RESEARCHES ON SOFTWARE ARCHITECTURE IN EMERGENCY RESPONSE NETWORK SPATIAL INFORMATION SYSTEM

Jian Tan*, Xiangtao Fan

Center for Earth Observation and Digital Earth, Chinese Academy of Sciences
No.612, B Block, National Observatory, Datun Road, Chaoyang District, Beijing
100101,china
Corresponding author: Jian Tan
Tel: +86+010+64807807
Fax: +86+010+64807805
Email:Tanjian1998@gmail.com

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ABSTRACT:

Software Architecture design is to be a key step in the process of software development. For large and complex emergency network geographical information system in practice, it is ridiculous to achieve the goal of emergency management based on unsuitable software architecture. At present, the network geographical information system software architecture can be divided into four layers: display layer (client), application server, spatial object server, database server. Most GIS products of major R & D manufacturers and research institutions comply with the rule. These network geographical information systems, according to their software architecture, are centralized software; the main features are data centralized and functionality centralized. The benefits of centralized software are easy development and deployment, spatial data and the function modules can be pooled in a single server, the higher the centralization, the simpler the deployment. It does not need to consider the direct data transfer in service layers and possible abnormal network transmission. Disadvantages of centralized deployment are, for the calculating job located on a single server, compute-intensive and instable Service. Because of the solo deployment, these systems cannot be restored or backup in a timely manner, from any harm to the system own safety and emergency communications, the system is fragile. In contrast to centralized network GIS, recently proposed GRID GIS, has distributing function modules and data source. Grid GIS is in fact a Grid Technology reflection in the form of Spatial Information system. GRID GIS store all the location related information in digital form and share them together as a wealth of resources via network. For its inner characteristic of distribution in functionality and data source, GRID GIS greatly improve reliability in the emergency management. While for the same reason GRID GIS is more complex in development and deployment, as well as high maintenance costs and lower system efficiency. Through analysis and synthesis of demands of both Network GIS and emergency information system in software architecture, this paper studies the suitable software architecture for ERNSIS (emergency response network spatial information system). By comparing the software architectures in centralized network GIS 、Grid GIS and the P2P software, a hybrid software architecture was proposed, which including three points: After deeply analysis of the network node in ERNSIS － namely execution node, this paper make definition of its functionality and covered data，put forward its spatial data preservation strategy and safety evaluation algorithm. For the first time this paper proposed the self wake-up message server queue, it will function with the message server for communication among the execution nodes, building a routing table with automatic updates, has automatic wake-up characteristic in servers queue, with less network resources occupancy, and higher reliability . Raise a push-pull mechanism to send a mixed message. It combines the two commonly used messaging mechanism, using push mode to ensure that the timeliness of communication and using pull mode in order to check communication validity. In conclusion, results of the three research parts are adapted to ERNSIS requirements of software architecture, that is, under the guarantee of the system response time, improved the system reliability and stability.

1 INTRODUCTION

Network Emergency Spatial information system is a network GIS, also a kind of emergency information systems. Therefore, the requirements of its software architecture can be analyzed in the two sides.

Network GIS Performance Evaluation includes the following aspects: user interface response speed, multi-user concurrent operation efficiency, the system's ability in large data processing, databases' operations efficiency, system portability (compatibility), scalability, security and the difficulty of system development and deployment and so on. Among them, the user response time is a first and foremost concern of network GIS users, because of large data volume in network traffic and handling greatly limits the response rate in network GIS.

the core issue of the software architecture proposed to increase the response speed, has two aspects: the improvement of computing speed and data transmission reduction. Improvement in both areas can improve the response speed of a particular system.

In the other side of Network Emergency Spatial information system, generally, emergency information systems should have the following features:

* Corresponding author. tanjian1998@gmail.com

Information Collection
Interface Performance
Information management

Analysis and decision-making aids:

Because of regional differences in natural conditions, economic and social development, the government management system, information resource base, emergency information systems should also be different in the functional performance and spatial layout.

