Analysis of Direct Communication Considering Mobility and Localized Distribution of Terminals

Tatsuya KABASAWA [1] and Keisuke NAKANO [2]

[1] Nagaoka College of Technology, Japan
[2] Dept. of Information Engineering, Niigata University, Japan

1 Introduction

In cellular systems, a mobile terminal is always connected to a base station (BS) during communication even if it communicates with another mobile terminal in the same cell. A new type of a cellular system is proposed, in which a mobile terminal is directly connected to another terminal if these terminals are close to each other only using one channel.

In [1], a theoretical technique for analyzing traffic characteristics of circuit switching calls in cellular networks with direct connection is proposed in a circular cell, where terminals are independently and uniformly distributed over the cell. In [2], we present theoretical analysis of direct communication and performance improvement in a one-dimensional cell with localized distribution. In [3], authors present theoretical analysis of direct communication and performance improvement in a two-dimensional cell with localized distribution. However, the mobility of terminals is not considered in the analysis. Mobility is an important factor. A direct connection between terminals can potentially fail due to mobility because the distance between them may become greater than the communication range for direct communication before the end of communication. In such a case, improvement of the efficiency of channel use depends on how long direct communication is possible before the direct link breaks. In [4], theoretical analysis with the effects of mobility is presented. However, it is assumed that a source terminal does not move from the point after call origination and only destination terminal moves in the cell. We extend our study to the analysis of the teletraffic characteristics in the model that two terminals move in a cell. We consider the model that there exist the points that terminals stay and tend to gather in a cell. The mean holding time of direct communication is important factor for teletraffic analysis. Hence, we theoretically evaluate the mean of the holding time for direct communication with the effect of mobility of terminals.

2 Definitions and Assumptions

Let us assume circular cell with radius R, as shown in Fig. 1. In this figure, BS means a base station. We assume the following: the received power levels are always sufficient for direct communication if the distance between the two terminals is not longer d. If the distance between the two terminals is not greater than d, these terminals can directly communicate with each other using one channel. Otherwise, these terminals are relayed by the BS, using two channels.

We consider a single cell system. We assume that two terminals can judge by themselves whether direct communication between them is possible or not based on the received power levels of control signals which are sent to each other. In this paper, we assume that the received power levels are always sufficient for direct communication if the distance between the two terminals is not longer d. We also assume that the terminals notify a BS of the result of the judgment. Then, we assume the following: Let Y be the distance between two terminals. If Y is not greater than d, these terminals can directly communicate with each other using one channel. Otherwise, these terminals are relayed by the BS, using two channels. Channel assignment is always done by the BS. The BS assigns a channel to a call which is carried by direct communication and assigns two channels to a call which is relayed by the BS based on the result of the judgment which is sent from the terminals. We assume that a channel is not spatially reused in a cell.

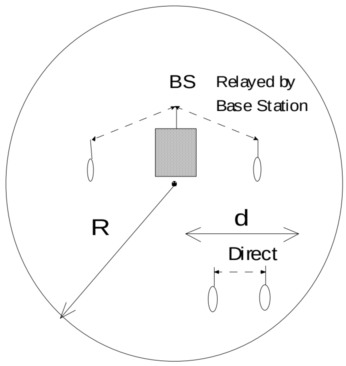

Fig. 1. Model of cell and communication range.

3 Mean Holding Time for Direct Communication

3.1 Definitions and Assumptions

We consider a one-dimensional model. Assume that each of the places is a point on the one-dimensional cell as represented in Fig. 2. Let x_i be the point i, where i = - n, ..., n. Distance between x_i and x_{i+1} is equal to 1, for $-n \le i \le n-1$.

We use a walk model of terminals. In this model, a terminal exists at one of the $(2n+1)$ points. It remains static for a pause time t_p at the point and then starts moving one step to the right or one step to the left. This movement is repeated according to the same rule. We assume that a terminal leaves the cell when it moves to the point x_{n+1} or the point x_{-n-1}.

Let us denote a source terminal with A and a destination terminal with B, as shown in Fig. 2. Denote the range in which a terminal can directly communicate with the terminal A with d. For simplicity, we assume that source A moves one step to the left and destination B moves one step to the right. Furthermore, we assume that terminal A and B stay at the same point x_0 at the time at which the terminal A aims to communicate with B.

We assume following: The pause time t_p obey an exponential distribution with a mean of t_s. The lifetime of a call obeys an exponential distribution with a mean of h_0.

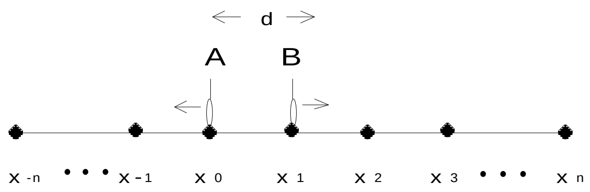

Fig. 2. One-dimensional model.

