OSS | Traffic Analysis | Silent Fault

Technology Reports

Implementation of New Silent Faults Detection Method for Base Station Equipment

As part of our agenda aimed at ensuring the safety and reliability of communication networks, we are studying the detection of silent faults in radio base station equipment. Although there are already systems capable of detecting silent faults, there are some types of event for which it is difficult to improve the detection accuracy and which must be addressed by maintenance personnel.
We have therefore developed a new system that can improve the detection accuracy of silent faults in radio base station equipment. This makes it possible to further improve the network quality.

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1. Introduction

As mobile terminals have established themselves as part of our everyday infrastructure over recent years, securing the safety and reliability of communication networks has become an important issue, and a variety of techniques are being studied for this purpose. Part of this agenda involves the detection of silent faults [*1] in radio base station equipment.

Symptoms of silent faults in radio base station equipment include being unable to allocate resources to Radio Resource Control (RRC) [*2] connections or Radio Access Bearer (RAB) [*3] connections, leaving users unable to communicate. This is assumed to occur when a card introduced into the equipment while it is engaged in processing communications becomes unable to process traffic for some reason.

Symptoms of silent faults also differ depending on the type of traffic being processed by each card. For example, when silent faults occur in a card that perform RRC connection processing for each user, the users that use this card to connect become impossible to communicate because radio resources are not allocated correctly.

A wide variety of methods have hitherto been studied for the detection of silent faults in communication equipment [1], but there are some events that require the intervention of maintenance personnel because it has been difficult to improve the detection accuracy.

In this article we describe a newly developed detection method that can detect silent faults quickly and accurately, and its implementation in the radio base station equipment [2].

2. Conventional Silent Faults Detection Methods

A wide variety of silent faults detection methods have hitherto been studied for use in communication

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*1 **Silent fault**: Faults that the maintenance personnel cannot detect such as those caused by breakdowns of the fault detection package and main processor, so that the equipment itself cannot rocognize the faults.

*2 **RRC**: Layer 3 protocol for controlling the radio resources.

*3 **RAB**: A bearer that connects a radio zone.

equipment. These can be broadly classified into active and passive detection methods.

Examples of active detection methods include (1) a method that performs dummy communication between each item of communication equipment and reports the results to a monitoring device, and (2) a method in which dummy user communication devices are set up between each item of communication equipment and silent faults are detected based on the results of communication between these dummy user terminals [3]. However, method (1) suffers from issues such as the additional cost of incorporating dummy communication functions into the communication equipment, and the possibility of silent faults of the dummy communication functions due to its effects on the performance of the communication equipment or as a result of silent faults of the equipment itself. Also, method (2) is very expensive to apply to systems that contain hundreds of thousands of items of equipment, such as radio base station equipment in a carrier network.

On the other hand, passive detection methods are suitable for this development because they detect silent faults based on data that can be constantly observed at a certain measurement location. Here, traffic information is known to be an effective source of observation data, and silent faults have hitherto been detected based on daily visual checks of the traffic status by maintenance personnel or by using a system that automatically detects events where the traffic level becomes zero. However, these approaches impose a heavy burden on maintenance personnel, and in order to implement automatic detection in existing systems, it has been difficult to detect silent faults with a high level of precision.

We have therefore developed a new method that can rapidly and accurately detect silent faults in radio base station equipment.

2.1 Relationship between Silent Faults and Traffic Information

Data about the traffic circulating on a network is obtained by monitoring the data of RRC or RAB connections.

RRC traffic relates to the radio zone control protocol, and RAB traffic relates to the control protocol associated with bearers*4 connected to a radio zone. This traffic data is used to count the traffic calls that have been generated and fully processed in a certain time interval, and this number is used as a measure of the amount of traffic flowing.

