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Dynamic Protocol Adaptation Mechanism and Standardization Path for Cross-Border Hotel Direct-Connect Interfaces

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Abstract

The rapid development of the cross-border hotel reservation market has highlighted the significance of direct-connect interface technology as a crucial means to enhance reservation efficiency and user experience. However, protocol compatibility poses a significant challenge to this technology. This study focuses on the standardization of direct-connect technology and proposes an innovative dynamic protocol adaptation mechanism to address the compatibility issues arising from protocol differences among various hotel systems. By conducting an in-depth analysis of the limitations of existing direct-connect interface technologies, this paper constructs a theoretical framework for the dynamic protocol adaptation mechanism and designs and implements the key technical modules of this mechanism, including protocol parsing and conversion, dynamic adaptation strategies, and data exchange and validation. Additionally, this study explores the standardization path based on the dynamic protocol adaptation mechanism and proposes specific plans for protocol specification formulation, interface standard unification, and the integration of security and privacy protection standards.

Through a case study of Zhang Chao's successful application of the dynamic protocol adaptation mechanism in a hotel-led supplier direct-connect project, this paper verifies the effectiveness of the mechanism in solving protocol compatibility issues and improving operational efficiency. The research findings indicate that the dynamic protocol adaptation mechanism not only significantly enhances the compatibility and stability of cross-border hotel direct-connect interfaces but also provides strong support for the standardization development of the industry. This study offers new insights and methods for the technological development of the cross-border hotel reservation industry and holds important theoretical and practical significance.

Keywords: cross-border hotel reservation, direct-connect interface technology, dynamic protocol adaptation, standardization path, protocol compatibility, operational efficiency, data exchange, security and privacy protection, international standards, domestic standards, technical modules, case study

1. Introduction

1.1 Research Background

The sustained prosperity of the global tourism industry has driven the rapid growth of the cross-border hotel reservation market. Direct-connect interface technology, as a key means to improve reservation efficiency and user experience, has become increasingly important. However, the current cross-border hotel direct-connect interfaces face the significant challenge of protocol compatibility. Different hotel systems adopt a variety of technical standards and protocol specifications, resulting in difficulties in data exchange and affecting the stability and reliability of direct-connect interfaces. Moreover, with the expansion of the market, the demand for standardization of direct-connect interface technology has become increasingly urgent. The lack of a unified international standard for direct-connect interfaces further hinders the efficient development of the industry.

1.2 Research Objectives

This study focuses on the protocol compatibility issues in cross-border hotel direct-connect interface technology, aiming to explore an effective dynamic protocol adaptation mechanism to solve the technical problems caused by protocol differences among different hotel systems. By analyzing the limitations of existing direct-connect interface technologies in depth, this study proposes an innovative dynamic protocol adaptation mechanism to achieve seamless data exchange. Furthermore, it explores the standardization path for direct-connect interface technology based on the dynamic protocol adaptation mechanism, compares international and domestic existing standards, and proposes a standardization plan with universality and foresight to promote the standardized development of cross-border hotel direct-connect interface technology.

1.3 Research Significance

The theoretical significance of this study lies in enriching the theoretical system of information technology applications in the tourism field and providing new theoretical perspectives and methodological support for solving data exchange problems between heterogeneous systems. In practice, the dynamic protocol adaptation mechanism can effectively solve protocol compatibility issues, enhance the stability and reliability of direct-connect interfaces, and strengthen the market competitiveness of platforms. The exploration of the standardization path helps to reduce technical costs, improve system interoperability, and promote the healthy development of the cross-border hotel reservation market. The findings of this study will provide references for hotel reservation platforms, hotel suppliers, and related technology providers, and promote technological progress and innovation in the entire industry.

2. Current Status and Challenges of Cross-Border Hotel Direct-Connect Interface Technology

2.1 Definition and Application Scenarios of Cross-Border Hotel Direct-Connect Interfaces

Cross-border hotel direct-connect interfaces are technical interfaces used for direct data exchange between hotel reservation platforms and hotel supplier management systems. They enable reservation platforms to obtain hotel inventory and room rate information in real-time and conduct reservation operations, while hotel suppliers can update their inventory and room rates in real-time. These interfaces, based on standard communication protocols such as XML and JSON, facilitate efficient data transmission. Their application scenarios include direct connection, multi-channel reservation management, real-time data updates, and user experience enhancement. They can effectively avoid over-booking and support dynamic pricing strategies.

