The Research on Effectiveness Evaluation of Mobile Broadband Wireless Communication System

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Abstract. It analyzes the classical methods of the effectiveness evaluation based on the research of the steps and principle of system effectiveness evaluation. It builds the indicator system from three aspects, such as: basic communication ability, communication reliability and interconnection ability, based on the characteristics and applications of wireless communication system. Then it evaluates the effectiveness of wireless communication by ADC method which can provide some suggestions for the system development.

1. Introduction
With development of the mobile broadband wireless communication system, the broadband wireless network has been widely used in range[1,2]. Can the performance of the wireless communication satisfy the task requirement with the transportation ability, transportation velocity, anti-jamming ability and reliability? It needs to evaluate the effectiveness of the wireless communication network.

2. Effectiveness evaluation of system
System effectiveness describes the ability to realize the system task of single system or complex system under some given conditions[3]. In order to evaluate system effectiveness, there are three steps. First, it needs make sure the indicator system according to the system’s practical conditions; Second, it should give the index weight because different index has different effect degree for the system effectiveness; Last, choose the suitable evaluation method, calculate the evaluation value and evaluate the system effectiveness[4].

There are six steps for system effectiveness evaluation from choosing evaluation method, establishing index system to efficiency analysis, showed as Figure1.
Figure 1. sketch map of the basic process for system effectiveness evaluation

1) Evaluation task. It mainly analyzes the task and aim of system evaluation;
2) System analysis. It should analyze the construction and function of the system, which can understand and hold the basic fact;
3) Build the index system of effectiveness evaluation. It should follow some principles to select index, which can reflect the technology characteristics and show the system requirement. Then it can make sure the index weight on the basis of different influence degree according to the system task object;
4) Build evaluation model. It should choose suitable evaluation method, build evaluation model and make sure the parameters and variables to describe the system efficiency. Then it can evaluate system effectiveness evaluation quickly on basis of the evaluation models;
5) Acquire index datum. The index datum can be acquired by the method of mathematics calculation, experiment measure, simulation statistics and so on. Then the value of effectiveness evaluation can be calculated by evaluation model;
6) System effectiveness evaluation. It can evaluate and analyze the system efficiency used the evaluation result. Then the system can be modified according to the problems.

3. Method of system effectiveness evaluation
In order to evaluate system effectiveness evaluation, it needs to choose suitable evaluation methods. There are three different methods, such as: measure method, simulation method and analytic method.
1) Measure method

Measure method is the way that analyzes and evaluates the system efficiency by the statistical datum which is the actual datum of the system acquired by hardware and software. The measure method has some excellence, such as realized easily, better real-time, reliable datum, dependability result. But it could not forecast the network performance before building the network. It needs collect large data in order to exactly evaluate the network performance.

2) Simulation method

Simulation method is the way that can simulate the system used computer simulation software, which can build the simulation scene and select the equipments, deploy operation according to the actual system. Then it can collect the simulation data in order to evaluate the system efficiency. The simulation system of communication network can simulate network operation and simulate the actual equipments, such as: line, switch, router and so on. It can analyze the performance of these equipments for the network, then evaluate the network. Simulation method can save large money, operate easily and the result of this method is reliable and close to fact. But simulation of communication network system is belongs to statics simulation, so the result of simulation running is uncertain. The similitude degree between simulation system and real system can affect the performance of simulation system. It is very difficult to ensure that the simulation system can factually reflect real system.

3) Analytic method

Analytic method can use the analytic expression to compute the index value according to the function describe effectiveness index and certain conditions. It can analyze the relation among technology performance index and change the real system into mathematics model. Then it can build relevant evaluation mathematics model by way of simulation and test in order to evaluate system efficiency. Analytic method analyzes the system by mathematics, so it can be easily understand and simply compute. It can show the relation among different variables and financing, equipments, technology don’t restrict it.

There are many different ways of analytic method, such as ADC(Availability, Dependability, Capability), SEA(System Effectiveness Analysis), grey analytic hierarchy process, grey cluster judgment evaluation method, information entropy evaluation method, and so on[5-9]. ADC method is provided by Weapon System Effectiveness Industry Advisory Committee which can evaluate system performance from system availability, dependability, capability. ADC method has good maneuverability, impersonality, practicability and veracity. ADC method emphasizes the whole system, which considers the bad influence for system efficiency because of the non-natural work state. It can evaluate system better, so it use ADC method to evaluate the performance of wireless communication system[5,6,9].