Figure 1 shows the observed traffic information and observation points. The RRC traffic counts the information for both location registration users and communication users. On the other hand, the RAB traffic monitors the connection status for users that perform communication by actually allocating bearers. Also, Circuit Switching/Packet Switching (CS/PS) traffic information is observed only for users that actually

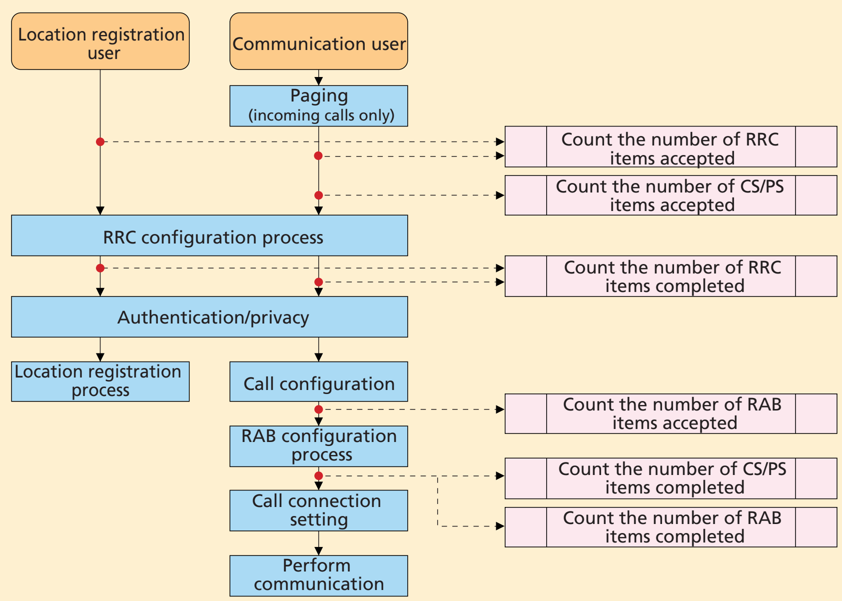


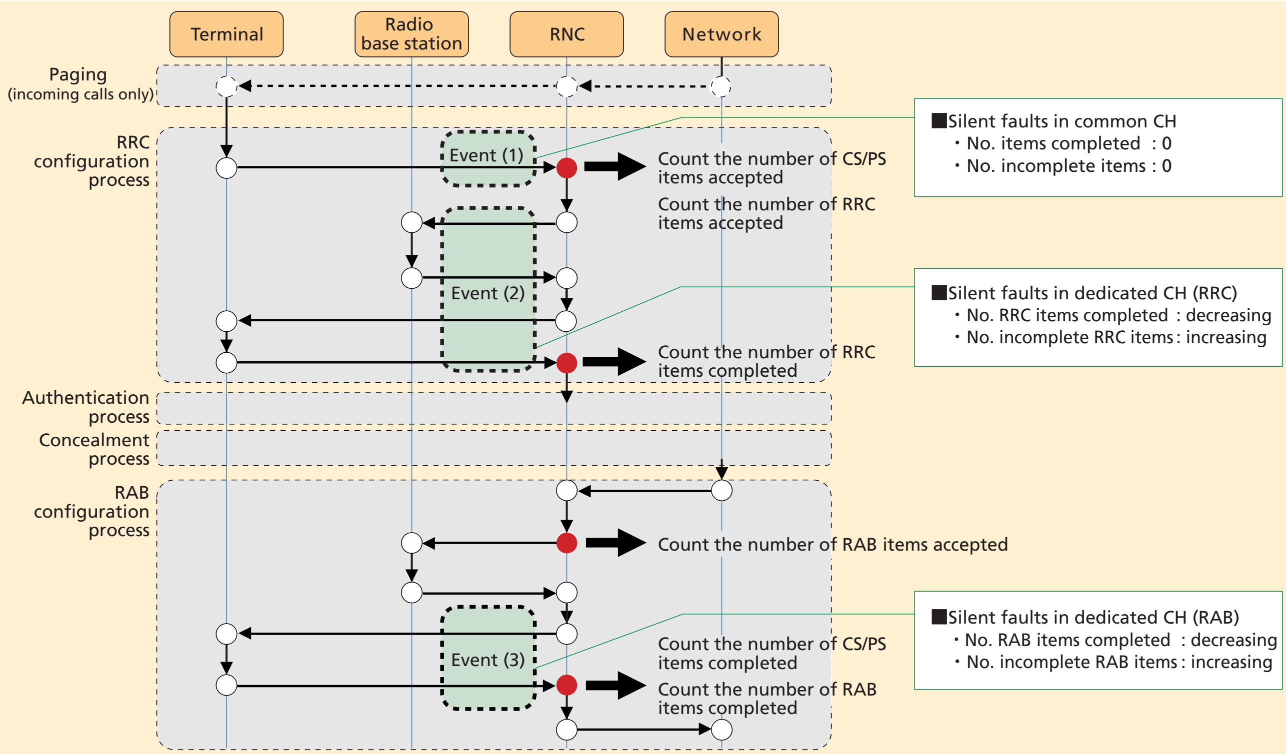
Figure 1 Traffic information and observation points