3.2 Analysis

We assume that source terminal A and destination terminal B exist at the same point x_0 after call origination. In this situation, source A can directly communicate with destination B.

Let us consider the mean of the holding time for direct communication, which is the time interval between the time at which direct communication begins and the time at which direct communication ends.

First, we consider the mean holding time for direct communication in the case that d is equal to 0. Let $s_{i,j}$ denote the state that terminal A exists at the point x_i and terminal B exists at the point x_j ,where $i = -n, ..., n$ and $j = -n, ..., n$. In this case, direct communication between terminals fails when terminal A moves one step to the left or terminal B moves one step to the right. Let t_{d1} be the mean of the time in this case. The probability that transition from $s_{0,0}$ to $s_{-1,0}$ or $s_{0,1}$ occurs is equal to 1/2. Therefore, t_{d1} is represented as follows:

$$t_{d1} = \frac{t_s}{2}. \tag{1}$$

Let h_1 be the mean holding time for direct communication. We assume that the lifetime of a call and the pause time obey an exponential distribution. Therefore, h_1 can be computed by the following equation :

$$h_1 = \frac{1}{\frac{1}{h_0} + \frac{1}{t_{d1}}}. \tag{2}$$

In second case, we consider the mean holding time for direct communication in the case that d is equal to 1. In this case, direct communication between terminals fails when the distance between two terminals becomes 2. Let t_{d2} be the mean of the time in this case. The mean of the time interval from the time at which direct communication begins to the time at which terminal A moves one step to the left or terminal B moves one step to the right is equal to t_s. The probability that transition from $s_{0,0}$ to $s_{0,2}$ or $s_{-1,1}$ occurs is equal to 1/4. The probability that transition from $s_{0,0}$ to $s_{-2,0}$ or $s_{-1,1}$ occurs is equal to 1/4. Therefore, t_{d2} is represented as follows:

$$t_{d2} = t_s + \frac{t_s}{4} = \frac{5t_s}{4}. \tag{3}$$

Let h_2 be the mean holding time for direct communication. h_2 can be computed by the following equation :

$$h_2 = \frac{1}{\frac{1}{h_0} + \frac{1}{t_{d2}}}. \tag{4}$$

3.3 Results and Discussions

The numerical results of the mean holding time h_1 for h_0 = 30, 60, and 90s are shown in Fig. 3. The horizontal axis is the mean pause time t_s. The results of computer simulations are also plotted in the figure. h_1 increases as h_0 and t_s increase. The theoretical results almost agree with the simulation results. From these results, we confirm the validity of the analysis.

The numerical results of the mean holding time h_2 are also shown in Fig. 4. The theoretical results almost agree with the simulation results. From these results, we confirm the validity of the analysis.

4 Conclusion

We theoretically evaluate the mean of the holding time for direct communication with the effect of mobility of terminals using a walk model of terminals. In the future, we plan to extend the theoretical methods to teletraffic analysis of carried traffic, two-dimensional scenarios, and other motion patterns.

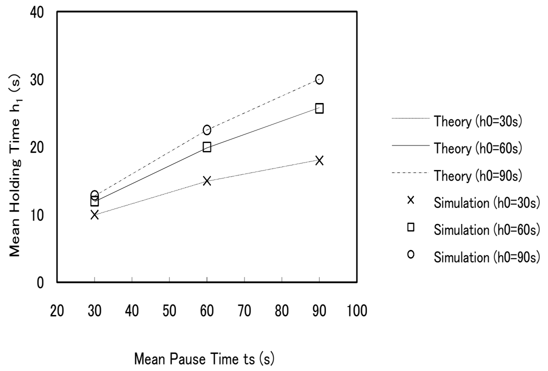

Fig. 3. Mean holding time (d=0).

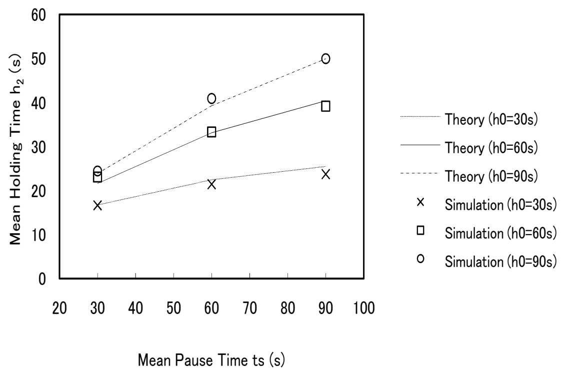

Fig. 4. Mean holding time (d=1).

References

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