무선통신망의 장애영향 평가 모델

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요 약

정보화 시대가 도래하면서 통신망의 장애에 의한 서비스 단절은 사회 각 분야에 치명적인 영향을 끼치게 된다. 통신망 장애에 의한 피해를 계량적으로 평가할 때 서비스를 이용하는 가입자 측면에서 살펴보면 얼마나 많은 장비가 장애에 의해 피해를 입었는가 하는 것보다는 얼마나 많은 가입자가 얼마나 오랫동안 서비스를 이용하지 못하였는지가 더 중요할 것이다. 따라서, 본 논문에서는 국내 무선통신망의 장애발생시 가입자에 대한 충격정도를 정량적으로 산출하여 장애영향을 평가할 수 있는 장애영향 평가 모델에 대하여 제안하였다. 이때, 국내 무선통신망 환경에 적합한 장애영향 평가 모델을 제안하기 위하여 국내 무선통신망의 가입자수, 무선서비스 유형별 중요도에 따른 가중치를 고려하였고 장애에 의해 영향 받은 가입자수를 계량화하는 크기비중값 계산식을 개발, 적용하였다. 장애영향 평가 모델의 적용결과를 살펴보면 PCS 네트워크에서 30,000명의 가입자가 30분 동안 "Mobile to Land" 서비스를 제공받지 못했을 경우 장애지수는 2.5로서 10,000명의 가입자가 서비스를 제공받지 못한 경우의 0.5 보다 5배 정도 가입자에게 충격을 주는 것으로 나타났으며, 30,000명의 가입자가 30분 동안 "Mobile to Land" 및 "Local Mobile to Mobile" 서비스를 동시에 제공받지 못했을 경우는 3.75 이었다.

An Outage Evaluation Model for Wireless Telecommunication Network

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ABSTRACT

Network reliability means network ability which perform normal operation of network components within defined time period, on the other hand, network survivability is the index of normal operation in network failure. In occurrence of network failure, network operator is interested in the measurement of network survivability, but, in a view of subscribers, it is more interested in how many subscribers are out of service and how long the out of service state lasts. In this paper, a service outage evaluation model fitted for telecommunication network in Korea is proposed, which measures the impacts of subscribers in case of network failure which induces a service outage. The outage evaluation result of "Mobile to Land" service outage which has 30,000 subscribers affected for 30 minutes is 2.5. This value is 5 times larger than that of the same service outage which has 10,000 subscribers affected for 30 minutes, i.e, the impact of subscribers in the former case is 5 times larger than that of the latter case. If 30,000 subscribers have isolated in "Mobile to Land," "Local Mobile to Mobile" service for 30 minutes by the exchange out of order in PCS network, then the evaluation result of this service outage will be 3.75 .

키워드 : 무선통신망(Wireless Telecommunication Network), 신뢰도(Reliability), 생존도(Survability), 장애(Outage), 장애영향평가(Evaluation), 가입자(Subscriber), 장애지수(Outage Index), 정규화(Normalization)

1. Introduction

Communication network is a basic infrastructure of a country for economical or social activities. If network outage is occurred by a natural disaster or human error, Communication services will be interrupted, then the economical and social activities get a lot of damages. Recently, As the number of wire and wireless subscribers are increased rapidly, the importance of network reliability is being spread widely. Network reliability means the network ability which performs normal operation of network components (node, link, etc) within defined time period. On the other hand, network survivability is the index of normal operation in network failure. In occurrence of network failure, network operator is interested in the measurements of network survivability, the other side, subscribers are not interested in the network survivability but the duration of service outage and number of affected subscribers. Service outage is defined by a service state which have damages in service request or service being provided.

In this paper, an outage evaluation model fitted for telecommunication network in Korea is proposed, which measures the impacts of subscribers in network failure which