For building emergency Platform there should be a combination of prevention and response and a combination of normal and abnormal; from the local, practical needs and the reality base; we should pay attention to the core emergency response techniques and equipment, especially their practicability, reliability, advanced level, standardization and scalability; but also should pay more attention to the contingency of the platform's own security, in the occurrence of disasters, the survive of the system itself, directly determine the viability of the effectiveness of the system.

Therefore, the appropriate software architecture of emergency response information system through various regions, departments should constitute a radical platform of pan-center grid. The system should be able to function independently, also can be accessed by all levels of government and units with integrated and interactive information, to inform their superiors, or issue an early warning to the public.

In according to requirements of these two sides, software architecture of the network emergency spatial information system, should meet the needs of system response speed and reliability, flexibility, construction and security needs in emergency information systems. Then this paper presents solutions in two sides of software architecture.

2 RESEARCH OF SOFTWARE ARCHITECTURE OF THE NETWORK EMERGENCY SPATIAL INFORMATION SYSTEM

2.1 Study of software architecture for data storage

From the conventional software structural analysis point, requires of the network emergency spatial information system are contradictions. Centralized software structure of spatial information system is simple in maintenance and construction, but limited in data storage and computing ability. While grid spatial information system is better in system scalability and storage space and unlimited in computing power, and of more safety like a part of nodes paralyzed do not break down the whole system, but it is more complex in design and development, processes cumbersome, larger amounts of data needed to transfer, not suitable for real-time response system.
In view of this, this paper, combined with part of P2P software technologies, presents a hybrid centralized grid network emergency spatial information system software architecture. Study of this structure is divided into three parts:
execution node

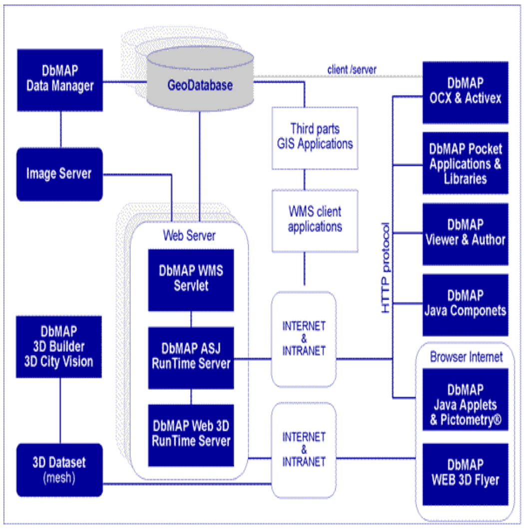

Figure 1. Centralized network emergency information system software architecture [1]

as shown in the figure a common software architecture to develop the network emergency information system is a centralized software architecture, security and reliability of such a system itself is very low, because the business processes and spatial data are on the remote server, once network or server is in problem, the entire emergency response information system does not work.

Therefore, for each connected computer(network nodes) in the network emergency response systems, the more independent in its data and computing requires, the more safety and reliable in its response to emergency. the most viable and efficient software deployment means is that each machine have a complete and data processing module. In the worst-case, that is, when the network is not available any more, each seperated node is still supporting the full functionality of emergency management.

So before the discussion in other parts of the software architecture, this paper determines in the network emergency spatial information system, each node has a complete processing capabilities and data sources, since each node in the centralized network system and grid system will possess of some parts of the data storage and cache functions, as to show the difference. The implementation of such a independent node called executive node.

Spatial data is the main part of data storage in executive node. For the emergency systems responsible for a large region, the relevant spatial data is of large volume. And the implementation of executive node，which is the most secure mode, need each node in the system processing identical functions and spatial data. To achieve this mode, it is great in investment and difficulty of the system construction. For example, in deployment of spatial data in 33 provinces nationwide, even the volume of vector data in scale 1:10 million reaches 1.46G, if the image map also preserved, it will reach TB level, such a large data storage needs of high-priced disk arrays, which is difficult to achieve. In the other side, unexpected events occur, after all, in a very low probability, that makes high-performance equipment, idle for a long-term.
Coping strategies as simple as that, each executive node only possess spatial data in its local region, the local region here refers to the deployed area of the executive node or the region

in responsibility specified in the emergency management system. This is undoubtedly the worst way in availability of security for two points:

On cross-regional emergencies, there was no spatial data of adjacent region for analysis.

