Traffic Control by Influencing User Behavior

We examined a means of influencing user behavior to reduce the number of repeated calls by providing information to users and controlling the traffic before it flows into the network, and analyzed the traffic characteristics by modeling repeated calls. This research was conducted jointly with the Takahashi laboratory (Professor Yoshitaka Takahashi), Faculty of Commerce, Waseda University.

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1. Introduction

Traffic generation in mobile networks is heavily dependent on user behavior because the users move around with their terminals. For example, at a special event such as a fireworks display or football game, the people will congregate in a specific place and may try to make calls, generating unpredictable excessive traffic, leading to network congestion. When the users cannot get through due to congestion, they tend to make call requests repeatedly (repeated calls), which aggravates the network congestion further and in the worst case might even cause the network functions to break down. In order to avoid situations where services cannot be provided due to excessive load on the network equipment, controlling the traffic is an important issue. Currently, mobile network operators control the traffic by restricting the users' communication demands (calls) forcefully by imposing calling restrictions or similar at congestion. However, when such methods are applied, the users lose the opportunities to use the services and the user satisfaction level may be decreased. To solve this problem, we examined a new traffic control method that attempts to influence user behavior before the traffic flows into the network. This effect is achieved by guiding the users to collaborate by providing information to them when the traffic is too heavy to control solely by network control methods. We call this new method "traffic control by influencing user behavior" [1]. This method aims to improve the opportunities of the users to use communication services by effectually controlling the number of repeated calls and ultimately increase the users' satisfaction level. Moreover, for the benefit of network construction, operation and management, it is of great importance to take repeated calls into consideration when understanding the traffic characteristics of the network. For this reason, we evaluated the effects of repeated calls on the network performance.

2. Traffic Control by Influencing User Behavior

2.1 Concept

We can consider three ways of controlling traffic before it flows into the network: balancing the distribution of traffic inflow between locations in the network (geographical balancing), balancing the time at which the traffic flows into the network (time balancing), and reducing the volume of traffic. We thus examined the following methods for traffic control that can be achieved by influencing user behavior.

1) Changing the communication place (move)

The network system encourages the users to move to a location where there is spare capacity available. This balances the traffic geographically.

2) Changing the communication time (wait)

The network system encourages the users to wait for a while until the network has spare capacity available. This balances the traffic in time.

3) Changing the communication medium (change media)

The network system encourages the users to switch to a different communication medium, for example, from voice call to text message. This reduces the traffic volume.

The relationship between traffic control and methods of influencing the users is shown in **Figure 1**.

The traffic control by influencing user behavior is based on

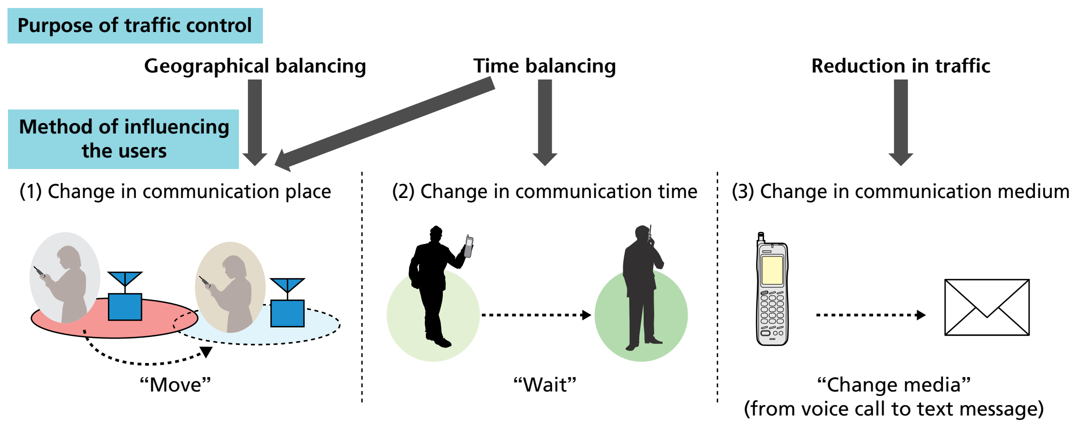

Figure 1 Relationship between traffic control and methods of influencing user behavior

the idea of controlling the traffic by notifying the users about system conditions and proposing better ways to communicate. As the users are made aware of the system conditions, deterioration of customer satisfaction can be prevented. It is still left up to the free judgment of the users whether or not they choose to follow the proposals from the system.

The information notified to the users can include system information such as the present and estimated future network load conditions. It may also include recommended places and times where communication is possible, as well as alternative media through which the users can attempt to communicate. If only the system information is sent, the users may not take the actions the operator expects, as the behavioral patterns of the users after receiving the information vary, and thus the expected traffic control may not be achieved. Nonetheless, users are able to know the system conditions, which is considered to be effective in preventing the deterioration of customer satisfaction. If recommendations are sent and the mobile terminal functions can be controlled upon obtaining agreements from users, it would be easier to obtain the expected effects from the traffic control.

2.2 Overview of Control Scheme

The sequence of events when implementing traffic control by influencing user behavior is explained below.