*4 **Bearer**: A communication circuit that carries information.

perform communication relating to the connection processing between the RRC configuration process and the RAB configuration process. This traffic information is observed not by the radio base station equipment that is the target of the detection, but by an Radio Network Controller (RNC)[*5] situated at a higher level than the target radio base station equipment.

Figure 2 shows the relationship between the call processing sequence and the symptoms that occur during silent faults. When a terminal wants to initiate communication by connecting to the network, it starts the RRC connection process. Based on the control information reported from the radio base station equipment, an RRC connection request is sent using the RRC common channel. Next, resources are allocated based on the RRC connection request, and are migrated to an RRC dedicated channel. Then, following the authentication and privacy processing, an RAB dedicated channel is allocated for RAB connection processing to allocate a bearer when communication is performed.

Due to the correspondence between this call processing sequence and the baseband card[*6] processing (hereinafter referred to as "BB card processing") in the radio base station equipment, a variety of symptoms occur when a fault has arisen (Fig. 2).



Event No.	Fault location	Symptom
Event (1)	Common CH BB card	Unable to complete all RRC connections. There are also cases where RRC acceptance processing is also impossible
Event (2)	RRC dedicated CH BB card	Unable to complete RRC connection processing for users allocated to a target BB card. Since only some users can be accommodated by the BB card, the number of completed RRC calls decreases by the number of RRC calls of these users
Event (3)	RAB dedicated CH BB card	Unable to complete RAB connection processing for users allocated to a target BB card. Since only some users can be accommodated by the BB card, the number of completed RAB calls decreases by the number of RAB calls of these users

Figure 2 Relationship between call processing sequence and silent faults

*5 **RNC**: Equipment that performs redio circuit control and mobility control in the 3G network specified by 3GPP.

*6 **Baseband card**: A card that implements diffusion/back-diffusion processing, Rake processing, etc. of a common CH or dedicated CH. Rake processing (reception) is a technique for receiving any radio wave (direct, reflected, refracted, etc.) and synthetically demodulating them as a single stronger radio wave.

2.2 Traditional Silent Faults Detection Methods and Their Issues

In the silent faults detection methods of traditional radio base station equipment, detection processing was performed based on the amount of traffic received, including location registration. For example, a fault is suspected when there are two or more consecutive time periods in which the number of RRCs received per unit time is zero. Specifically, with regard to the detected time, the traffic status at the same time on the previous day or previous week is checked, and when the previous traffic level is above a fixed number then it can be judged that this area has an adequate level of traffic under normal circumstances, so the status where the traffic level has fallen to zero is judged to be a fault. Checks are also made regarding the status of the faults, maintenance details and the like that normally arise up in the detected time period, and the implementation of the corresponding recovery measures is judged.