If a regional executive node is destroyed, it will not be able to carry out emergency management of this area.

For the first fault, this paper presents the concept of the responsible buffer zone; buffer zone refers to the area out of the responsibility of the executive node. Specification of the scope uses the buffer method in the following two ways.

Along the border to expand a certain radius;

Figure 2. First kind of division of responsibility buffer zone

Along the specific direction expands a certain region;

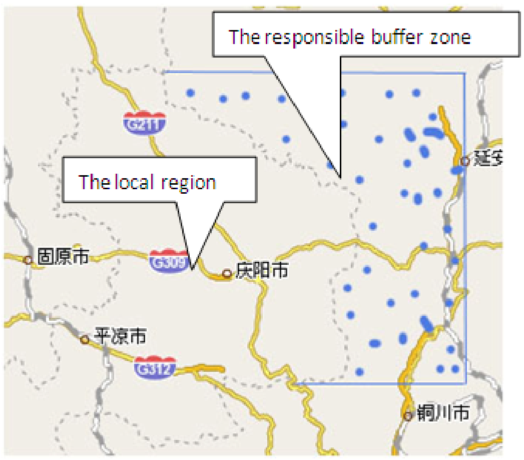

Figure 3.Second kind of division of responsibility buffer zone

Then a executive node will be able to response of a number of cross-border emergency. Further research can be conducted in accordance with the characteristics of different incidents in order to determine a area of certain occurrence probability as the common responsibility buffer region.

For the second fault, the responsibility region can be divided in grid, such as the blue grid divided the responsibility region into eight parts in the figure below.

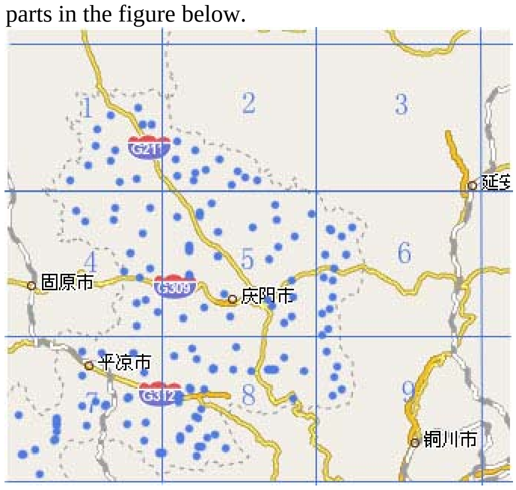

Figure 4. Implementation of the Spatial Data backup node segmentation method

Partition of spatial data is only the first step, in order to ensure the safety and continued work ability of the system in the time of the regional disaster, in accordance with the principle of risk diversification, these division of the data placed in the spatial farthest server. In this paper, the following formula is presented to measure the spatial data security.

$$S_i = \frac{\sum_{j=0}^{n} D_{ij}}{n \times D_d}$$

Si is the data security level of responsibility region of the no. I executive node , n is the total count of data blocks of the responsibility region, Dij is the straight line distance between the soratage locations of the spatial data block I and data block j , Dd is the diagonal distance of the full spatial field covered by all executive nodes in network emergency spatial information system.

The ranges of Si value from 0 to 1, bigger the value, larger the average distance between the locations of back up regional spatial data and its origin. That means when the disaster occurs, these spatial data will be preserved in a higher level of possibility and security.

