# INTEGRATION OF BUSINESS INTELLIGENCE SYSTEMS THROUGH MULTI-AGENT TECHNOLOGIES BASED ON CLOUD SOLUTIONS AND SERVICE-ORIENTED ARCHITECTURE

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**Annotatsiya**

Today, the development of information technologies creates new opportunities aimed at optimizing management and educational processes in higher educational institutions. Digital transformation not only changes the content of the educational process, but also requires the use of modern technologies to increase the effectiveness of educational institutions. At the same time, the integration of business intelligence systems into educational management is a pressing issue. Higher educational institutions have large databases, which store various types of information, such as student ratings, academic results, financial calculations, and employee performance. However, the quantity and complexity of this data limit its full use. Business intelligence systems are an important tool in this matter, allowing higher educational institutions to improve decision-making processes, automate data analysis, and effectively organize management processes.

Kalit so'zlar: cloud computing, big data, service-oriented architecture, database, ETL, automated analysis, decision-making systems

## Introduction

In recent years, the development of information technologies has created new opportunities aimed at optimizing management and educational processes in higher educational institutions (HEIs). Digital transformation not only changes the content of the educational process, but also requires the use of modern technologies to increase the effectiveness of educational institutions. At the same time, the integration of business intelligence (BI) systems into educational management remains a pressing issue.

Higher education institutions have large databases, which contain student ratings, learning outcomes,

various types of data are stored, such as financial statements and employee performance. However, the quantity and complexity of this data limit its full use. BI systems are an important tool in this matter, allowing universities to provide:[2]

- **supporting strategic decision-making**: optimizing management strategies based on statistics and analytical indicators.
- **efficient use of resources**: control over the targeted allocation of personnel,

audiences, and financial resources.

- educational process individualization: **students and teachers**

Formation of personal approaches through analysis of activities.

- **developing new innovative programs**: using technologies to improve the effectiveness of curricula.

However, the implementation of BI systems and ensuring their effective operation presents a number of technical and methodological problems. The most important problem is the integration of data from different sources and the creation of a flexible integration model [3]. At this point, multi-agent technologies stand out as the main solution due to their high flexibility and the ability to manage complex interconnected processes. By combining multi-agent technologies with BI systems, it is possible to solve the following problems:

- **adaptive data management**: agents collect, analyze, and manage data in an automated manner.
- **joint decision-making**: agents develop appropriate solutions for each element of the system through interaction.
- **Real-time analysis**: constantly monitors the flow of data and responds promptly to changes in the activities of the university [4].

For the effective application of these technologies, XYA is of great importance. XYA technology provides the following capabilities:

1. **Ensuring intersystem compatibility**: Integrating different software systems into a single platform during the learning process.
2. **adaptability and scalability**: the ability to easily add new agents or services to the system.
3. **efficient use of resources**: increasing the economic efficiency of data storage and processing using cloud technologies [5].

Aimed at integrating BI systems and multi-agent technologies in universities using XYA and cloud solutions

The goal is to develop effective models and algorithms. To achieve this goal, the following main tasks have been defined:[6]

1. **Analysis of data management processes:** Assessment of the effectiveness of BI systems in universities, identification of existing problems and development of proposals for their solution.
2. **Develop integration models based on multi-agent technologies and XYA: t**Develop integration models based on XYA and multi-agent technologies to enhance system functionality, ensure flexibility, and improve interaction between various resources[7].
3. **Ensuring the stability and security of systems using cloud technologies:** Implementing data storage and processing processes through cloud infrastructure, developing effective solutions to improve the stability and security of systems[8].

Through these tasks, more innovative and sustainable solutions for BI systems and multi-agent technologies are formed in universities[9].

Construction of multi-agent systems based on cloud technologies and service-oriented architectures

Building multi-agent systems based on cloud technologies and IPs provides a high level of flexibility and intersystem compatibility to ensure efficient data management and resource-efficient use.