With this logic, it is possible to detect a "Zero RRC completion" fault condition where RRC connection processing is impossible for all users, and as shown in Fig. 2, it can be said that this is suitable for the detection of silent faults in the common CH. However, it is difficult to apply this method directly to a dedicated CH where the completion rate may decrease without necessarily becoming zero. Consequently, in the silent fault of a dedicated CH, by focusing on the point where the relationship between the number of items accepted and the number of items completed departs from the usual situation by deteriorating sharply with regard to traffic such as RRC and RAB, there have existed methods that perform detection based on fluctuations in the completion rate calculated from the number of items accepted and the number of items completed. Specifically, fault is detected when the completion rate drops below a predetermined threshold. However, when using this method in equipment that normally has a low level of traffic and in equipment that has a high level of traffic, the change in completion rate differs widely even for the same change in the number of items accepted, so the threshold has had to be determined separately for each number of accepted items.

3. New Silent Faults Detection Method

Earlier detection methods for silent faults in a dedicated CH are based on the traffic completion rate, and have entailed difficulties in that the optimal threshold value depends on the traffic conditions.

We have developed new silent faults detection method that implements a fault detection process using correlation coefficients to detect possible silent fault events, which are then subjected to a similar event detection process based on congestion[*7] using a Kalman filter, and then to a similar event detection process based on area factors using the number of incomplete items, and finally to silent faults decision based on these results.

3.1 Silent Faults Detection Process Using Correlation Coefficients

In the silent faults detection function using correlation coefficients, detection is performed by using a correlation coefficient showing the correlation between the number of items accepted and the number of items completed.

The correlation coefficient is a statistical indicator that shows the correlation (i.e., the degree of similarity) between two random variables, and is defined as follows.

For a given data series comprising two groups of numbers $(x, y)=\{(x_1, y_1)\}$ $(n=0, 1, \ldots, N-1)$, the correlation coefficient $Corr(x, y)$ is obtained as shown in Equation (1).

$$Corr(x, y) = \frac{Cov(x, y)}{\sqrt{\sigma_x^2 \sigma_y^2}} \quad (1)$$

Here, $Cov(x, y)$ is the covariance of x and y, and σ_x^2 and σ_y^2 are the variance of x and y, respectively. These can be obtained from Equations (2), (3) and (4).

$$Cov(x, y) = \sum_{n=0}^{N-1} (x-\mu_x)(y-\mu_y) \quad (2)$$

*7 **Congestion**: A state where communication requests are concentrated inside a short time period and exceed the processing capabilities of the network, thereby obstructing communications.

$$\sigma_x^2 = \frac{1}{N}\sum_{n=0}^{N-1}(x-\mu_x)^2 \qquad (3)$$

$$\sigma_y^2 = \frac{1}{N}\sum_{n=0}^{N-1}(y-\mu_y)^2 \qquad (4)$$

Here, μ_x and μ_y are given by Equations (5) and (6), respectively.

$$\mu_x = \frac{1}{N}\sum_{n=0}^{N-1}x_n \qquad (5)$$

$$\mu_y = \frac{1}{N}\sum_{n=0}^{N-1}y_n \qquad (6)$$

Here, the correlation coefficient *Corr* (x, y) takes real values ranging from −1 to 1. Values closer to 1 indicate a positive correlation between the two random variables, and values closer to −1 indicate a negative correlation.

With regard to the values of the correlation coefficient, when the equipment is operating normally, the number of items accepted and the number of items completed are almost equal to each other, so they are highly correlated and have a correlation coefficient close to 1. In contrast, in a fault condition, a large number of calls are generated for which the processing cannot be completed due to a BB card failure, so a discrepancy arises between the number of items accepted and the number of items completed. Thus by calculating the correlation coefficient with variable x set to the number of items accepted and variable y set to the number of items completed and detecting the decrease in correlation coefficient that accompanies a fall in the correlation between these variables, it is possible to detect the timing at which the system switches from its normal condition to a fault condition. By using the change in correlation coefficient in this way, it is possible to detect that something unusual has occurred when the correlation coefficient has fallen below a threshold (**Figure 3**).