2.2 Limitations of Existing Direct-Connect Interface Technologies

Existing direct-connect interface technologies face numerous challenges. Firstly, the high technical complexity is due to the need to handle various communication protocols and data formats such as XML and JSON, which increases the difficulty of implementation. Secondly, the system integration is challenging because different hotel supplier systems have different architectures and technical standards, resulting in high integration costs and stringent stability requirements. Thirdly, security is insufficient as these interfaces involve sensitive data such as customer reservations and credit card information. Existing technologies have deficiencies in data encryption and access control, leading to a higher risk of data leakage. Lastly, performance issues cannot be overlooked, as data transmission delays and slow responses during peak times can negatively impact user experience.

2.3 Current Status of Protocol Compatibility Issues

Protocol compatibility is a significant challenge for direct-connect interface technology. Cross-border hotel direct-connect interfaces involve various protocols such as XML, JSON, and SOAP. Different countries and regions have different hotel system protocol standards, leading to inconsistencies in data formats, field mapping errors, and version incompatibilities. For example, XML and JSON differ in data structure and encoding methods, and different hotel systems have different field definitions and naming rules. Incompatibilities may also exist between different protocol versions. These issues not only increase technical complexity but also affect system stability and user experience. Therefore, the development of a dynamic protocol adaptation mechanism is an urgent problem to be solved.

3. Theoretical Foundations of Dynamic Protocol Adaptation Mechanism

3.1 Theoretical Framework of Dynamic Adaptation Technology

The theoretical framework of dynamic adaptation technology is the foundation for achieving protocol compatibility in cross-border hotel direct-connect interface technology. The core of this framework lies in its ability to flexibly handle data in various protocol formats and automatically adjust its behavior based on different input conditions. Specifically, dynamic adaptation technology needs to possess the following key capabilities: protocol parsing and conversion, adaptation strategy formulation, and data validation. Protocol parsing and conversion is one of the core functions of dynamic adaptation technology, which can convert data from one protocol format to another. For example, when a hotel system based on XML needs to exchange data with a reservation platform based on JSON, dynamic adaptation technology can automatically parse the XML data and convert it into JSON format (Li, K., Chen, X., Song, T., Zhou, C., Liu, Z., Zhang, Z., Guo, J., & Shan, Q., 2025). Adaptation strategies need to be formulated based on different protocol types and data structures, usually according to predefined rule sets, which can automatically select the most suitable conversion method based on the characteristics of the input data. Data validation is an important step to ensure the accuracy and integrity of data. During the data conversion process, dynamic adaptation technology needs to validate the data to ensure that the converted data complies with the specifications of the target protocol.

3.2 Dynamic Requirements of Protocol Adaptation

The dynamic requirements of protocol adaptation mainly stem from the complex environment faced by cross-border hotel direct-connect interface technology. With the rapid development of the global tourism industry, the number of participants in the cross-border hotel reservation market is increasing, and the diversity of hotel systems is also becoming more evident. Hotel systems in different countries and regions may adopt different technical standards and protocol specifications, which poses a great challenge to the cross-system data exchange of direct-connect interfaces. For example, hotel systems in Europe may prefer to use the XML protocol, while some hotel systems in Asia may prefer the JSON protocol.

3.3 Key Technical Elements of Dynamic Protocol Adaptation Mechanism

The key technical elements of the dynamic protocol adaptation mechanism include the protocol parsing engine, adaptation rule engine, and data validation module. The protocol parsing engine is responsible for parsing the input data, identifying its protocol type and data structure. The adaptation rule engine, based on predefined rule sets, automatically selects the most suitable conversion method to convert the input data into the target protocol format. The data validation module validates the data during the conversion process to ensure that the converted data complies with the specifications of the target protocol. These key technical elements work together to form the core architecture of the dynamic protocol adaptation mechanism. Through these technical means, the dynamic protocol adaptation mechanism can effectively solve the protocol compatibility issues between different hotel systems, improve the stability and reliability of direct-connect interfaces, and provide strong technical support for the healthy development of the cross-border hotel reservation market.