**2.1.** Advantages of cloud technologies for BI systems

Cloud technologies provide BI systems with a number of advantages. Their most important aspects are the following[10,11]:

1. **Adaptability**: Quickly customize BI systems for cloud technologies organizations according to their current needs allows. When the data volume increases, it is possible to immediately increase or decrease the server capacity. This ensures efficient resource management.
2. **Expanding capabilities**: Cloud platforms make it easy to work with large amounts of data. An increase in the number of users or the addition of new services will not affect the system's efficiency. Cloud providers provide the ability to continuously expand the service.
3. **Resource saving**: When using cloud solutions, companies do not need to purchase large equipment and provide maintenance. Only the resources used are paid for, which significantly reduces costs.

The main cloud providers offering the best solutions for managing and optimizing BI systems and their capabilities are presented in Table 1.

**Table 1. Cloud service providers**

| **Provider name** | **Capabilities** |
|---|---|
| Amazon Web Services (AWS) | Amazon QuickSight has visualization and big data analysis capabilities through Redshift |
| Microsoft Azure | Analysis and visualization with Power BI and Synapse Analytics services will be provided |
| Google Cloud Platform (GCP) | BigQuery capabilities for processing large amounts of data and visualization through Looker |

**2.2. Service-oriented architecture**

Service-oriented architecture is a modern approach to the organization, connection, and integration of systems, in which information systems are built in the form of independent services. Each service performs a specific task assigned to it and operates independently. This approach is a general approach to systems

Along with increasing their effectiveness, it also ensures their flexibility[12,13].

The main goal of the XYA architecture is the integration of various services into each other and the establishment of effective communication between them. This serves to increase the mutual compatibility of the systems. One of the important

advantages of XYA is that by dividing systems into modules, it is possible to control and interconnect each module separately, while ensuring functional and technological independence.

XYA is used in data management and analysis, as well as in

Widely used in BI systems, it is an important tool for ensuring integration between modern information systems. With the help of XYA architecture, it becomes possible to collect, manage, and analyze data by creating various services. These services facilitate data exchange between systems and help effectively integrate multiple systems. XYA is especially important for BI systems, accelerating decision-making processes by strengthening integration and cooperation between systems[14]. In the field of education, the XYA architecture provides new ways to integrate services and manage resources between universities. For example, a university can create separate services for managing student lists, class schedules, and data related to scientific work. Each service is aimed at a specific goal and increases the effectiveness of the educational process. In addition, the XYA architecture facilitates the sharing of online courses and resources, creating a convenient platform for strengthening cooperation between universities[15]. This serves to effectively organize communication between students and teachers. The implementation of XYA will make a significant contribution to the optimization of educational processes, creating the possibility of fast and convenient information exchange between higher educational institutions.

Integration of XYA with multi-agent systems ensures the independent functioning of the systems, a high level of reuse capabilities, easy integration, and effective coordination. Multi-agent systems interact consists of agents that work together, each of which processes data independently. XYA facilitates communication between these agents, facilitating their integration, data exchange, and integration processes[16]. Below are the main advantages of XYA in the integration of multi-agent systems:

1. **Independence and modularity:** Each agent performs its own independent function, and XYA organizes communication between agents based on modules. Each agent creates its own separate service, ensuring minimal interaction with other agents.
2. **Reuse:** Services (used by agents) generated with XYA may be reused. This allows you to reuse existing services when creating new agents and systems. Reuse between services optimizes the system and ensures efficient use of resources.
3. **Simple integration:** XYA simplifies data exchange and integration between different systems. Given that multi-agent systems utilize different platforms or technologies, XYA facilitates efficient and fast communication between agents.
4. **Effective Coordination:** Effective coordination is established between agents with the help of IA, since the services of each agent are clearly defined and work separately. Each agent in the system performs individual tasks related to their service and achieves the overall goal of the system through minimized interaction with other agents[17].

With the help of XYA and multi-agent technologies, university BI systems play an important role in improving effective decision-making and management processes.

