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# 임의 요구 가용도의 성질과 근사방법

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# Properties and Approximation Method of the Random-Request Availability

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The characteristic of the random-request availability is that random task arrival is included as one of system elements. If the mean number of task arrivals grows, the computational complexity for deriving the random-request availability becomes extremely high. Using a simulation method, the effect of 'random task arrival' elements on the random-request availability is investigated. Some approximation methods are also discussed.

***Keywords*** : random-request availability, random task arrival, system state, operational requirement of the system

## 1. Introduction

In addition to traditional availabilities such as point availability, interval availability, and steady-state availability, special measures have been proposed to represent availabilities for specific application systems. Reibman (1990) introduced computation- availability to describe system performance and reliability. There are several other kinds such as mission availability, work mission availability, and joint availability(A. Birolini, 1998).

Some systems require to perform randomly arriving tasks during the fixed mission duration. Example might include the packet switching network system, which processes randomly arriving packets. Other examples include:

- a fault-tolerance mechanism which is required to handle errors resulting from transient errors (called single-event upsets) and permanent failures of system components,
- an information-measuring system which operates continuously and delivers information on user-demand only at some random moments of time.

For such systems the new availability measure, random- request availability, has been proposed by Lee (2000). The stochastic model provides closed-form mathematical expression, which incorporates 3 basic elements:

1. Random Task Arrival
   A system is presented with a stream of tasks which arrive according to some random processes.
2. System State
   The system has periods of operation and repair that form an alternating process. At each task arrival time, the system is in 1 of 2 states; On or Off.

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3. Operational Requirement of the System
For mission success, it might not be necessary to complete all the tasks arriving randomly during the mission time, i.e., completion of some of the arriving tasks might lead to mission success. For the operational requirements of the system, 3 systems are introduced :
i ) perfect system, ii ) $r(k)-out-of-k$ system, and iii) scoring system.

The random-request availability is defined for each of the following 3 systems.

i . Perfect System: The system needs to be in the On-state at every task arrival time.
ii . $r(k)-out-of-k$ System: The system needs to be in the On-state at the times of at least some task arrivals. The minimum number, $r(k)$, depends on the number of task arrivals, $k$.
iii. Scoring System: If the system is in the On-state at $j\,(j \le k)$ out of $k$ task arrival times, a score $S_{j,k}$ is given to denote the successful completion of the mission. The conventional interval availability is a special case of the scoring system, with $S_{j,k} = j/k$.

Based on the mission effectiveness model of Lee *et al.* (1990), the multiple availability on stochastic demand was suggested by Finkelstein (1999) and some useful applications were discussed. Since the multiple availability does not include operational requirements as a system element, however, its usefulness is rather limited. The multiple availability can be considered as the random-request availability for the perfect system.

The main contribution of stochastic models developed by Lee(2000) is to introduce random task arrival into the availability measure. The task arrival rate might be constant, or time-dependent function. The random-request availability must have different values according to the task arrival rates and its rate pattern. Due to the computational complexity, however, the effect of 'random task arrival' element on the random-request availability has not been investigated. In this paper, simulation method is used to derive the random-request availability. Varying the task arrival rate, arrival rate pattern, and the length of sojourn times in On and Off-states, the random -request availability is obtained for each of the following three systems: the perfect, the $r(k)-out-of-k$, and the scoring systems. From the simulation results, the effect of 'random task arrival' element on the availability can be seen under the various system parameter values.

If the mean number of task arrivals is large, the computational complexity is extremely high. If there are average two task arrivals during the mission time under the Poisson arrival assumption, the seventh order of multiple integral is required to get a solution with error bound less than $10^{-2}$. Simple approximation formulae were suggested without estimating the level of accuracy by Finkelstein(1999). In this paper, using simulation method we can show that his approximation is reasonably accurate over the significant range of system parameters. However, his approximation method is good only for the perfect system. It seems that to get approximation methods for the $r(k)-out-of-k$ and the scoring systems is not easy because of the inherent complexity of the system. In this paper, we suggest simple intuitive method based on the interval availability value. Even though this method seems to be rudimentary, it gives accurate results for some range of system parameters.

