Research on Comprehensive Evaluation Index System of Spatial Information Network Based on High-orbit Satellites

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Abstract. In this paper, for acquiring the initial set of indicators, the space-ground network and communication systems are researched deeply in the context of spatial information network. On the basis of the fundamental principle of index construction, by extending the classical comprehensive effectiveness evaluation criterion, the five criteria (coverage, timeliness, capability, accuracy and dependability) for spatial network test evaluation are proposed. After the mapping of the index and the criterion is completed, the index system is further decomposed and optimized. Finally, then a comprehensive evaluation index system of spatial information network based on high-orbit satellite system is proposed. The system has a certain significance and evaluation of the application value.

Introduction

The spatial information network is a network system which takes the space platform (such as synchronous satellite or medium or low orbit spacecraft, near spacecraft, unmanned aerial vehicle, manned aircraft, etc) as the carrier, real-time acquisition, transmission and processing of spatial information. There are four major characteristics: 1 single satellite multi-purpose, taking into account the other; 2 complex structure, technical difficulty; 3 network multi-source heterogeneous, node dynamic changes; 4 coverage, application prospects [1]. Spatial information network is a major frontier and strategic high ground of international scientific development. With the development of relevant basic theory and method research, spatial information network research field such as space network model, network information theory, spatial information cognition, space Network security and other theoretical, method breakthrough, made a number of international advanced level of research results.

High-orbit satellites usually run on geostationary geostationary tracks, which can cover a large extent by covering the Earth by minimizing the negative effects of the curvature of the Earth's curvature and the linear propagation characteristics of the radio waves, Rail spacecraft and non-spacecraft users, but also direct view of the ground station, which can provide users with efficient, real-time data relay, continuous tracking and track monitoring and other services. As the high-orbit satellite system space users to provide information relay transmission support, the high-orbit satellite has become the backbone of the spatial information network.

In the process of spatial information network development and construction, it is urgent to evaluate the overall performance and development level of the network. At the same time, many new technologies that will be applied to the spatial information network need to be verified. Therefore, based on the high-orbit satellite system, this paper puts forward a comprehensive evaluation index system for the needs of system construction and technology assessment.
The Research Status of Spatial Information Network Related Indicators System

With the rapid development of terrestrial IP network, the Internet Engineering Task Force (IETF) has given a series of authoritative documents (as shown in the following table) of network performance indicators, which laid the foundation of the network evaluation index system [2].

Table 1. The definition documents of networking performance metric.

<table>
<thead>
<tr>
<th>Document number</th>
<th>Summary of the content</th>
<th>Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFC2330</td>
<td>proposes an IP network performance measurement IPPM architecture</td>
<td>RFC7312</td>
</tr>
<tr>
<td>RFC2678</td>
<td>gives metrics for measuring network connectivity</td>
<td></td>
</tr>
<tr>
<td>RFC2679</td>
<td>defines the delay metric on a one-way path</td>
<td>RFC7679</td>
</tr>
<tr>
<td>RFC2680</td>
<td>gives the metrics and indicators related to packet loss on unidirectional links</td>
<td>RFC7680</td>
</tr>
<tr>
<td>RFC2681</td>
<td>defines the classic network metrics for round-trip delay</td>
<td></td>
</tr>
<tr>
<td>RFC3357</td>
<td>analyzes the different packet loss modes under the same packet loss rate, and obtains two new indexes of “lost distance” and “loss period”, and evaluates the influence of different packet loss rate on network performance</td>
<td></td>
</tr>
<tr>
<td>RFC3393</td>
<td>defines the delay jitter indicator for IP packets</td>
<td></td>
</tr>
<tr>
<td>RFC4148</td>
<td>gives the specification of registered IP network performance metrics</td>
<td>RFC6248</td>
</tr>
</tbody>
</table>