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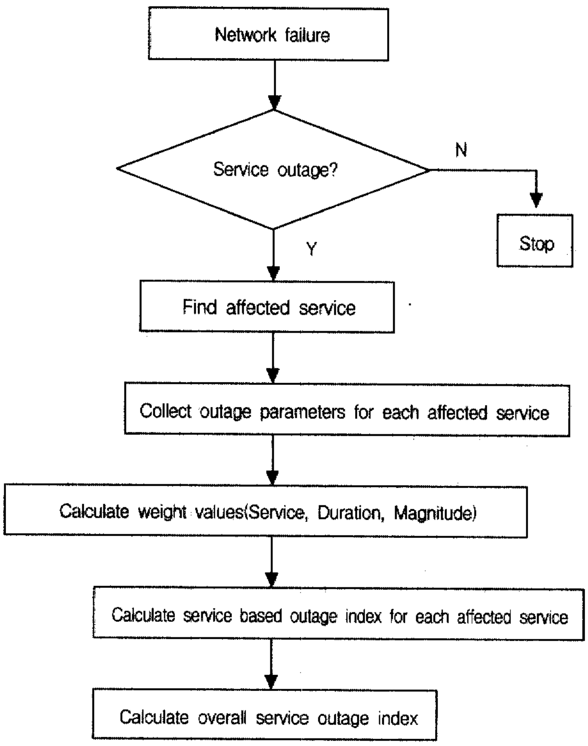
induce a service outage.

2. Procedures for Service Outage Evaluation

In network failure, some induces service outage, others not. If network failure induces service outage, It is necessary to evaluate the impacts of subscribers with service outage, the result of these service outage evaluation is called outage index [1, 3].

There are two types of outage index, overall service outage index and service based outage index [5, 12]. Overall service outage index represents the subscriber's impacts of overall service outage as a unity measure, but service based outage index represents the impacts of a single specific service outage. (Figure 1) shows the procedures for service outage evaluation. In network failure, to evaluate a service outage, first of all, we have to determine that the service outage is induced or not. To do this, it is necessary to collect three parameters, unservability, outage duration and outage extent. Unservability[3] is defined as belows,

$$\text{Unservability} = \frac{\text{Blocked service demand unit}}{\text{Requested service demand unit}}$$



(Figure 1) General flow of service outage evaluation

Outage duration is the total time duration that the unservability exceeds critical value and outage extent is the number of affected subscribers with outage. If the values of these three parameters exceed predefined critical points, then we can determine that the network failure induced the service outage. Next, we have to find affected services and collect the outage parameters for each affected service. In this point, we can calculate service based outage indices for each affected service using the outage parameters collected for each service. Finally, We can find overall outage index (shortly, outage index) by adding them.

3. Outage Evaluation Model

3.1 General

We usually calculate the outage index to measure the impacts of subscribers with service outage by network failure [1, 3]. The general characteristics of outage index are as belows.

- Outage index will be found by adding the each service based outage index.

$$\text{Outage Index} = \sum_{j=1}^{N} W_s(j) \cdot W_D(j) \cdot W_M(j) \qquad (1)$$

Where , j means j_{th} affected Service

- Each service based outage index will be calculated by multiplying the service weight(W_S), Magnitude Weight (W_M) and Duration Weight(W_D).
  These weight values, also, can be calculated by the related equations using the outage parameters (unservability, outage extent, outage duration).
- Magnitude weight value and Duration weight value have the S-shaped curve, i.e., the increasing rates of these values are small at small scaled outage and large at large scaled outage. The section point of the S-shaped curve is called reflection point.

This reflection point (a set of weight value and outage parameter) should be determined by communication carriers and related organizations.

3.2 Model for service weight

To get the service weight, we have to consider two factors, i.e., critical values of unservability to determine the service outage in network failure and in case of service outage, weight values for each affected services [1, 3, 18]. If the unservability is below the critical point, then 0 (no service outage). Above the critical point, then 1 (service outage). Weight values for each services are determined for the consideration of the service importance in view of subscribers. So, the service weight of j_{th} affected service can be calculated by equation as below.

$$W_S(j) = U_S(j) \cdot W(j) \qquad (2)$$

Where, $W_S(j)$ means service weight value for j_{th} service

$U_S(j)$ equals 0, if the unservability of j_{th} service is below the critical point.

1, if the unservability of j_{th} service is above the critical point.

$W(j)$ means weight values for j_{th} service.