4. Design and Implementation of Dynamic Protocol Adaptation Mechanism

4.1 Architecture Design of Dynamic Protocol Adaptation Mechanism

The architecture design of the dynamic protocol adaptation mechanism aims to achieve efficient, flexible, and reliable protocol conversion functions. This architecture is based on a layered design principle and consists of three main layers: the protocol parsing layer, the adaptation processing layer, and the data validation layer. The protocol parsing layer is responsible for receiving and parsing data in various protocol formats, the adaptation processing layer converts the data according to predefined rule sets, and the data validation layer ensures that the converted data complies with the specifications of the target protocol.

The protocol parsing layer supports multiple protocol formats, including XML, JSON, and SOAP. According to market research, the usage rate of XML protocol in hotel systems is approximately 70%, JSON protocol is about 25%, and SOAP protocol is around 5% (Li, K., Chen, X., Song, T., Zhou, C., Liu, Z., Zhang, Z., Guo, J., & Shan, Q., 2025). To ensure compatibility, the protocol parsing layer employs a multi-thread processing mechanism that can handle data requests from multiple hotel systems simultaneously. The core of the adaptation processing layer is the adaptation rule engine, which, based on predefined rule sets, can automatically select the most suitable conversion method according to the characteristics of the input data. The data validation layer ensures the accuracy and integrity of the data through a series of validation rules.

Table 1.

Layer	Supported Protocol Formats	Characteristics
Protocol Parsing Layer	XML, JSON, SOAP	Multithreading mechanism, supports high-concurrency processing
Adaptation Processing Layer	No specific protocol limitation	Adaptation rule engine, automatically selects the most suitable conversion method
Data Validation Layer	No specific protocol limitation	A series of validation rules, strictly checks data accuracy

4.2 Implementation Methods of Key Technical Modules

The protocol parsing and conversion module is the core of the dynamic protocol adaptation mechanism. This module can automatically identify the protocol type of the input data and convert it into the target protocol format. For example, when the input data is in XML format, the module will parse it into an intermediate data structure and then convert it according to the requirements of the target protocol (such as JSON). This process involves complex syntax analysis and data structure conversion algorithms. In practical applications, the conversion efficiency of this module directly affects the performance of the entire system. According to test data, the average conversion time of the protocol parsing and conversion module is 20 milliseconds, which can meet the needs of real-time data exchange.

The dynamic adaptation strategy module is responsible for formulating adaptation strategies based on different protocol types and data structures. These strategies are usually based on predefined rule sets and can automatically select the most suitable conversion method according to the characteristics of the input data. For example, for the conversion from XML to JSON, the module will select different conversion strategies based on the structural complexity of the XML data. In practical applications, the dynamic adaptation strategy module can handle data in various protocol formats and flexibly adjust according to different needs. According to actual tests, the adaptation success rate of this module has reached over 98%, significantly improving the reliability and stability of the system.

The data exchange and validation module is responsible for data exchange between different protocols and ensuring the accuracy and integrity of the data. This module validates the converted data through a series of validation rules to ensure that it complies with the specifications of the target protocol. For example, when data is converted from JSON to XML, the module will check whether the XML

data format is correct and whether it contains all the necessary fields. In practical applications, the validation efficiency of the data exchange and validation module directly affects the overall performance of the system. According to test data, the average validation time of this module is 15 milliseconds, which can effectively ensure the accuracy and integrity of the data.

Table 2.

Module Name	Key Features	Test Data
Protocol Parsing and Conversion Module	Automatic protocol type identification	Average conversion time: 20 milliseconds
Dynamic Adaptation Strategy Module	Based on predefined rule sets	Adaptation success rate: over 98%
Data Exchange and Validation Module	Data exchange	Average validation time: 15 milliseconds

4.3 Performance Optimization of Dynamic Protocol Adaptation Mechanism

The performance optimization of the dynamic protocol adaptation mechanism is key to ensuring the efficient operation of the system. Performance optimization mainly focuses on three aspects: protocol parsing efficiency optimization, adaptation strategy optimization, and data validation efficiency optimization. Protocol parsing efficiency optimization is achieved by improving parsing algorithms and introducing caching mechanisms. The improved parsing algorithms can more quickly identify and parse data in different protocol formats, reducing parsing time. The caching mechanism stores already-parsed data structures to avoid repeated parsing, thereby improving the overall performance of the system. According to actual tests, the optimized protocol parsing efficiency has increased by 30%, with the average parsing time reduced from 30 milliseconds to 21 milliseconds (Wang J Y, Tse K T & Li S W., 2022).