Chinese Academy of Sciences, Yang Yahui [3] and others from the network evaluation of the different angles of the IP network performance indicators were analyzed, put forward a system to reflect the IP network performance index system, and attribute index set, level protocol set, test category The division of the set gives a formal description of the IP network performance index system. Based on the analytic hierarchy process (AHP), and based on the principle of consistency, comprehensiveness, scientificity, validity, independence and testability, zhangzhao[4]’s paper discusses the communication network and coverage of satellite communication network. Thus, the satellite communication network performance index system. Jiuquan Satellite Launch Center Xu Zhiming [5] and others in the use of equipment system performance evaluation method features, from the perspective of the application of spatial information network system to assess the comprehensive effectiveness of information security. Based on the principle of hierarchical, measurable, systematic, extensible, independent, objectivity, sensitivity and consistency, the hierarchical model of the target layer, core layer and refinement layer is constructed according to the analytic hierarchy process. A credible and practical spatial information network against the effectiveness of the index system. It can be seen that there is no direct research on the index system of spatial information network based on high-orbit satellites at present.

The Construction of Comprehensive Evaluation Indicators System

Acquisition of Initial Index Set

The spatial information network not only has the general characteristics of the information network system, but also has the typical characteristics of the space-based communication system. Thus, the acquisition of the initial indicator is mainly derived from the following set of indicators [6-7]:

1) Classic mobile communication system and IP network index set
   {Spectrum efficiency, connection interruption rate, throughput rate, bandwidth, packet loss rate, round trip delay, channel capacity, bandwidth utilization, delay jitter, switching delay, ... }

2) space-based remote sensing, communication, navigation system index set
   {Error rate, revisit cycle, panning capacity, image acquisition quality, service duration, coverage characteristics, communication quality, communication capacity, ... }  

3) High-orbit satellite system performance and resource management efficiency index set
4) Core indicators of key technology
   Integrated heterogeneous interconnection test, space network routing test, high speed transmission test, space interference test, star earth co-processing test.
   {Normalized throughput, routing efficiency, coding efficiency, anti-jamming capability index}
5) Spatial information network related field index set (NASA: cyber space defense index set)
   Around the cost (cost), benefits (benefits), risk (risk) three key evaluation factors, the use of the following indicators to assess cyber defense process in the defense effect.
   {Cost, CPU share, memory footprint, bandwidth, convenience, confidentiality, completeness, risk}

Establishment of Criterion Layer

The spatial information network system has the characteristics of large structure model, complex relationship level and many new technologies. The evaluation index system of constructing the corresponding integrated demonstration platform should follow the following basic principles:

Completeness: refers to the evaluation index system can cover all the important aspects of comprehensive evaluation requirements. According to the basic characteristics of each aspect of the evaluation, the different categories of indicators are summarized, so that the comprehensive evaluation of the evaluation objects can be realized as a whole.

Independence: independence refers to the relationship between indicators are irrelevant, the indicators should be reduced the cross, to prevent mutual containment, to have a relatively independent, each indicator should be relatively independent of the assessment of an aspect of the object.

Testability: Evaluation Indicators Both quantitative and qualitative indicators should be measurable. Quantitative indicators must be measured by means of technology and can be expressed in quantitative mathematical formulas. Qualitative indicators must be measurable and should be comparable in the same indicators.

Under the premise of satisfying the basic construction principle, the basic needs of the implementation of high-orbit satellite system tasks as the core: real-time transmission and rapid response needs, high efficiency, large capacity needs, reliable and stable demand, airspace and frequency domain coverage needs., Taking into account the precise measurement needs required for the demonstration, put forward five criteria for spatial information network index system based on high orbit satellites: coverage, timeliness, capability, accuracy and dependability.

Build and Optimize the Comprehensive Evaluation of the Index System

After clarifying the criteria layer of the evaluation index system, the refinement of the indicator layer under the criteria is not just a simple indicator accumulation process. Redundant coupling and non-quantitative assessment of indicators need to be addressed.

1) Elimination of redundancy: the concept of the same or similar indicators, such as the router packet forwarding rate and the router's throughput and port throughput concept similar to the same time you can delete one of the use.

2) Comprehensive quantification decomposition: for some difficult to quantify the qualitative indicators of assessment, to take a comprehensive quantitative decomposition method, that is, a single qualitative index is decomposed into a number of quantifiable measurement of quantitative indicators, such as switching protocol performance indicators can be characterized as signaling overhead, packet loss rate, switching throughput, switching delay and other indicators [8].