First, when the communication system receives a connection request, it judges whether or not it is necessary to guide the users based on the current radio resource usage rate and other information. When the system guides the users, it sends the users guidance messages. These guidance messages contain information encouraging the users either to change the communication place, time or media.

Upon receiving a guidance message, the user can judge whether or not to follow the guidance. When the user decides to follow the guidance, the user behaves as recommended (move, wait or change media) and requests a connection again. Depending on the spare communication resources, the call request may then be accepted or rejected.

2.3 Evaluation of Traffic Control by Influencing User Behavior

We evaluated the effects of the traffic control by influencing user behavior using a method called multi-agent simulation. Multi-agent simulation is a method where multiple individual subjects (agents) that behave and make decisions autonomously are defined on a computer, and the global states resulting from the decisions each agent makes are observed. We have defined the users as agents and developed models of their behavior (movement, communication, and reaction to the guidance). The developed simulator is able to display and check the present position and communication status (standby/calling) of all the users existing in the simulation. Moreover, it allows observing status changes of various evaluation metrics (e.g., blocking probability) in realtime. In other words, it is possible to measure not only macroscopic results but also transient changes of status over time. **Figure 2** shows the simulation screen.

As a specific example, we selected a fireworks display for the simulation scenario. In this scenario, users move from a station in the vicinity of the fireworks site to the destination, and after the event is over, they walk back to the station. The blocking probability was evaluated for the two cases: the case in which our traffic control (influencing the users to move, wait, or change media) is applied, and the case in which no control is applied in a series of events from before the opening to the ending of the fireworks display. The blocking probability is determined as "the number of blocked calls divided by the number of call attempts (including repeated calls)." The simulation encompassed 2,500 individual agents (users). Each agent was set to make random calls independently at intervals of 2,000 to 5,000 seconds on average in order to generate traffic. In other words, we set the average number of call requests per second for all the users as a whole in the simulator to 0.5 to 1.25 requests per second to generate traffic enough to represent congested condition. Then, we observed changes in the characteristics by changing the volume of traffic (degree of congestion). We set realistic values for the average holding time and interval between repeated calls, 100 seconds and 15 seconds, respectively. Moreover, the average holding time at changing media was set to 1/10 of the normal time, i.e., 10 seconds. **Figure 3** shows the blocking probability characteristics obtained from the simulations. The results show that all the proposed methods of traffic control tend to decrease the blocking probability compared to the case where no control is applied. In particular, recommending to "Change media" results in a dramatic improvement when the traffic volume is large (high network load). On the other hand, "Move" and "Wait" are not so effective in the high load situation in terms of reducing the blocking probability. As a consequence of the lower blocking probability generated by our traffic control, the users can benefit from increased access to the communication services. Repeated calls generated while influencing the user behaviors are complicatedly distributed and thus difficult to analyze. For this reason, it is important to understand the effects of repeated calls on the network performance evaluation quantitatively beforehand in order to design and operate such a system.

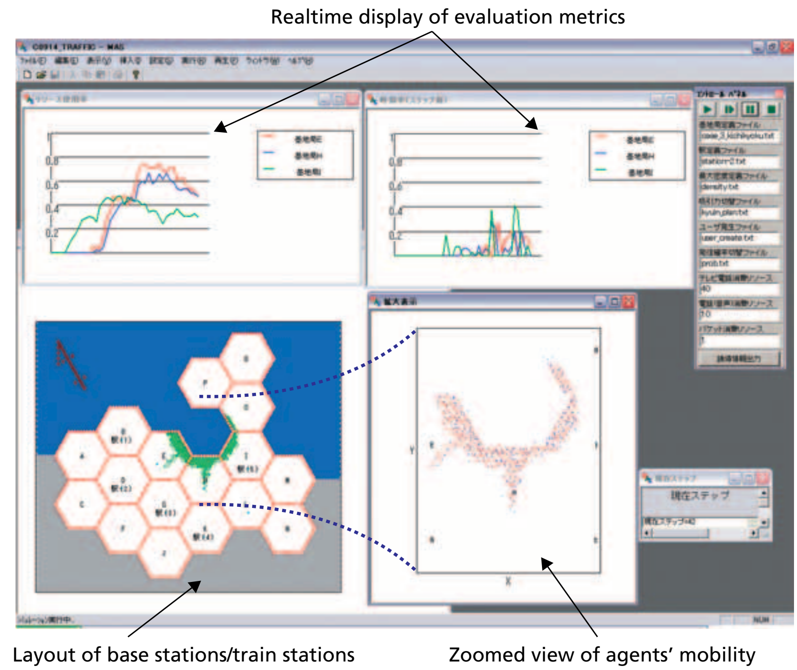

Figure 2 Simulation screen

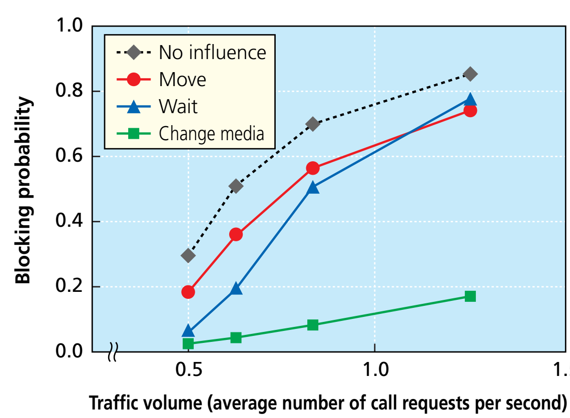

Figure 3 Blocking probability characteristics

3. Characteristics of Repeated Call Traffic

To construct, operate and manage an information communication network, it is important to understand the effects of repeated calls, which facilitate congestion, quantitatively. For this reason, we developed a model of the "repeated call phenomenon" and analyzed the traffic characteristics quantitatively.