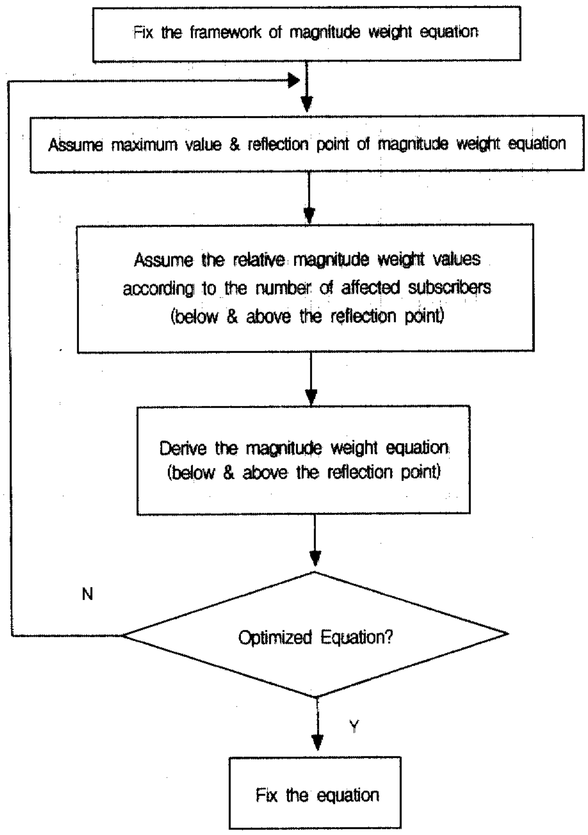
<Table 1> Shows service weight values which represent the impact degrees of subscribers for each kinds of service outage[3]. For example, the service outages of "Land to Mobile" and "Mobile to Land" impact two times more than the service outage of "Local Mobile to Mobile" to subscribers. These service weight values at <Table 1> were defined by the T1 Committee in America and currently, is being used for the service outage evaluations of wireline and wireless network in America. This paper, also, adopt these service weight values for the service outage evaluation model for wireless network in Korea without change. Because service weight values are not quantitative values but emotional values that almost all of people feel the degree of relative impacts with each kinds of service outage.

〈Table 1〉 Service weight for wireless network

Type of service	Service weight ($W_S(j)$)	Remark
Local Mobile to Mobile	1	In case of $U_S(j) = 1$
Inter Service area Mobile to Mobile	2	〃
Land to Mobile, Mobile to Land	2	〃
Emergency Service	3	〃

3.3 Model for Magnitude weight

Magnitude weight represents the extent of service outage [1, 3]. It's value can be calculated based on the number of affected subscribers by service outage. The most important factor in modeling of magnitude weight is to find the equations for calculation of the Magnitude weight based on the number of affected subscriber. So, In this paper, we focused our study for finding the equations applicable to evaluate service outage in Korea wire and wireless networks. (Figure 2) represents the derivation processes for finding the magnitude weight (W_M) equations.

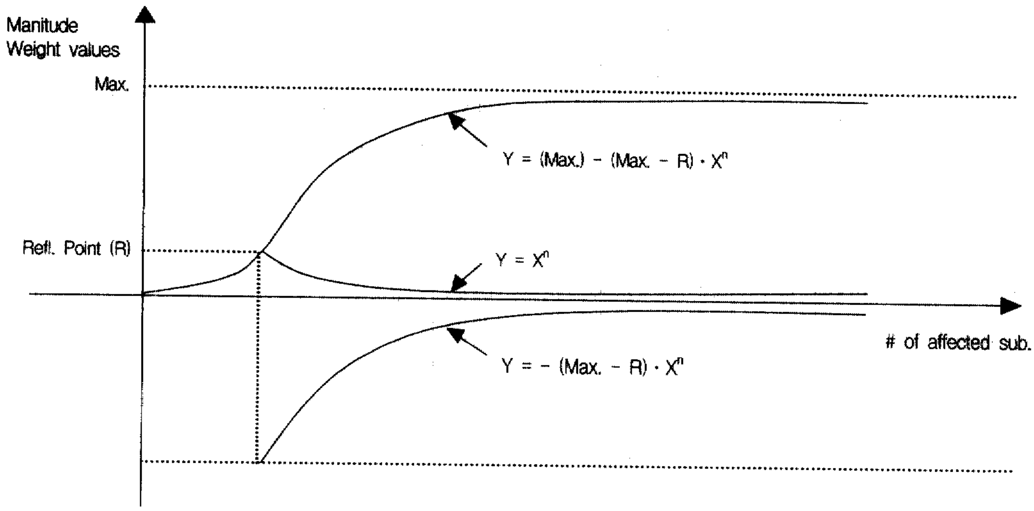


(Figure 2) The flow for the derivation of magnitude weight equation

3.3.1 The framework of equations

We assumed that the equations for finding the magnitude weight values have a S-shaped curve with reflection point and maximum values. The reasons for our assumption are as bellows,

- Magnitude weight values are defined by the relative impact degrees of subscribers with the number of affected subscribers in service outage.