While XYA organizes each agent as an independent service and ensures system integration, multi-agent technologies establish information exchange and effective cooperation between agents (Figure 1):

**1.** Student Agent Activities:

- reviews class schedules, exam results, and course information.
- sends updates to teachers and administrative agents when they occur.

**2.** Activities of the teacher's agent:

- updates grades and enters course data into the system.
- Changes will be automatically communicated to students and administrative agents.

**3.** Activities of the Administrative Agent:

- omanages learning processes, adds new courses or updates existing ones.
- increases system efficiency by sending necessary information to student and teacher agents.

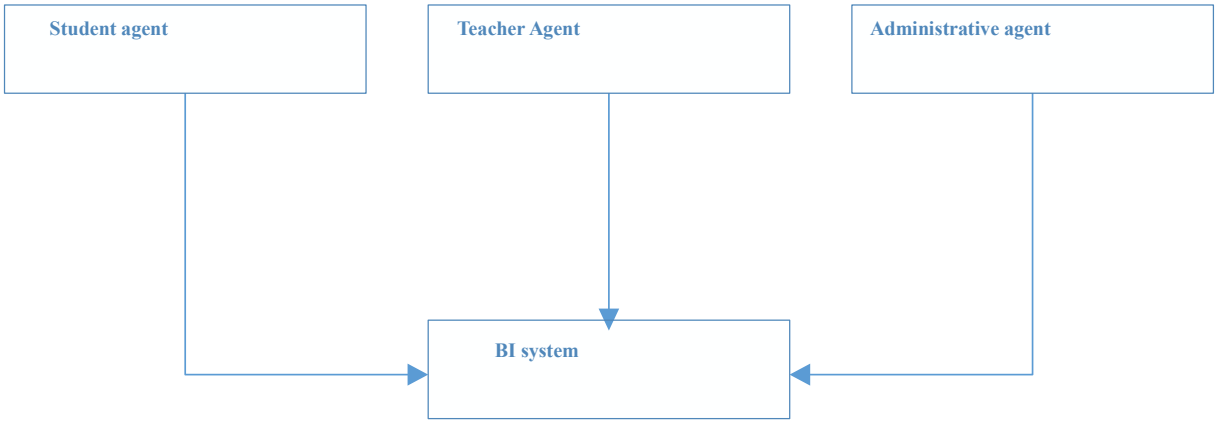


**Figure 1. BI system using multi-agent technologies**

The integrated activity of these agents supports the adoption of specific decisions based on BI systems and improves university management processes.

**2.3.** Multi-agent technologies and systems

Multi-agent systems play an important role in the effective organization of data collection, analysis, and decision-making processes in the field of BI. Each agent carries out the collection, filtering, processing, and analysis of data in accordance with its assigned task. For example, a storage agent is engaged in data collection and storage, while an analytical agent provides analysis and decision-making based on BI systems. Such an approach increases the efficiency of the system and improves decision-making processes[18,19].

The classification of multi-agent systems in the field of Business Intelligence (BI) is carried out based on the following criteria:

1. By functional role:

- ***Data-collecting agents:*** Collect and store data through ETL processes.
- ***Analytical agents:*** Perform data processing and analytical operations.
- ***Visual Agents:*** Provide users with BI results.
- ***Management Agents:*** Provides coordination between agents.

2. By interactivity:

- ***Co-agents:*** makes decisions together.
- ***Hybrid agents:*** Combine partnership and competition.

3. Architecture:

- ***Centralized:*** All agents are controlled by a single center.
- ***Distributed:*** agents make independent decisions.
- ***Hierarchy:*** higher-level agents manage lower-level agents.

4. By method of interaction:

- ***Data exchange agents:***

Exchanges data with.

- ***Independent agents:*** reliance only on their own data.
- ***Training agents:*** adapt to new information.

Multi-agent systems allow improving business processes in real time through the application of adaptive algorithms. These systems increase the effectiveness of organizations in making strategic and operational decisions.

Architecture for multi-agent system and BI integration

The architecture of multi-agent system (MAS) and BI integration ensures effective management of agents' interaction and independent decision-making processes.