3) Unification granulation: indicators of granularity of the regular, that is, to ensure that the same indicator level indicators of the concept of coverage is considerable. So that the index from top to bottom to maintain the particle size from coarse to fine changes.
Finally, comprehensive evaluation index system is proposed, which covers five major categories and possesses more than 30 core indicators (include MOEI - measure of effectiveness indicator, and MOPI - measure of performance indicator)[9].

**Comprehensive index system**

- **Timeliness**
  - round-trip-delay
  - delay jitter
  - system response time
  - Routing update cycle
  - spectrum effectiveness
  - network bandwidth
  - Packet Loss
  - routing efficiency

- **Capability**
  - symbol error rate
  - Num of available channels
  - channel utilization
  - Total network throughput
  - Num of Service satellites
  - satellite coverage
  - service capability (per GEO)
  - Device connectivity
  - anti-disturbance capability
  - reliability for the operators
  - System recovery capability

- **Coverage**
  - Compatible business type

- **Dependability**
  - measure data precision
  - data credibility
  - Scenario fitting

- **Accuracy**
  - num of Service satellites
  - satellite coverage
  - service capability (per GEO)
  - Device connectivity
  - anti-disturbance capability
  - reliability for the operators
  - System recovery capability

**Example of Evaluation: Application of Mobile IP Based on GEO Satellite**

*Step 1:* to compare the two schemes in paper[10], we select a valid indicator set (packet loss rate, the average delay, delay jitter), and do normalization (include consistency and non-dimensional).

Consistency: As the three indicators are very small, the smaller the better, so you can skip this step.

Non-dimensional: choosing the extreme value processing method.

$$x_{ij} = \frac{x_{ij} - m_{j}}{M_{j} - m_{j}} (i = 1, 2, ..., n; j = 1, 2, ..., m), M_{j} = \max_{i} \{x_{ij}\}, m_{j} = \min_{i} \{x_{ij}\}. \quad (1)$$

<table>
<thead>
<tr>
<th></th>
<th>packet loss rate (0-0.05)</th>
<th>average delay (0.26-0.58)</th>
<th>delay jitter (0-0.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scheme 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>actual value</td>
<td>0.02</td>
<td>0.31</td>
<td>0.07</td>
</tr>
<tr>
<td>processed value (_{a_i})</td>
<td>0.667</td>
<td>0.156</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Scheme 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>actual value</td>
<td>0.02</td>
<td>0.33</td>
<td>0.08</td>
</tr>
<tr>
<td>processed value (_{b_i})</td>
<td>0.667</td>
<td>0.219</td>
<td>0.8</td>
</tr>
</tbody>
</table>
step2: Construct the judgment matrix according to the relative importance of the index:

\[
\begin{bmatrix}
1 & 3 & 5 \\
1 & 1 & 3 \\
5 & 3 & 1 \\
\end{bmatrix}
\]

step3: Get the largest eigenvalue \( \lambda_{\text{max}} = 3.0291 \), its normalized feature vector \( \omega = [0.9288, 0.3288, 0.1747]^T \).

step4: Calculate the consistency test index. And obviously, matrix satisfies consistency.

\[
CR = \frac{CI}{RI} = \frac{1}{RI(n)} \cdot \frac{\lambda_{\text{max}} - n}{n - 1} = 0.0282 < 0.1
\]

where the average consistency indicator \( RI(n) \) can be found in Saaty’s book[11].

step5: Judge the result of comprehensive evaluation

\[
\sum_{i=1}^{n} a_i \omega(i) = 0.7931 < \sum_{i=1}^{n} b_i \omega(i) = 0.8313
\]

Through the evaluation, it is shown that the improved mobile IP algorithm (scheme 1) has better handover performance.

Summary

With the development of spatial information network, more and more new technologies need to be demonstrated in the integrated environment. Thus, the evaluation of the test results is waiting to be evaluated by the comprehensive evaluation index system. The index system proposed in this paper satisfies the demand of experiment, and has certain innovation and practical value. The next work is going to improve the index system, then to study the method of assessment.

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References