(Figure 3) Framework of the Magnitude Weight Equation

- In service outage, initially, as the number of affected subscribers increases, the impacts of subscribers increase quickly but, as the number of affected subscribers are above the specific point, named reflection point, the impacts of subscribers are increased slowly.

So, the magnitude weight equations consist of two different equations with reflection point as a base line. (Figure 3) shows framework of magnitude weight equation.
As shown in (Figure 3), We can represent the framework of equation in the region of below the reflection point as a equation (3) and in the region of above the reflection point as a equation (4).

$$W_M = (\#\text{ of affected sub. }/a)^2 / b \qquad (3)$$

$$W_M = \text{Max} - (\text{Max} - R)\left(\frac{C_1}{C_2\frac{\#\ of\ affected\ sub}{a}}\right)^n \qquad (4)$$

We have determined the equation (3) and equation (4) as a framework in order to consider the S-shaped curve and asymptote method. So, we try to find the optimal coefficient values a, b in equation (3) and C_1, C_2, n in equation (4), to fix the equations completely.

3.3.2 Assumption of reflection point and relative magnitude weight values.

We made a various assumptions in reflection point, maximum values of magnitude weight and relative values of magnitude weight with a various number of affected subscribers to find the optimal coefficients (a, b, n, C1, C2) in equation (3) and equation (4), Because the impacts of subscribers with the number of affected subscribers, i.e, magnitude weight values, are not absolute but relative. <Table 2> shows one of the sets of the magnitude weight values assumed for each items which are used to produce the optimal coefficients.

<Table 2> Set of the Magnitude weight values assumed foreach items

Items	Weight Values(W_M)	Remark
Maximum Value	12.5	
Reflection Point	0.5	# of affected sub. = 10,000
5k Sub. Affected	0.125	$W_M(10k) = 4xW_M(5k)$
30k sub. Affected	2.5	$W_M(30k) = 5xW_M(10k)$
100k sub. Affected	6.25	$W_M(100k) = 2.5xW_M(30k)$

In general, the total impact of several small outage is less than the impact of a single medium-sized outage and the total impact of several medium-sized outage is greater than the large outage. These effects result from the S-shape of the curve which rise slowly at first, then rises quickly in the midrange, and then slowly rises in the high region. So, As shown in <Table 2>, we assumed that the impact of outage affected 30k subscribers is 5 times greater than the impact of outage affected 10k subscriber and the impact of outage affected 100k subscribers is 2.5 times greater than the impact of outage affected 30k subscribers. If the number of affected subscriber is more than 10k subscribers by service outage, then the social trouble is issued. So, We assumed that the reflection point of magnitude weight is fixed at 10k affected subscribers and 0.5 of magnitude weight value at that point. Also, very large scaled service outage which affects 100k subscribers is rare, so we assumed the maximum value of magnitude weight is 12.5 which means two times occurrence of service outage affecting 100k subscribers.

3.3.3 Derivation of Equations

In reflection of the assumption items and contents in <Table 2> to the equation (3) and equation (4), we can find the optimal coefficients. In equation (3), applicable to the region of below the reflection point, coefficient value a, b was found as 250, 3200 each other. So, equation (3) becomes equation (5) as follows,

$$W_M = \left(\frac{\#\ of\ affected\ Sub.}{250} \right)^2 / 3200 \tag{5}$$

In equation (4), applicable to the region of above the reflection point, the procedures to find coefficients C_1, C_2 and n using the assumptions of <Table 2> as follows.

- In case of the number of affected subscribers are 10,000 persons, The magnitude weight value is 0.5.

$$W_M = 12.5 - 11.5\left(\frac{C_1}{C_2+40}\right)^n = 0.5$$

$$\left(\frac{C_1}{C_2+40}\right)^n = 1.043478$$

At this point, applying the Log function to each side of equation,

$$n \log\left(\frac{C_1}{C_2+40}\right) = \log(1.043478),\quad \frac{C_1}{C_2+40} = 10^{\frac{0.018483}{n}}$$

$$So,\ C_1 = 10^{\frac{0.018483}{n}} \cdot (C_2+40) \tag{6}$$

- In case of the number of affected subscribers are 30,000 persons, The Magnitude weight value is 2.5