This architecture increases the efficiency of BI systems by optimizing the processes of data collection, analysis, and decision-making, and makes quick and accurate decisions for organizations[20].

**3.1.** Architectural model

This model is optimized for ERP systems of higher educational institutions by combining multi-agent system (MAS), business intelligence (BI), and cloud technologies. The main components of the model are:

- **Users** - ERP System Users
- **Multi-agent system**- Independent agents process user requests and send data to the BI system.
- **The Cloud Platform** - Provides real-time data exchange and storage by mediating between Agents and the BI system.
- **BI system** -provides data analysis, visualization, and decision-making.
- **ERP database** - a central database integrated with university information systems.

This architecture is based on processing user requests through agents, uploading data to the cloud platform, and obtaining results using the BI system.

**3.2.** Interaction between elements

**contact**

This model is based on the principles of service-oriented architecture. Components interact in the following sequence:

1. The user sends a request through the ERP system.
2. Agents receive the request and transfer the relevant data to the cloud.
3. The cloud platform acts as a communication channel between agents and the BI system, ensuring data transfer and storage.

4. The BI system processes, analyzes the received data, and visualizes the results.
5. The user receives analytical reports and results through the BI system.

**3.3.** Algorithms for the operation of agents in a multi-agent system

In multi-agent systems, each agent performs its own specific tasks. Below are the main types of agents in such systems and their functions:

1. **Data collection agent:** collecting data from various sources, such as ERP systems, and transferring it to other agents for further processing.
2. **Data cleaning agent:** improving data quality by analyzing the collected data, cleaning it, identifying and correcting errors.
3. **Data transfer agent:** transfer the cleaned data to cloud platforms or other storage systems, thereby ensuring the secure storage and efficient use of data.
4. **BI agent:** analyzing the collected and cleaned data, preparing analytical reports using BI systems, and providing them to users in a visual form.

Through collaborative work, these agents automate processes from data collection to analysis and presentation of results, which helps organizations increase efficiency in decision-making.

**3.4.** Interconnections between elements using service-oriented architecture

With the help of XY, the interaction between components becomes clear and effective. Each system or agent is independent, and the relationship between them

communication is carried out through services (API or web services). These services allow users to exchange data and work with them. The following benefits are provided through the TSA:

- **Independence and scalability**: Each component or system operates independently and can be updated as needed. This will reduce the impact of any changes on the system.
- **Reuse:** Services can be reused in multiple systems, which increases flexibility between systems and improves data exchange efficiency.
- **Adaptability:** Each system will have the ability to update, replace, or expand its services. This is especially useful when it is necessary to make changes to the ERP systems of educational institutions.

**3.5.** Multi-agent algorithms and distributed environment

Special algorithms are used for the effective operation of multi-agent systems in a distributed environment. These algorithms ensure the interaction of agents and coordinated decision-making. Here are some of the basic algorithms:

1. **Coordination and Synchronization Algorithms**: Agents use these algorithms to coordinate their activities. This effectively manages resource allocation and achieving common goals.
2. **Adaptive algorithms:** Agents use adaptive algorithms to adapt to new data and optimize their strategies in real-time. This will allow you to quickly respond to changes in educational institutions.
3. **Distributed decision-making algorithms:** Agents make final decisions by exchanging information with each other. This will help optimize the educational and administrative processes of the institution.