‘A’ (Availability) shows the possible state measurement before system running, which can express as:

\[ A = [a_1, a_2, \ldots, a_n] \] (1)

‘a’ shows the probability of state ‘i’ when the system begins to run and \( \sum a_i = 1 \).

The possible states include: work state, breakdown state, work state with fault, maintain state.

‘D’ shows the state exchange characteristic in process of system running, which can express as:

\[
D = \begin{bmatrix}
    d_{11} & d_{12} & \cdots & d_{1n} \\
    d_{21} & d_{22} & \cdots & d_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    d_{n1} & d_{n2} & \cdots & d_{nn}
\end{bmatrix}
\] (2)

‘d_{ij}’ shows the probability from state ‘i’ to state ‘j’ when the system is running.

Dependability mainly describes the probability of fulfilling certain task without breakdown at work when system is running. Dependability directly lies on reliability of the equipment.

‘C’ shows capability which means the probability or degree to complete the certain task, which can express as:
\[ C = \begin{bmatrix} c_{11} & c_{12} & \ldots & c_{1m} \\ c_{21} & c_{22} & \ldots & c_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \ldots & c_{nm} \end{bmatrix} \]  

(3)

\[ 'C_{jk}' \text{ shows the probability of fulfilling 'k’ effectiveness index under state 'j'}. \]

Capacity matrix \( C \) is the key of ADC method which shows system performance and is correlative with effectiveness index system.

The effectiveness evaluation ‘E’ of ADC method can be showed the product of availability ‘A’, Dependability ‘D’ and Capability ‘C’.

\[ E = A \times D \times C \]  

(4)

4. Effectiveness evaluation index system

The task of wireless communication system is to complete the communication between source and destination which can satisfy some communication qualities. The effectiveness evaluation index system\(^{[10]}\) of wireless communication system should include three aspects, such as: basic communication capability, communication reliability and connectivity capability, showed as Figure 2.

![Figure 2. Effectiveness evaluation index system of wireless communication system](image)

1) Basic communication capability

Basic communication capability weighs the communication quality of wireless communication system. According to factual requirement, it can select different evaluation index which includes Service type, Communication rate, Bit error ratio, Communication delay, Packet loss ratio, and so on.

Service type: Service type is the number of information types according to communication services which wireless communication system can provide, for example, voice, datum, video, information and so on.

Communication rate: the biggest communication capability of wireless communication system, which can be scaled by the biggest transmission rate.
Bit error ratio: the ratio of wireless communication user received wrong information relative to original information.

Communication delay: the time from the information beginning to send from source and arriving at destination. It includes signal sending delay, transmission delay, processing delay and queue delay.

Packet loss ratio: the percentage of loss packets during packets in wireless communication system which can scale the capability to correctly transmit user data.

2) Communication reliability

Communication reliability mainly weigh the reliability of wireless communication system which can be evaluated from Survivability capability, Anti-jamming capability, Security capability.

Survivability capability: the capability to provide communication service when some parts are failure or be destroyed in wireless communication system.

Anti-jamming capability: the capability to provide communication service when the wireless communication system is disturbed by third party, which is weighed by jamming threshold [11].

Security capability: the degree of information encrypting and the capability of network security which is weighed by the number of safety and secrecy methods

3) Connectivity capability

Connectivity capability mainly weighs the connectivity capability of wireless communication system from Coverage capability and Network capability.

Coverage capability: the coverage area of wireless communication system which is weighed by largest communication distance.

Network capability: the network degree of wireless communication system which is weighed by user numbers in the wireless network.

5. Effectiveness evaluation of wireless communication based on ADC method

ADC method considers the influence of abnormal condition for whole performance. So it should the possible states of wireless communication system. There are two possible states, work state and breakdown state in wireless communication system. The availability ‘A’ is showed as: A=[a1,a2]

a1 shows the probability of work state when system begins to work;

a2 shows the probability of breakdown state when system begins to work.

In case of, there are 8 hours under breakdown state in every week for the wireless communication system. The other 160 hours are work state. So the system reliability is 98%. The system fault maybe temporary fault caused by jam or other factors. The probability of maintainability is 5%.