$$W_M = 12.5 - 11.5\left(\frac{C_1}{C_2+120}\right)^n = 2.5$$

$$So,\ 10 - 11.5\left(\frac{C_1}{C_2+120}\right)^n = 0 \tag{7}$$

- In case of the number of affected subscribers are 100,000 persons, The Magnitude weight values is 6.25

$$W_M = 12.5 - 11.5\left(\frac{C_1}{C_2+400}\right)^n = 6.25$$

$$So,\ 6.25 - 11.5\left(\frac{C_1}{C_2+400}\right)^n = 0 \tag{8}$$

- We found the coefficient C_1, C_2 and n of equation (4) by using equation (6) ~ equation (8) and computer programming technique.

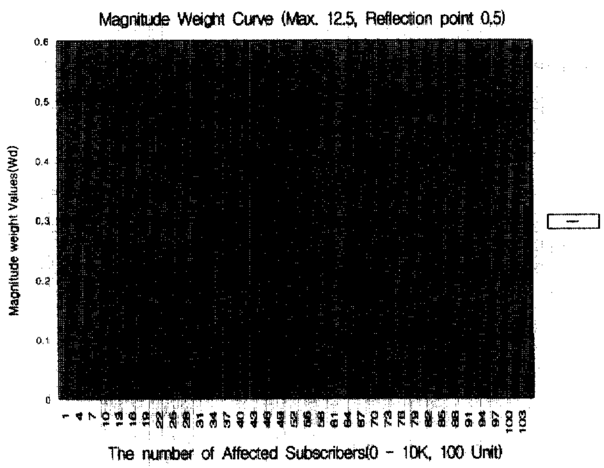
The various sets of coefficient values were shown at <Table 3>.

〈Table 3〉 Sets of coefficient values

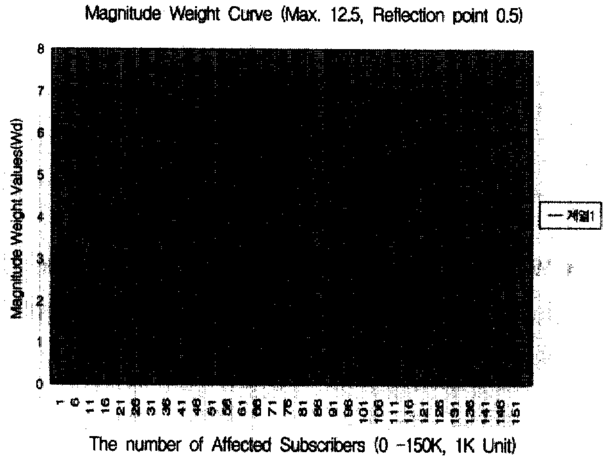
Coeff. C_1	Coeff. C_2	Coeff. n
410.89	354.11	1.021
453.56	396.12	1.085
472.13	414.42	1.113
·	·	·
·	·	·
·	·	·
·	·	·
591.5	651.2	1.386

In the sets of coefficient values, we have found that C_1 = 456.56, C_2 = 369.12 and n = 1.085 is the optimal values. So, equation (4) becomes equation (9). (Figure 4), (Figure 5) and (Figure 6) show the magnitude weight curves applied by equation (5) and equation (9).

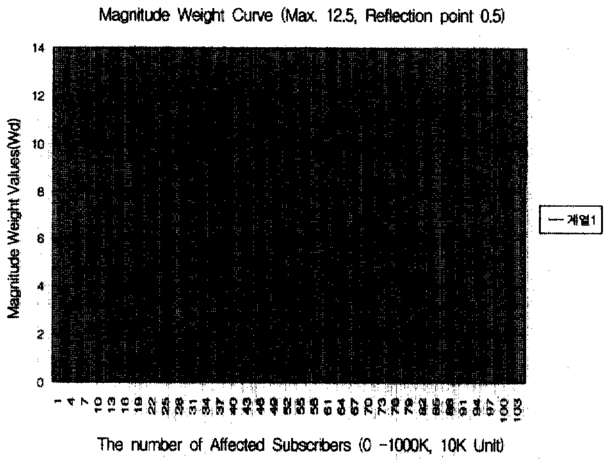
$$W_M = 12.5 - 11.5\left(\frac{453.56}{396.12 + \frac{\#\ of\ affected\ sub}{250}}\right)^{1.085} \tag{9}$$



(Figure 4) In case of "0 ≤ # of affected sub. ≤ 10k"



(Figure 5) In case of "0 ≤ # of affected sub. ≤ 150k"



(Figure 6) In case of "0 ≤ # of affected sub ≤ 1,000k"

As shown in (Figure 5) and (Figure 6), we can find that the curve shows the S-shape curve and approach asymptote as the number of affected subscribers are increased. and as shown <Table 4>, we can find the magnitude weight values calculated by equation (5) and equation (9) are equal to the assumption values in <Table 2> and also, magnitude weight values approach asymptote as the number of affected subscribers are increased.