Also, in the correlation coefficient, the covariance representing the correlation between the two variables is normalized to the product of their respective standard deviations (σ). In this way, the effects of traffic conditions are essentially eliminated, and there is no need to adapt the silent fault detection threshold to multiple settings according to the traffic conditions.

3.2 Detection of Events Similar to Silent Faults

Events similar to silent faults can be caused by congestion and area-related factors, and may cause false detection when detecting fault based on correlation coefficients. It is therefore necessary to distinguish between silent faults and events that are similar to silent faults .

1) A process for Using a Kalman Filter to Detect Similar Events Based on Congestion

When a device becomes overloaded with calls, the number of items completed decreases relative to the number of items accepted, resulting in an event that resembles silent faults.

In general, traffic levels exhibit periodic variations over various time intervals such as 24 hours, one week (different traffic levels on weekdays and weekends), and one year (including seasonal variations and events such as summer firework displays). It is possible to learn these periodic variations and detect errors caused by congestion by detecting the departure from these variations.

There are various methods for learning about traffic conditions of this sort. For our proposed method, we used Kalman filtering [4][5]. Kalman filtering is a method that uses observed data to estimate the most appropriate state of a system while eliminating noise components contained in this data [6]. In this study, a Kalman filter is defined based on a model that can resolve data into a level component, a gradient component and a periodic component.

Specifically, the Kalman filter detects silent faults by calculating outlier values in the level component, gradient component and periodic component estimated for the number of RRC items accepted and the number of RRC items completed in one-hour time units (**Figure 4**).

2) A Process for Using the Number of Incomplete Items to Detect Similar Events in Area Factors

In general, if radio resources are abundant and are functioning normally, situations where traffic cannot be processed will be very rare, and the number of incomplete items (i.e., the number of processes that could not be completed in a unit time period) is small. However, depending on the area covered by the radio base station equipment, there may be events that cause steady deterioration of the RRC completion rate. This is often not a fault condition, but is due to a steady shortage of radio resources or a constraint on call performance at radio cell boundaries. An event in which this sort of tendency occurs is defined as an area factor.

A characteristic of area factors is that the RRC completion rate is steadily impaired while the number of incomplete RRC items tends to fluctuate in strong proportion with the number of RRC accepted items and completed items, so this characteristic can be used to detect abnormal traffic conditions that are caused by an area fault.

Specifically, correlation coefficients are calculated between the number of RRC accepted items and the number of RRC incomplete items, and between the number of RRC completed items and the number of RRC incomplete items, and an area factor is judged when any of these correlation coefficients exceeds a predetermined threshold (high correlation). In addition, since area factors are judged from long-term trends, it is sufficient for the traffic information used in this calculation to be highly granular, but since it is necessary to be aware of changes in traffic trends on different days of the week,