The probability of work state a1 can be computed as:

\[ a_1 = \frac{\text{work time}}{\text{work time} + \text{fault time}} = \frac{160}{168} = 95.2\% \]  (5)

\[ \sum a_i = 1 \]

\[ a_2 = 1 - a_1 = 4.8\% \]

Dependability matrix ‘D’:

\[ D = \begin{bmatrix} d_{11} & d_{21} \\ d_{12} & d_{22} \end{bmatrix} \]  (6)

\( d_{11} \) express the work state probability when system is running, which includes probability of reliability condition and probability of work state after maintaining when system is fault, showed as:

\[ d_{11} = r + (1 - r) \times m \]  (7)

‘r’ is system reliability;

‘m’ is system maintainability.

\[ d_{11} = 0.98 + (1 - 0.98) \times 0.05 = 0.981 \]  (8)

\( d_{12} \) shows the probability from work state to breakdown state, showed as:


\[ d_{12} = 1 - d_{11} = 0.19 \]  

(9)

\[ d_{21} \] shows the probability from breakdown state to work state, showed as ‘m’.

\[ d_{21} = 0.05 \]

\[ d_{22} \] shows the probability of breakdown state of system which means that the system can’t be maintained from breakdown state to work state.

\[ d_{22} = 1 - d_{21} = 1 - 0.05 = 0.95 \]  

(10)

Capability ‘C’ can be showed as:

\[ C = \left( \begin{array}{c} c_1 \\ c_2 \end{array} \right) \]  

(11)

\[ c_1 \] shows the system probability to fulfill the task when the system is under work state;

\[ c_2 \] shows the degree to fulfill the task when the system is under breakdown state.

For wireless communication system, it can’t fulfill any object under breakdown state, so \( c_2 = 0 \)

The system efficiency of wireless communication system evaluated by ADC method can be showed as:

\[ E = \text{ADC} = (a_1, a_2) \begin{pmatrix} d_{11} \\ d_{12} \\ d_{21} \\ d_{22} \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} \]

\[ = (0.952, 0.048) \begin{pmatrix} 0.981 \\ 0.019 \\ 0.05 \\ 0.95 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} = 0.934824c_1 \]  

(12)

The value of \( c_1 \) depends on the task of wireless communication system which is the probability between system performance and expectation value. According to the system requirement, it can select key index from index system to evaluate system efficiency. The factual index can be acquired by different ways, such as: measure method and simulation method. It is the index of wireless communication system by simulation, showed as table 1.

| First level index                     | Second level index      | System value | expectation value |
|---------------------------------------|-------------------------|--------------|-------------------|
| Basic communication capability        | Service type            | 4            | 4                 |
|                                       | Communication rate      | 16kbps       | 20kbps            |
|                                       | Bit error ratio         | 0.003        | 0.001             |
|                                       | Communication delay      | 4.556ms      | 4.5ms             |
| communication reliability             | Anti-jamming capability | 16dB         | 20dB              |
|                                       | Security capability      | 3            | 3                 |
| connectivity capability               | Coverage capability      | 100km        | 150km             |
|                                       | Network capability       | 8            | 10                |

From table 1, it can provide four different services in the wireless communication system, such as: voice, video, data, information, which can satisfy the factual object; Communication rate is 16kbps which is less than 20kbps, so it can not satisfy the system object; Bit error ratio is 0.003 which is more than 0.001; Communication delay is 4.556ms which can satisfy the basic requirement; Anti-jamming capability is 16dB which is more than expectant 20dB; Security capability can provide 3 methods.
which can satisfy the system object; Coverage capability is 100km which is far from the object value; Network capability can accomplish 8 users in the network at same moment which is less than 10 users. If factual system performance can satisfy the expectation value, the value of $c_1$ is 100%. The worse system performance is, the less $c_1$ value is. So the value of $c_1$ can be get by the effectiveness evaluation index system. In fact, it should use many methods to evaluate system efficiency and ensure the weight value of different index according to user’s requirement. Then value of $C_2$ can be confirmed which can better evaluate system efficiency.

6. Conclusion
With development of wireless communication technology, the wireless communication system is used widely. It needs to evaluate the system efficiency. It analyzed the process and principle of system effectiveness evaluation. Then it compared the methods of effectiveness evaluation, especially analyzed ADC method. According to the factual of wireless system, it built the evaluation index system from Basic communication capability, communication reliability, connectivity capability. At last, it evaluated the efficiency of wireless communication system by ADC method.

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