Based on these algorithms, the interaction between users, agents, the cloud platform, the BI system, and the database.s

Based on the general architecture reflecting the dependence, the entire system is developed (Fig. 2)

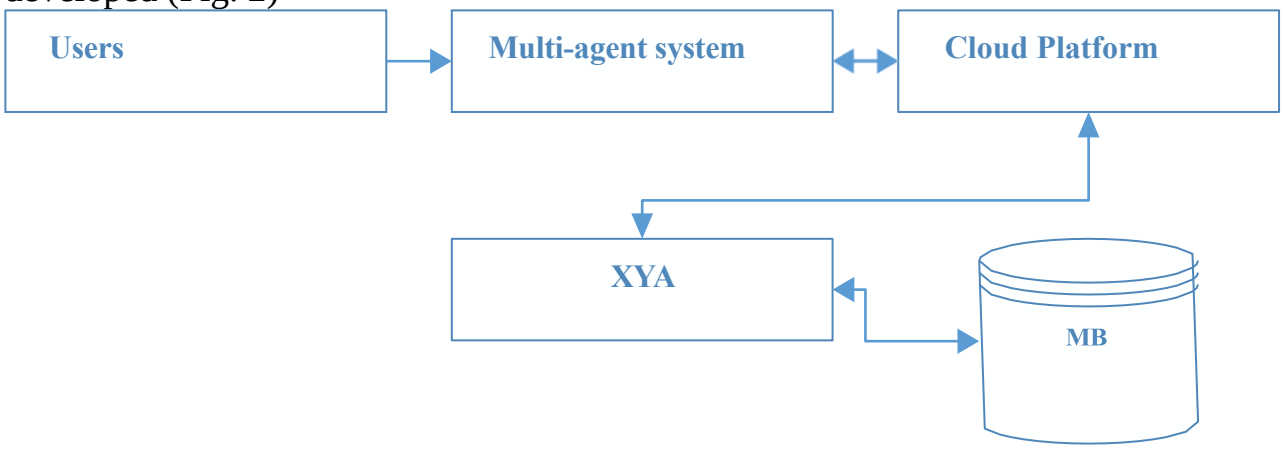


**Figure 2.**

- **Multi-agent systemsBI system:** analyzes data received from agents and uses it to make business decisions.
- **Cloud Platform:** provides cloud infrastructure for data storage and analysis.
- **Service-Oriented Architecture (SAR):** organizes data exchange and interaction between elements through services.
- This **architecture** ensures effective interaction between components, which improves the overall performance of the system. Reflects user requests, the process of working with agents, and the process of providing information through the BI system (Figure 3):

1. **Data** storage and transfer: The cloud platform stores the collected data and transfers it to the BI system for analysis.
2. **Data** analysis: The BI system analyzes data and makes decisions based on the results.
3. **3. Data analysis: The BI system analyzes the data and makes decisions based on the results.**
4. **Result Returns and Adaptation**: Agents retrieve analyzed data and decisions, adapt to the system, and optimize their operations.

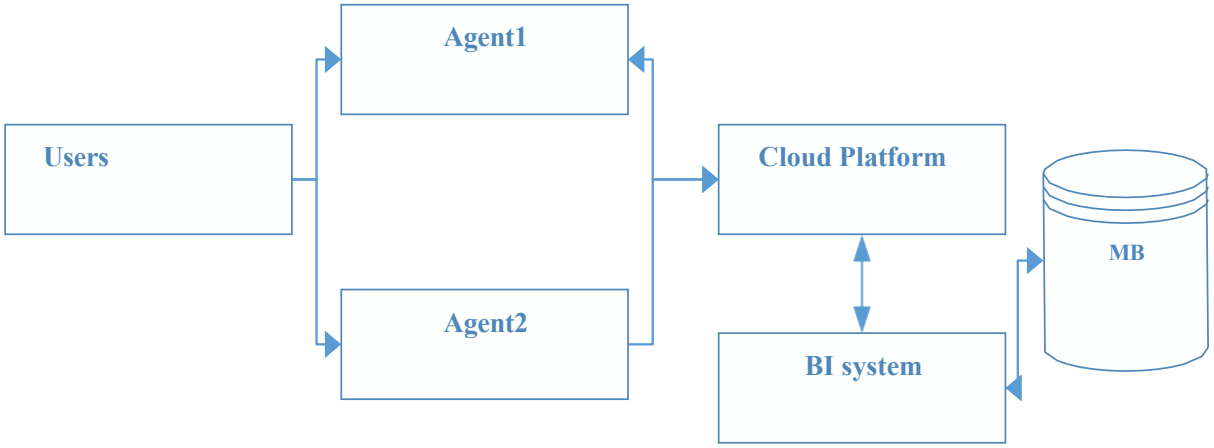


**Figure 3. Through this process, each component of the system performs its function precisely and effectively cooperates with each other to achieve a common goal.**