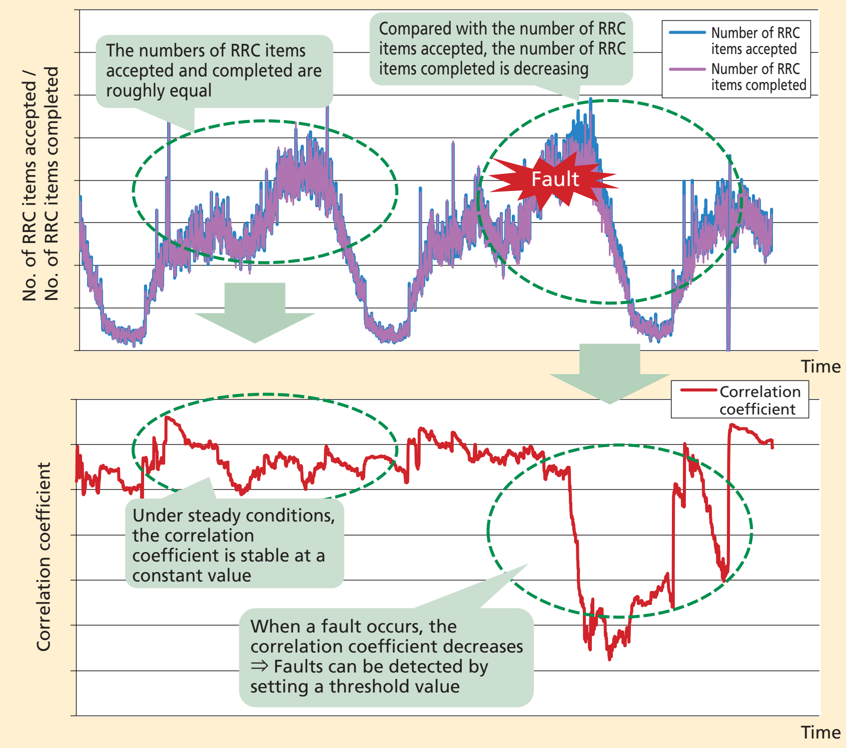


Figure 3 Silent faults detection using correlation coefficients

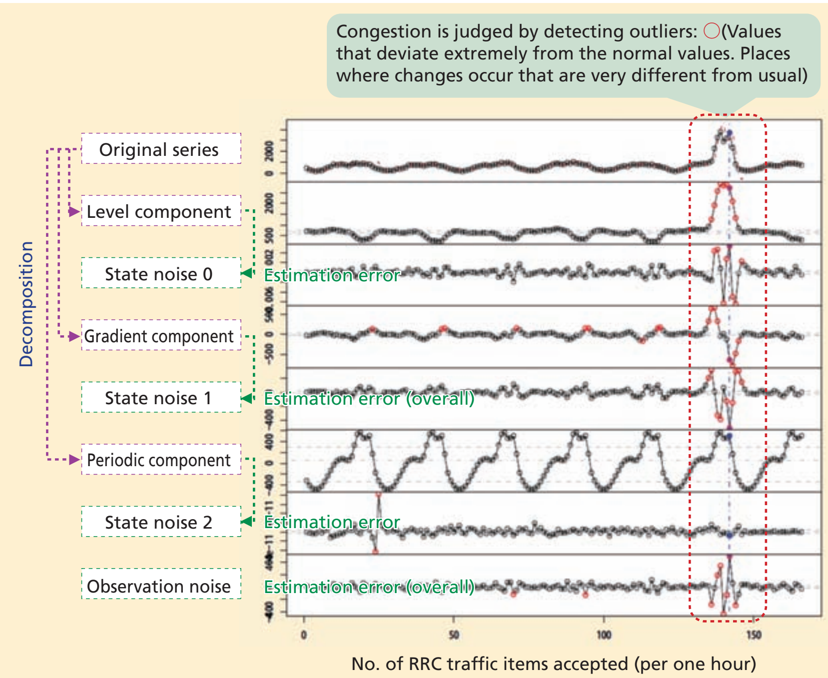


Figure 4 Detecting congestion using a Kalman filter

correlation coefficients are calculated separately for each day of the week based on traffic with a temporal granularity of about one hour.

4. Implementation of the Proposed Method

We implemented the proposed method as a function of DOCOMO's network maintenance system (called "Knowledge System") [7], and the parts relating to the silent faults analysis logic were implemented as a scenario. The configuration of the Knowledge System is shown in **Figure 5**.

In implementing this technology, we also added the following new functions:

1) Related Traffic Data Acquisition Function

The Knowledge System used an Network Element-Operation Support System (NE-OSS)*8 to gather traffic data and process the data for fault detection.