3.1 Theoretical Analysis

Conventional methods of traffic analysis taking repeated calls into account have mainly been addressing the question of how much the blocking probability (evaluated using the Erlang-B formula) in a complete group loss system grows due to the presence of repeated calls. That is, the focus was on determining how high the extension of arrival ratio in the Poisson process should be set. Moreover, loss communication systems that include Markovian repeated calls have also been modeled and analyzed [2], but the models obtained are not suited for numerical calculation.

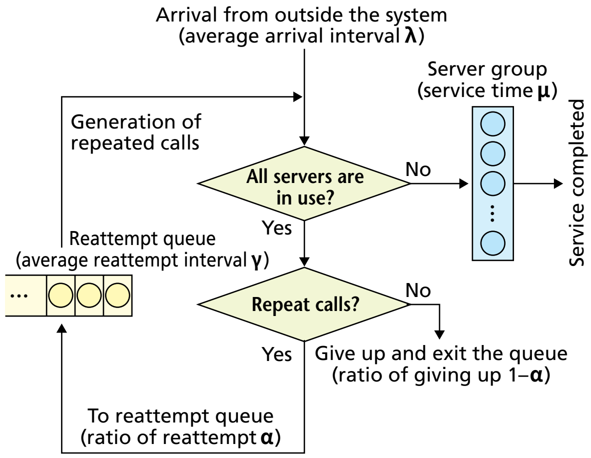

Figure 4 Repeated call model

In this research, we incorporated the user behaviors in our model, whose calls were blocked from accessing services but do not wish to give up; these users are placed in a reattempt queue and wait for some time interval before repeating their service request (**Figure 4**). To analyze the results of this behavior, it is necessary to take into account reattempt queue and reattempt interval distribution (distribution of waiting time in the reattempt queue). The conditions we assumed in the analysis are shown below.

- The users' calls arrive at the system independently and the interval of arrival follows an exponential distribution with parameter λ.
- If all servers (channels) are used, the users attempt repeated calls. The number of repeated calls varies depending on the user (and may, depending on the conditions, even vary for the same user). If the users are blocked from accessing a server, they repeat calls with a constant probability α ($0 \leqq \alpha \leqq 1$).
- The interval of repeating calls depends on the user and follows an exponential distribution with parameter γ.
- The service time when a user accesses to a server successfully (communication time) depends on the user and follows an exponential distribution with parameter μ.

Using the model outlined above and obtaining the blocking probability and average waiting time by applying "Little's formula"* as well, we propose a new calculation method suited for numerical calculation [3].

* Little's formula: If the arrival rate of user calls to a system is denoted λ and the average number of users waiting in the system denoted L, then the average waiting time from the time calls arrive at a system until processing is completed, W, is given by the relation $W=L/\lambda$.

3.2 Simulation Analysis

In conventional research, repeated calls meant redials where people would manually dial numbers again. For this reason, the reattempt interval was analyzed as an exponential distribution. Presently, however, it is possible to repeat calls using redial functions implemented in the terminals. Moreover, when the traffic is controlled by influencing user behavior, the characteristics of repeated calls vary depending on the method of influencing user behavior and become complicated. In the theoretical analysis, we assumed an exponential distribution for the reattempt interval distribution. However, when examining equipment design and traffic control, it is useful to estimate the influence of the reattempt interval distribution on the system performance by clarifying the effects on traffic characteristics by differences of reattempt interval distribution which is one of the user behaviors. For this reason, we evaluated the characteristics through simulation for four cases where the reattempt interval distribution is set to be an exponential distribution, a uniform distribution, 2-stage Erlang distribution and 2-stage hyper exponential distribution. As a result, it was found that the blocking probability (the ratio of customers giving up and withdrawing from the redial queue) does not depend on the reattempt interval distribution [3]. In other words, it became clear that it is necessary to measure the average reattempt interval as far as design, control and operation are conducted based only on the blocking probability, but it is not necessary to obtain any other statistical information.

4. Conclusion

This article provided an overview of a traffic control method that relies on influencing user behavior by providing guiding information to them and investigated its effects. Characteristics of repeated calls which cause a congestion was also introduced. In the future, we intend to study how the customer satisfaction level can be quantified based on subjective evaluation using questionnaires, as well as methods for modeling the users' communication activities. Moreover, we plan to further examine specific methods of influencing users, such as contents and delivery means of information to users, and evaluating them from the perspective of customer satisfaction.

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