**Discussion and results**

**The Role of Multi-Agent Systems and Service-Oriented Architecture in Modern Business and Educational Institutions**

**Multi-agent systems and service-oriented architecture play a crucial role in enhancing flexibility within modern business and educational environments. In Business Intelligence (BI), multi-agent systems help optimize processes. For example, in supply chain management, agents can monitor inventory levels, forecast demand, and coordinate with suppliers, leading to increased efficiency and reduced costs.**

**The integration of multi-agent systems with BI technologies is becoming increasingly important. This combination enables organizations to analyze data more effectively and automate decision-making processes, driving better operational outcomes**.

Elements:

1. **Data storage:** Designed for collecting and storing data from various sources. This warehouse is the main source of information for BI systems.
2. **Multi-Agent System:** Provides collaboration between different agents. Each agent performs a specific task and provides the BI platform with the necessary information for analysis.
3. **BI Platform:** Used for data analysis, visualization, and report generation. The BI platform processes and provides users with data obtained from multi-agent systems.

Integration process:

- **Data collection:** Multi-agent systems collect data from various sources and store it in a database.
- **Data analysis:** BI platform will collect and analyze data from the database.

presented in the form of visualizations.

Service-oriented architecture in higher education management

SOA is an architectural approach that allows you to independently develop and

use various services. Higher educational institutions can integrate educational processes, student data, and management systems through SOA. This approach facilitates the implementation of new services and provides flexibility in updating existing systems. For example, by creating a portal that provides a single access point for students, access to various services (such as class schedules, grades, library resources) can be simplified.

Cloud technologies and SOA make the integration of multi-agent systems and BI more effective. Cloud technologies provide a flexible and scalable infrastructure for data storage and processing. SOA makes it easier to integrate different services with each other.

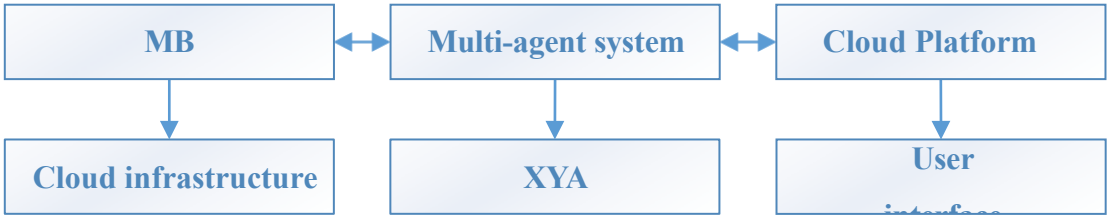


**Figure 4. Benefits**

**Adaptability:**

- **Flexibility:** Cloud infrastructure allows you to dynamically manage resources.
- **Extension:** SOA makes it easier to add new services to the system.
- **Efficiency:** Multi-agent systems and BI integration automate and accelerate the data analysis process.

This architecture allows organizations to effectively manage and analyze data, which improves decision-making processes.

Conclusion

The advantages of integrating Business Intelligence (BI) systems and multi-agent systems in higher educational institutions using cloud technologies and service-oriented architecture (SOA) are shown. BI systems play an important role in optimizing educational processes and effective information management in higher educational institutions. The application of multi-agent technologies in BI systems allows for fast and accurate information processing, while increasing the integration between systems. With the help of cloud technologies, efficient use of resources and a high level of integration between systems are ensured. The article emphasizes the advantages of SOA architecture and the important role of multi-agent systems in ensuring integration between systems. This, in turn, will lead to an increase in the efficiency of BI systems in higher educational institutions, further optimization of educational processes, and the creation of new opportunities.

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