Now, we can give the full definition of the executive node, The node implements a complete emergency management functions and necessary spatial data, and connects to each other through network, the node contains the spatial data can be divided into three categories: area of responsibility, the responsibility buffer zone and other responsibility areas’ backup, as the following figure:

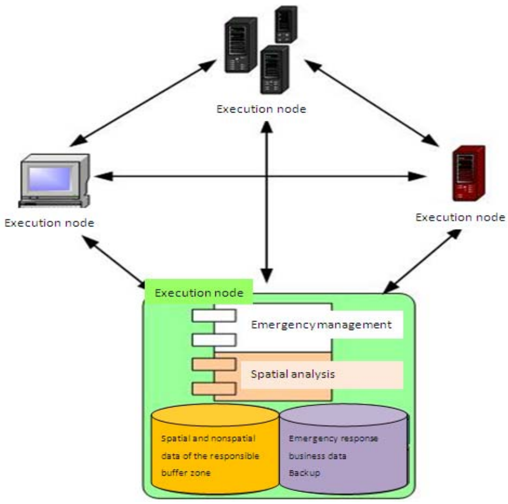

Figure 5. The contents of the executive node

3 STUDY OF SOFTWARE ARCHITECTURE FOR DATA UPDATE

The establishment of the executive node, clear that each node of the network emergency information system has a complete processing function and a certain degree of spatial data coverage. But in the case of executive node damaged in disaster or in the necessary data or functions change, it will require the transfer and synchronization of data to maintain consistency of emergency management functions.

In the centralized software architecture, the data, whether spatial or not, is concentrated on the control node (server).Update directly work on the server, and is non-transparent to the other nodes. As a result, this mode is of highly efficiency, but of poorer security, server breakdown will lead to the whole network system paralyzed.

On the other hand, The process of synchronize between two peers in the grid GIS can be classified into 4 phases arranged in time.

The stability of the synchronizing could be challenged in every phase. The most uncontrollable part is the period of data traveling on the net. The status of the network can be hardly predicted, simulated and tested in developing in laboratory. In practice, frequently occurs the routing error, the connection breaking off or the data package lost more or less. It could be no harm in the daily grind because the system has enough time to retry, but emergency will not waiting for the synchronizing circulation, moreover, the grid nodes could out of work partly during incident.

To conquer the shortcomings of both single center mode and the multiple servers mode, in this paper, two solutions in software architecture have been addressed to improve the efficiency and stability of the geographical data synchronizing process.

3.1 Auto wake-up server queue

A combined message server mode is adopted. In this mode, each node keeps a routing table of all nodes ordered by arithmetic average of the network bandwidth between one node and the rest. Initially the first node is the only message intermediate repeater. The update procedure is listed below：
Once a node updates its data, it sends an empty message to the message server,

And then the server must send a receipt back to confirm reliability of the link.

The node waiting for a fixed time

If the receipt arrived in time, the node sends data wrapped messages, and the message server transfers the messages to the other node in the GRID.

But if the receipt does not arrive, the node sends a new empty message and waiting for a longer period which increase in geometric progression. The loop times can be assigned according to the system demand.

If the link still failed after assigned loops, the node sends a woke-up message to the second node in the routing table, and also waiting for the receipt.

When the second node woke up, it sends a message to the other nodes to make them move the new message server node to the top of the routing table.

In this way, the message server always has its alternative in preparation for breakdowns, and the whole GRID always has single working message server. Then the message server queue can be constructed and effectively woks. This mode has the advantages of the other two modes that the message delivery is more reliable and less time-costing.

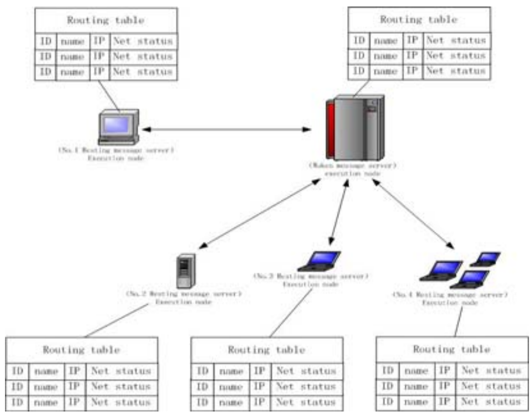

Figure 6. Message server queue mode

3.2 Combination of message deliver mode

Both push and pull modes are adopted to keep update in time. Push mode means the node which has altered its data is responsible for the delivery of the changed part, like “push” the data to the message server.