<Table 4> calculated magnitude weight values (W_M)

# of affected subs.	W_M	Remark
0	0	
2,500	0.031	
5,000	0.125	Assumption point
10,000	0.500	Reflection point
30,000	2.504	Assumption point
70,000	5.043	
100,000	6.254	Assumption point
500,000	10.660	
1,000,000	11.522	
5,000,000	12.323	
10,000,000	12.412	

3.4 Verification of service outage evaluation model

In evaluation of service outage, duration weight values represent the impact degrees of subscribers with service outage duration [10]. In general, the impact degree of subscribers is in proportion to service outage duration and the service outage duration exceed 30 minutes, then the social trouble is issued. The service outage lasting above 150 minutes is rare and the number of affected subscribers is much more important factor than service outage duration in service outage evaluation. So, we assumed the equations for finding the duration weight values as follows,

- W_D = 0.5 M (M is 30 minutes Unit, i.e, M has value 1 in case of 30 minutes)
- W_D(Max.) = 2.5 (In case that the service outage duration exceeds 150 minutes)

In this paper, We verified the service outage evaluation model using equation (1)~equation (9) with fixed outage duration, 30 minutes, as shown in <Table 5>. In <Table 5>. We can see that the evaluation result of "Mobile to Land" service outage which has 30,000 subscribers affected

<Table 5> Verification results of the service outage evaluation model

Service outage category / W_S	# of affected sub. / W_M	Outage duration(Min.) / W_D	Evaluation results(Outage Index)
Mobile to Land / 2	10,000 / 0.5 30,000 / 2.5 70,000 / 5.0 100,000 / 6.25	30 / 0.5	0.5 2.5 5.0 6.25
Local Mobile to Mobile / 1	10,000 / 0.5 30,000 / 2.5 70,000 / 5.0 100,000 / 6.25		0.25 1.25 2.5 3.125

for 30 minutes is 2.5. This value is 5 times larger than that of the same service outage which has 10,000 subscribers affected for 30 minutes, i.e, the impact of subscribers in the former case is 5 times larger than that of the latter case. If 30,000 subscribers have isolated in "Mobile to Land," "Local Mobile to Mobile" service for 30 minutes by the exchange out of order in PCS network, then the evaluation result of this service outage will be 3.75 (2.5 + 1.25). This outage evaluation model will be useful to measure and compare the quality of service of each wireless communication carriers [5, 9, 10, 12].

4. Conclusion

In this paper, we have discussed an outage evaluation model fitted for telecommunication network in Korea. In network failure, Network operator is interested in the measurement of network survivability, but in a view of subscribers, it is more interested in how many subscribers are out of service and how long the out of service state last. So, we have proposed that the methodology which measure the impacts degree of subscribers in network failure which induces a service outage as follows,

- The processes for service outage evaluation
- Methodology for calculating outage index of service outage
- Optimal model for service weight
- Optimal model for magnitude weight

In the survey of the application results of the proposed outage evaluation model, the outage evaluation result of "Mobile to Land" service outage which has 30,000 subscribers affected for 30 minutes is 2.5. This value is 5 times larger than that of the same service outage which has 10,000 subscribers affected for 30 minutes, i.e, the impact of subscribers in the former case is 5 times larger than that of the latter case. If 30,000 subscribers have isolated in "Mobile to Land," "Local Mobile to Mobile" service for 30 minutes by the exchange out of order in PCS network, then the evaluation result of this service outage will be 3.75 . In the future, we have plan not only to make and propose as a standard for outage evaluation of the wireless network based on the model discussed in this paper, but also to study an outage evaluation methodology for IP-based telecommunication network and services.

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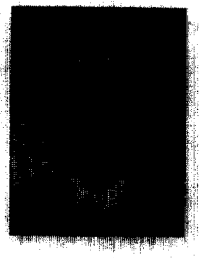

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