For the traffic data used in subsequent processing, it is necessary to use previous data as well as data for a particular time. Also, since data is required for radio base station equipment nationwide, the amount of data collected is very large. However, earlier traffic acquisition functions are specified so that every time the necessary traffic data is used, this data is acquired by NE-OSS, and in this method, the exchange of messages between the Knowledge System and NE-OSS is known to cause a performance bottleneck. We therefore implemented a traffic acquisition function based on a new method. The implementation of this function is shown in **Figure 6**. In this new function, traffic data from all parts of the equipment is periodically acquired from the NE-OSS, and is expanded into data expansion memory for storage. Consequently, when traffic data is needed during fault detection, it can be acquired by searching the data expansion memory, thereby eliminating the performance bottleneck associated with the time taken for data retrieval. In the data expansion memory, data is managed as a distributed Key-Value Store*9 so that the system can be scaled up flexibly when adding further base station equipment or increasing the

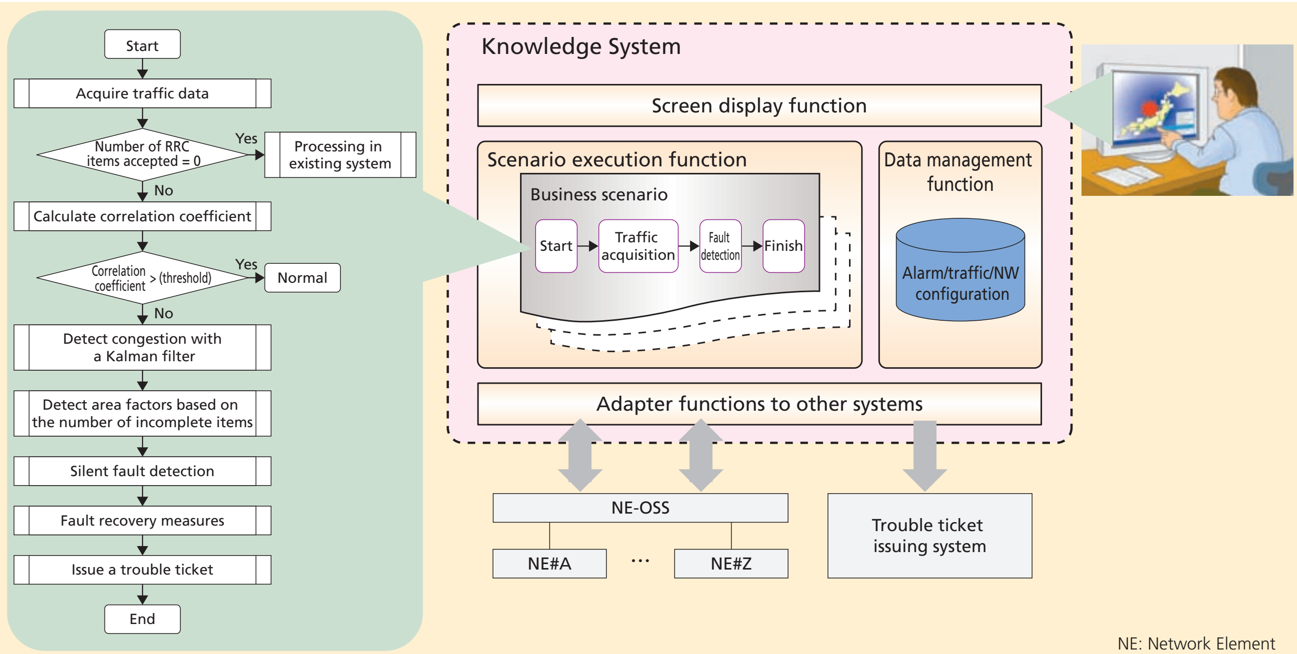


Figure 5 Functional overview of Knowledge System

*8 **NE-OSS**: A maintenance system for communication equipment.