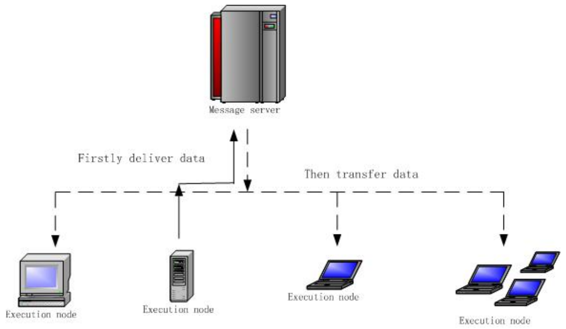

Figure 7. Push mode

While pull mode means the demand node or the message server is responsible to check the data status in other nodes and "pull" the new data from the source. In push mode, if the network between the sponsor node and the message server breakdown, the message could be missing or the sponsor could be halted, when the network resumed, the update action could not be invoked again. And in pull mode, the message server needs to check the data and collect update parts in the whole grid, it is a time-costing operation that could not be executed frequently.

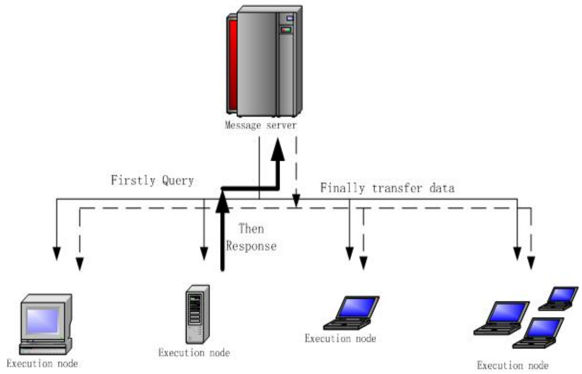

Figure 8. Pull mode

So the combination mode is adopted. In combination mode, not only each node has its own update trigger to invoke the delivery of the new data, but also the message server also can recurrently check the data status after an assigned interval according to the network situation and the computation ability, for example, normally the execution node sends message at once whenever it has just altered data, and the message server poll all peers in the midnight when it is idle in network to check against incidental lost of spatial data or recover the halt message. Then the duly update can be guaranteed.

4 CONCLUSION

Execution node and the responsible buffer zone make a stable encapsulation of emergency response functions and data. Auto woke up server queue has the advantages that the message delivery is more reliable and less time-costing. Combination of message deliver mode guaranteed the duly update.

In conclusion, results of the three research parts are adapted to ERNSIS requirements of software architecture, that is, under the guarantee of the system response time, improved the system reliability and stability.

REFERENCES

Centralized network emergency information system software architecture，Http://www.abacogroup.com/eng/dbm/index.htm. [web].

Louis Burry. OpenGIS Implementation Specification :Grid Coverage [EB/ OL] . http : / / www. open2geospatial. org/ specs/ ? page = specs/ Grid CoveragesGC Implementation Specification [1] . pdf ,2001 , 1271.

Jeff de La Beaujardiere. Web Map Service (WMS) Implementation Specification [EB/ OL] . https : / / por2tal . opengeospatial. org/ files/ index. php ? artifactid = 7176/ 042024 ISO DIS 19128 2 Web MapService. pdf , 2003 , 14235.

Panagiotis A. Vretanos. Web Feature Service (WFS)Implementation Specification [EB/ OL] . https : / /portal. opengeospatial. org/ files/ index. php ? artifactid = 7176/ Web Feature Service WFS 022058.pdf , 2003 , 25269.

John Evans. Web Coverage Service (WCS) Implementation Specification [EB/ OL] . http : / / www. open2geospatial. org/ docs/ 032065r6. 1pdf , 2003 , 38259.

The Globus Project, www.globus.org

Chervenak, I. Foster, C. Kesselman, C. Salisbury, S.Tuecke, "The Data Grid: Towards an Architecture for the Distributed Management and Analysis of Large Scientific Datasets," to be published in the Journal of Network and Computer Applications.

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