Performance evaluation of priority control scheme for shortest reservation calls under disaster congestion

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Abstract: When disasters such as earthquakes occur, telephone traffic to the disaster area increases rapidly, to confirm the safety of residents, leading to telephone network congestion. The existing congestion control for telephone networks consists of call regulation control, through which call demands at the subscriber network switches or cellular phones are suppressed. This results in a drastic decrease in the call completion rate. Disaster emergency message dial services do not meet users’ needs either to confirm the safety of people at the disaster area or to speak with them directly. In this paper, we propose a priority control scheme based on call reservations and evaluate its transient characteristics. We also propose an improved scheme to shorten the desired holding time by a fixed rate, when the number of waiting reservation calls exceeds a threshold, which can suppress the divergence of the number of reservations. We evaluated the average waiting time and threshold excess rate characteristics, and confirmed that the proposed scheme can provide stabilization.

Keywords: Communication Traffic, Congestion Control, Reservation Control, Transient Characteristics

Classification:

References

[1] NTT East homepage, http://www.ntt-east.co.jp/traffic/disaster.html.
[2] H. Tokunaga and H. Kawano, “Traffic congestion control based on call density control,” The IEICE Transactions (Japanese Edition), vol. J71-b, no. 3, pp. 322-329, 1988.
[3] D. Satoh, “Disaster contingency planning research -from call regulation to behavior change induction,” IEICE ESS Fundamentals Review, vol. 12, no. 4, pp. 301-311, 2019, (in Japanese).
[4] Y. Tohana, K. Hiraguri and H. Yoshino, “Reservation congestion control scheme and its evaluation for telephone services during disasters,” IEICE Technical Report, vol. 114, no. 131, CQ2014-21, pp.35-38, 2014, (in Japanese).
[5] D. Asano, S. Takahashi, T. Hiraguri and H. Yoshino, “Improvement and
evaluation of a reservation-type telephone congestion control system for disaster,” Proceedings of the IEICE General Conference, B-11-25, 2016, (in Japanese).

1 Introduction

In the event of large-scale disasters, such as earthquakes or torrential rain, the demand for telephone calls increases sharply to confirm the safety of people at the disaster area. This results in congestion, which makes it difficult to connect calls. Congestion can also occur during planned events due to a concentration of incoming calls at specific destinations at specific times, such as telephone requests for ticket reservations, and in event venues due to the high-density concentration of people with mobile terminals at specific events, such as firework displays, coming-of-age ceremonies, and concerts.

In the aftermath of the Great East Japan Earthquake in 2011, the use of telephones to confirm people’s safety increased 50 to 60 times compared to normal traffic conditions, resulting in congestion. The outgoing call restriction rate was 70% to 95%, with most users being unable to make calls.

Congestion occurs when communication requests exceed the processing capacity of a communication system. Re-dialing can amplify congestion, adding more traffic to the communication system than during the original request. Outgoing call regulation control [1][2], which is the existing congestion control scheme used in telephone networks, merely regulates telephone calls, which leads to an increase in the total traffic, including redialing calls. That is, the existing scheme does not provide a fundamental solution to congestion. Disaster Message Dial [1] is a service in Japan that can be used after a disaster. However, it only provides the ability to send one-way messages, failing to meet the needs of users who want to communicate with each other directly.

For disaster-type congestion in telephone networks, Satoh [3] categorized countermeasure technologies by their abilities to maintain/increase the supply and disperse/substitute/reduce the demand. In addition, he proposed and evaluated a scheme for distributing users to Session Initiation Protocol (SIP) servers and a scheme for grouping users and setting callable hours for each group.

In this paper, we propose a priority scheme based on call reservation control [4] and evaluate its transient characteristics. We also propose an improved scheme to shorten the desired holding time by a fixed rate when the number of waiting reservation calls exceeds a threshold. We evaluated the average waiting time and threshold excess rate characteristics, and confirmed that the proposed scheme can suppress the divergence of the number of reservations.

The remainder of this paper is organized as follows. In Section 2, we describe the reservation congestion control system and the shortest-call-first scheme. In Section 3, we propose an improved scheme that adds a threshold to the shortest-call-first scheme. In Section 4, we describe the evaluation model and conditions using a simulation. Section 5 describes the experimental results, and Section 6 concludes the paper.
2 Reservation Control Scheme in Disaster Congestion

The reservation control scheme (RCS) for disaster congestion proposed in [4], automatically transfers calls from the originating exchange and accepts reservations. In this scheme, when a call is made to or from a congested area, it is automatically transferred from the originating exchange to the RCS, which accepts the call reservation and connects the call in the order in which it was reserved. In this original RCS scheme, although calling can be suppressed, the number of waiting calls diverges as the traffic volume increases.