*9 **Key-Value Store**: A data storage format based on a data model comprising key-value pairs consisting of an item of data (Value) and an arbitrary label (Key).

amount of traffic data due to the addition of traffic types used for decision-making and learning.

2) Mathematical Computation Engine Function

In earlier Knowledge Systems, there were no scenarios requiring complex numerical computation, and computations were processed as part of the scenario execution function. However, since the Kalman filter calculations in our proposed function require a large amount of complex numerical computation, we have developed a mathematical computation engine function that can be called from the scenario execution function as shown in **Figure 7**. This function is implemented so as to be able to run a numerical computation program including external programs (OSS, commercial applications, specialist applications, etc.), and its functions can also be enhanced in the future.

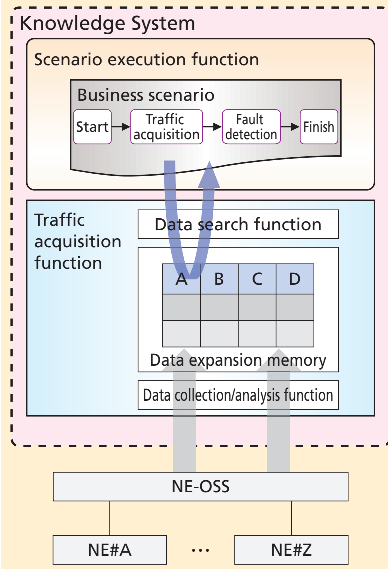


Figure 6 Traffic acquisition function

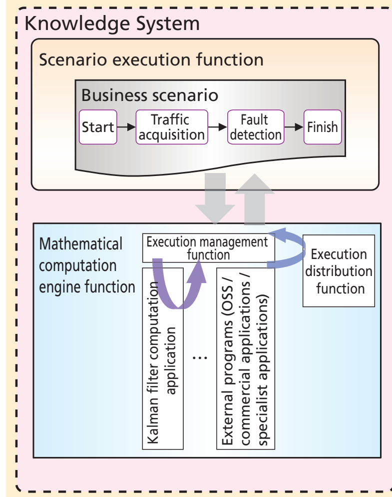


Figure 7 Mathematical computation engine function

5. Conclusion

In this article, we have described the development of a new method that uses traffic information for the detection of silent faults in radio base station equipment. This method overcomes the issues of the conventional approach and has made it possible to detect silent faults in radio base station equipment with greater speed and accuracy.

In the future we plan to study the application of this method to LTE [*10] equipment.

REFERENCES

[1] Wazumi and Y. Nemoto: "Network traffic anomaly detection techniques,Åh IEICE General Conference, BS-5-1, Mar. 2008 (In Japanese).

[2] H. Kouno, Y. Sagae, A. Benjebbour, M. Furutani and J. Hagiwara: "A study on silent failure detection using base station traffic information," IEICE Tech. Rep., ICM2010-54, Vol.110 , No.466, pp.1-6, Mar. 2011.

[3] H. Kouno et al.: "Hihly Accurate Failure Detection System for Large-scale IP networks," NTT DOCOMO Technical Journal, Vl.12, No. 1, pp.22-28, Jun. 2010.

[4] M. West and J. Harrison: "Bayesian forecasting and dynamic models," Springer Verlag, 1997.

[5] J. Hagiwara, B. Anass, Y. Sagae, H. Kouno and Y.Uzawa: "On Kalman Filter Modeling for Network Traffic Monitoring," Proc. Soc. Conf. IEICE, B-14-1, Sep. 2010.

[6] A. C. Harvey: "Forecasting, structural time series models and the Kalman filter," Cambridge Univ. Pr., 1991.

[7] H.Kouno et al.: "Development of a Network Operation Knowledge System", NTT DOCOMO Technical Journal, Vol. 12, No. 2, pp. 43-50, Jul. 2004 (In Japanese).

*10 **LTE**: Extended standard for the 3G mobile communication system studied by 3GPP.