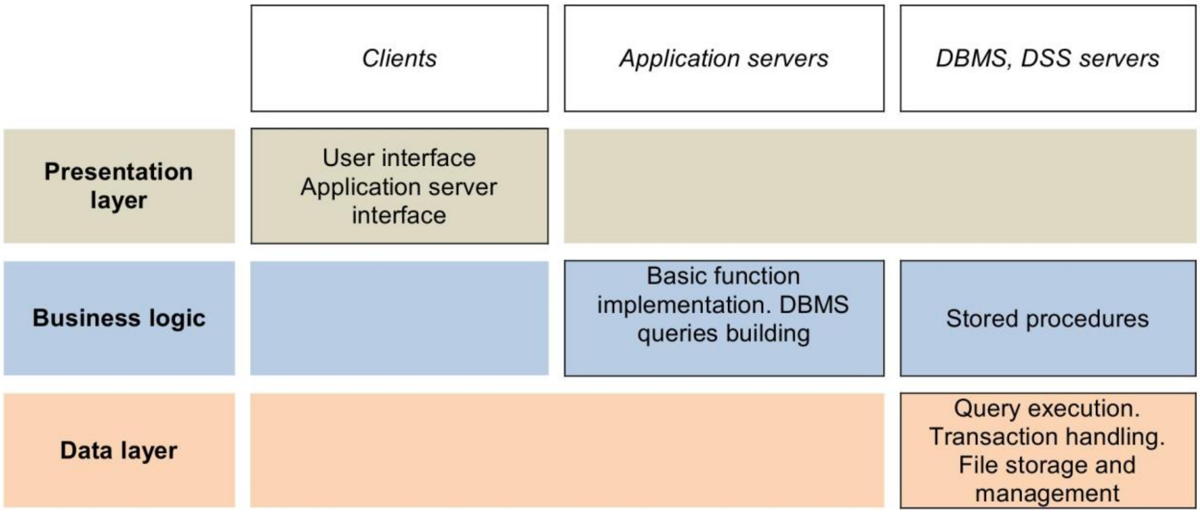

Figure 5. Three-tier architecture of the DCS.

The DCS consists of the following main elements:

- telemetry collection server (TCS);
- telemetry application server (TAS);
- database management system failover cluster and data storage system;
- access router and switch.

The TCS and TAS servers are related to application servers. They implement the core functionality of the DCS for the collection and processing of information and the report generation. The TCS (telemetry service) directly interacts with the LDCS concentrator and receives DMS telemetry data from it. It also performs time synchronization with the use of precise time signals from GPS / GLONASS satellites. The TAS manages external system users to provide access to telemetry data. For this, it includes an FTP-service and a web-service that provide access to information via FTP and HTTP protocols. The proxy service provides regulated access to services, monitoring and balancing of application traffic.

The DCS provides the solution for the following tasks:

- automatic and / or on-demand collection and storage of measurement results from all LDCS included in the system;
- logging of events from all LDCS;
- databases backup and copying of their archive to an external storage;
- automatic time correction in the DCS and their time synchronization with a common calendar time;
- automatic transmission of measurement results and status of measuring instruments to the DCS and other interested entities, provision of regulated access to visual, printed and electronic data to users and operating personnel;
- mechanical and software protection against unauthorized access to the DCS elements.

In the DCS, the following functional subsystems can be distinguished, which are of an auxiliary nature:

1) the network subsystem, designed to organize the interaction between the DCS components by the TCP / IP family protocols. The subsystem consists of switching and traffic routing equipment. The equipment is intended for routing and switching traffic inside the DCS and between the system elements;

2) the information security subsystem (IS), is designed to reduce the probability of confidential information leakage, unauthorized modification or loss of information (destruction, irreversible distortion with loss of meaning, failure to get the information to the addressee or block the access to it). The information security subsystem includes a set of the following tools:

- firewall means—necessary for package filtering of network traffic inside the DCS and between the system elements;
- means to detect and counter attacks—designed to detect and exclude network attack traffic from the data stream;
- means of access control of end devices to the network—designed to prevent access to a system of devices that do not comply with the security policy;
- means of centralized access control—designed for centralized control of administrator access to the system equipment;
- management tools of the IS subsystem—designed for IS resources centralized management.

3) management and monitoring subsystem—designed for system elements secure management, including centralized administration, system messages collection, statistics collection and software update.

8. Conclusion
Thus, we considered the main architectures used in the corporate information system for resources monitoring and accounting. The choice of certain architecture depends on the position in hierarchy and functions of the system element. We reviewed the current trends in the information systems development and those concepts of building that provide the requirements established for systems of similar class and purpose.

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