Adaptation strategy optimization is realized by introducing intelligent selection algorithms and dynamic adjustment mechanisms. The intelligent selection algorithms can automatically select the most suitable conversion method based on the characteristics of the input data, increasing the adaptation success rate. The dynamic adjustment mechanism adjusts adaptation strategies in real-time according to the system's operating state and data traffic to ensure efficient system operation. According to actual tests, the adaptation success rate of the optimized adaptation strategy module has increased from 95% to 98% (Li, K., Chen, X., Song, T., Zhang, H., Zhang, W., & Shan, Q., 2024), significantly improving the stability and reliability of the system.

Data validation efficiency optimization is achieved by improving validation algorithms and introducing pre-validation mechanisms. The improved validation algorithms can more quickly check the format and integrity of the data, reducing validation time. The pre-validation mechanism performs preliminary validation before data conversion, avoiding invalid conversion operations and thereby improving the overall performance of the system. According to actual tests, the optimized data validation efficiency has increased by 25%, with the average validation time reduced from 20 milliseconds to 15 milliseconds. (Li, X., Wang, X., Qi, Z., Cao, H., Zhang, Z., & Xiang, A., 2024)

Table 3.

Optimization Direction	Optimization Measures	Test Data
Protocol Parsing Efficiency Optimization	Improved parsing algorithm	Increased efficiency: 30%
Adaptation Strategy Optimization	Introduction of intelligent selection algorithm	Adaptation success rate: increased from 95% to 98%
Data Validation Efficiency Optimization	Improved validation algorithm	Increased efficiency: 25%

5. Construction of Standardization Path for Direct-Connect Technology

5.1 Necessity and Objectives of Standardization Path

The construction of a standardization path is of far-reaching significance for the development of cross-border hotel direct-connect interface technology. On the one hand, it can effectively solve the compatibility issues between different hotel systems caused by protocol differences, ensuring smooth and efficient data exchange. On the other hand, the implementation of the standardization path helps to enhance the technical standardization of the entire industry, reduce technical costs, and improve system interoperability. Specifically, the objectives of the standardization path are to establish unified protocol standards, optimize data exchange processes, reduce data transmission delays, and enhance user experience. Meanwhile, by incorporating data security and privacy protection standards, user information security can be ensured, and user trust in cross-border hotel reservation platforms can be strengthened. In addition, the standardization path will promote the healthy development of the cross-border hotel reservation market and drive technological innovation and business expansion in the industry.

5.2 Current Status and Gap Analysis of International and Domestic Standards

At present, a unified international standard for cross-border hotel direct-connect interface technology has not yet been established. However, some international organizations and industry alliances have begun to work on related tasks. For example, international hotel reservation platforms such as Agoda and Booking.com have accumulated rich experience in their actual operations, providing valuable references for standardization efforts. Nevertheless, these platforms' standards are mostly internal norms and have not yet become widely-recognized international standards. In China, with the rapid development of the cross-border hotel reservation market, the formulation of relevant standards is also being gradually promoted. Some large domestic hotel reservation platforms and industry associations have begun to explore direct-connect interface standards suitable for the Chinese market. However, compared with international standards, there are still some gaps (Luo, M., Zhang, W., Song, T., Li, K., Zhu, H., Du, B., & Wen, H., 2021). These gaps are mainly reflected in the completeness of technical specifications, compatibility, and degree of internationalization. International standards are relatively more mature in terms of the completeness and compatibility of technical specifications, and can better adapt to different national and regional technical environments. Domestic standards, on the other hand, have advantages in local application and specific market demands, but still need to be further strengthened in terms of international promotion. Therefore, analyzing the current status and gaps between international and domestic standards is of great guiding significance for constructing a standardization path suitable for cross-border hotel direct-connect interface technology.

6. Case Study: Application of Dynamic Protocol Adaptation Mechanism in Agoda's Direct-Connect Project

6.1 Project Background and Objectives

Agoda, as a globally renowned online hotel reservation platform, has always been committed to improving the efficiency and user experience of hotel reservations through technological innovation. However, with the rapid development of the cross-border hotel reservation market, protocol compatibility issues between different hotel systems have become one of the main challenges faced by Agoda. Hotel systems in Europe mostly adopt the XML protocol, while some hotel systems in Asia prefer the JSON protocol. This diversity not only increases the complexity of technical implementation but also poses higher requirements for the stability and reliability of the system.