To solve this problem, we propose the shortest-call-first (SCF) scheme [5], in which a user selects or inputs a desired holding time at the time of reservation, and priority control is performed to connect calls with shorter desired holding times.

3 Improvement of the Shortest-Call-First scheme

3.1 Proposed control scheme

Fig.1 shows the model of the SCF scheme. Calls are registered in the reservation list in ascending order of the desired holding time. If a reservation with the opposite originating and terminating number is already in the reservation list, the caller is given the highest priority and is placed at the top of the reservation list. Because the calls are processed in the order of the shortest desired holding time, the average waiting time is expected to be reduced. When a call is a re-dialed reservation, the call is repositioned at the end of the reservation list to prevent dialing. An outline of the proposed scheme is shown in Fig.1. In this scheme, a threshold \( L \) is set for the reservation list, and when the queue length is exceeded, the desired holding time is reduced by a certain percentage. We refer to this percentage as the reduction rate. We expect this scheme to reduce the divergence of the queue and shorten the waiting time.

3.2 Evaluation of the desired holding time distribution

Before the simulation evaluation of the proposed scheme, it is necessary to determine the distribution of users’ desired holding times. Therefore, we conducted two questionnaire surveys to obtain this information. In Survey 1, we asked for the desired holding time; the sum of the times of the answers to the multiple choices of conversation contents, such as “Are you safe or not injured?” was defined as the desired holding time. In Survey 2, we asked the subjects what percentage of the total holding time they could accept for the improved scheme. A total of 105 subjects aged around 20 years, responded to the survey. Fig.2 shows the distribution of desired holding times based on the survey results. As shown in
Fig. 2, the number of people whose total desired holding time was 180s was the largest, and the average desired holding time was 113s. The distribution excluding mode 180s has an average of 63s and a coefficient of variation of 0.554. From the shape of the distribution and the coefficient of variation, the Erlang-3 distribution fits the desired holding time distribution excluding 180s, as shown in Fig.2

4 Simulation model and conditions

In this section, we present the model and conditions under which we evaluated the SCF scheme using the discrete event simulation Visual SLAM. The simulation model is based on the situation in which, after a disaster occurs, safety confirmation calls are concentrated in the disaster area from other regions. The number of subscribers in the other region and the disaster area are defined as $m_1$ and $m_2$, respectively, and the call generation rates are defined as $\lambda_1$ and $\lambda_2$, respectively.

The number of communication lines between the two regions is $n$, the traffic intensity is $a = (\lambda_1 + \lambda_2) / \mu$, the average holding time is $T = 1 / \mu$, and the holding time distribution is a mixture of Erlang-3 distribution with an average of 63s and a unit distribution of 180s.

5 Simulation results

Fig.3(a) shows the results of a comparison of the transient characteristics of the SCF scheme and the improved scheme with an additional threshold for $n = 20$ and $m_1 + m_2 = 100$. The threshold $L$ and reduction rate were set to 60 and 20%, respectively. Thus, we can see that the improved scheme can suppress the divergence of the queue length of the reservation list.

Fig.3(b) shows the characteristics of the average waiting time and threshold excess rate, as the reduction rate was varied. A total of 10 runs of 24 h simulations were performed, and 95% confidence intervals were calculated. The traffic intensity was set to 19 and 19.5 erl.

From Fig. 3(b), we can see that with $a = 19$ erl, the waiting time is stabilized at a call time reduction rate of approximately 7.5%. However, with $a = 19.5$ erl, the waiting time can be stabilized when the call time reduction rate is set to 15% or higher.
(a) Transient characteristics of SCF scheme and modified scheme

(b) Average reservation waiting time and threshold excess rate.

Fig.3 Simulation results

6 Conclusion

In this paper, we proposed an SCF reservation-based congestion control scheme for disasters and an improved SCF scheme that reduces the desired holding time by a certain percentage, by setting a threshold. We confirmed that the improved scheme can reduce queue length and waiting time. We also clarified that it is necessary to set an appropriate reduction rate according to the intensity of the traffic. These results suggest that the improved scheme can reduce the average latency after congestion and thus, enable the stable operation of communication networks even during disasters. Future work will include evaluations under more realistic simulation conditions.

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