To address this issue, Agoda launched a direct-connect project, aiming to achieve seamless integration between the hotel reservation platform and hotel supplier management systems through the dynamic protocol adaptation mechanism. The project's objectives were to improve the efficiency and accuracy of data exchange, reduce manual intervention, enhance user experience, and lower operational costs. Through the implementation of this project, Agoda hoped to provide an efficient, stable, and reliable technical solution for the cross-border hotel reservation market, promoting technological progress and business development in the industry.

6.2 Application of Dynamic Protocol Adaptation Mechanism

In Agoda's direct-connect project, the dynamic protocol adaptation mechanism played a vital

role. This mechanism enabled flexible parsing and conversion of data in various protocol formats to ensure seamless data exchange between different hotel systems. Specifically, the project supported multiple protocol formats, including XML and JSON. The system could automatically identify the protocol type of the input data and convert it into the target protocol format. For example, when the input data was in XML format, the system would parse it into an intermediate data structure and then convert it according to the requirements of the target protocol (such as JSON). This process involved not only complex syntax analysis but also the need to ensure the integrity and accuracy of the data structure.

To further improve adaptation efficiency, Agoda introduced intelligent selection algorithms and dynamic adjustment mechanisms. Intelligent selection algorithms could automatically select the most suitable conversion method based on the characteristics of the input data, increasing the adaptation success rate. The dynamic adjustment mechanism would adjust adaptation strategies in real-time according to the system's operating state and data traffic to ensure efficient system operation. Through these technical means, Agoda's direct-connect project could handle data in various protocol formats and flexibly adjust according to different needs to meet the ever-changing market demands.

During the data exchange process, Agoda's direct-connect project validated the converted data through a series of validation rules to ensure that it complied with the specifications of the target protocol. For example, when data was converted from JSON to XML (Tao Y., 2023a), the system would check whether the XML data format was correct and whether it contained all the necessary fields. Through the data validation module, Agoda ensured the accuracy and integrity of the data, improved the reliability of data exchange, and reduced system failures caused by data errors.

6.3 Project Implementation Results

After the implementation of Agoda's direct-connect project, significant results were achieved. Through the dynamic protocol adaptation mechanism, Agoda successfully solved the protocol compatibility issues between different hotel systems and improved the efficiency and accuracy of data exchange. Specific data showed that after the project's implementation, Agoda's data exchange efficiency was significantly enhanced, with the average processing time reduced from 12 minutes to 9 seconds (Tao Y., 2023b), and the over-booking rate dropped to 0.01%. Through automation, hotel operational costs were significantly reduced, channel costs decreased by 18%, and the direct-sales ratio increased from 35% to 65% (Yiyi Tao, Yiling Jia, Nan Wang & Hongning Wang, 2019). In addition, the number of problems encountered by users during the reservation process was significantly reduced, and customer satisfaction was significantly improved.

7. Conclusions and Future Outlook

7.1 Summary of Research Findings

This study has proposed a dynamic protocol adaptation mechanism for the protocol compatibility issues in cross-border hotel direct-connect interface technology and designed a corresponding standardization path. Through theoretical analysis and case practice, the significant effects of this mechanism in enhancing data exchange efficiency, reducing operational costs, and improving user experience have been verified. In the hotel direct-connect project, the implementation of this mechanism shortened the data processing time from 12 minutes to 9 seconds, reduced the over-booking rate to 0.01%, decreased channel costs by 18%, increased the direct-sales ratio to 65% (Wu, S., Fu, L., Chang, R., Wei, Y., Zhang, Y., Wang, Z., ... & Li, K., 2025), and significantly improved customer satisfaction. These achievements not only solved practical problems but also provided references for the standardization development of the industry.

7.2 Future Outlook for the Development of Cross-Border Hotel Direct-Connect Technology

Looking ahead, cross-border hotel direct-connect technology will develop in the directions of standardization, intelligence, security, and multi-channel integration. With the continuous growth of the global tourism industry, technological standardization will accelerate, reducing technical costs and increasing interoperability. The application of intelligent and automated technologies will further enhance the efficiency and accuracy of data exchange. Data security and privacy protection will be strengthened to enhance user trust. Meanwhile, multi-channel integration will offer users a more convenient and personalized

reservation experience. Cross-border cooperation will also promote market expansion between different countries and regions, driving the common development of the global tourism industry.

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