## 2. Mathematical Expression for the Random-Request Availability and Simulation Model

### Notation

| | |
|---|---|
| $A(t_1, t_2, \cdots, t_k)$ | random-request availability, given task arrival times: $t_1, t_2, \cdots, t_k$ |
| $A(T)$ | random-request availability for mission of length $T$ |
| $M(T)$ | mean value function of a non-homogeneous Poisson process |
| $N(T)$ | number of tasks arriving during time $T$ |
| $T$ | mission-duration time |
| $Z(t)$ | indicator variable for the system state at time $t$ 0: Off-state 1: On-state |
| $ST_{on}, ST_{off}$ | mean sojourn times for the [On, Off] system state |
| $m(t)$ | $dM(t)/dt$: task-arrival rate |
| $r(k)$ | minimum number of tasks which must be in the On-state, given $k$ task arrivals |
| $F_d(x)$ | $\exp[-\int_0^x m(\mu)\,d\mu]$ |
| $f_d(x)$ | $dF_d(x)/dx$ |
| $\theta(t)$ | $\Pr[Z(t)=0]$ |
| $M$ | average number of On-Off cycles during the mission time, $M = T/(ST_{on} + ST_{off})$ |
| $\alpha, \beta$ | rate parameters of the exponential distributions for the [On, Off] system states |

**Assumption**

1. Task arrival is a non-homogeneous Poisson process with mean-value function $M(T)$
2. The random variable representing the system state(On or Off) follows a time homogeneous Markov process. The sojourn times in both states are exponentially distributed.
3. The mission time is of fixed duration, $T$.
4. The mission is defined to occur when, and only when, there are task arrivals.

### 2.1 Random-Request availability

The random-request availability can be expressed as follows (K. W. Lee, 2000).

$$A(T)=\frac{\sum_{k=1}^{\infty}\left[\int_{0\le t_1<t_2<\cdots<t_k\le T}\cdots\int A(t_1, t_2, \cdots, t_k)\cdot\prod_{i=1}^{k} m(t_i)\,dt_1\,dt_2\cdots dt_k\right]\cdot\exp[-M(T)]}{1-\exp[-M(T)]} \quad (1)$$

The mathematical expressions for $A(t_1, t_2, \cdots, t_k)$ can be also seen in Lee(2000) for the perfect, the $r(k)-out-of-k$, and the scoring systems.

### 2.2 Simulation Model

As the number of task arrivals during the mission time increases, the calculation burden of the above equation (1) grows enormously. Simulation method can be used to get a solution. The simulation model is constructed using ARENA simulation language. The task arrival time is generated according to the non-homogeneous Poisson process. At each task arrival time, the system state is observed. Base on this observation, the random-request availabilities for the perfect, the $r(k)-out-of-k$, and the scoring systems are determined.

The simulation results are compared with the analytical ones in the following example. To obtain the analytical solution without much computation using equation (1), we assume an average of only 0.8 task arrivals during the mission for all 3 types of task arrivals.

Example 1.

1. 3 types of task arrivals with:
   - type 1: $m_1(t) = 0.016t$
   - type 2: $m_2(t) = 0.08$
   - type 3: $m_3(t) = 0.16-0.016t$
2. Mission duration time is $T=10$ ; This produces an average of 0.8 task arrivals during the mission.
3. Sojourn times in On and Off system-states follow the negative exponential distributions with $\alpha=1$ and $\beta=5$, respectively.
4. For the $r(k)-out-of-k$ system,
   - $r(k) = \left[\frac{k}{2}\right]$, for an even $k$
   - $r(k) = \left[\frac{k}{2}\right]+1$, for an odd $k$
5. For the scoring system, $S^1_{j,k} = j/k$ or $S^2_{j,k} = (j/k)^2$ (In this example, only $S^1_{j,k}$ is used.)

**Table 1.** The comparison of the Analytical and the Simulation Results

| Arrival rate / Result / System | $m_1(t)=0.016(t)$ Analytic | $m_1(t)=0.016(t)$ Simulation | $m_2(t)=0.08$ Analytic | $m_2(t)=0.08$ Simulation | $m_3(t)=0.16-0.016(t)$ Analytic | $m_3(t)=0.16-0.016(t)$ Simulation |
|---|---|---|---|---|---|---|
| Perfect | 0.776 | 0.777 | 0.779 | 0.779 | 0.782 | 0.783 |
| $r(k)$-out-of-$k$ | 0.876 | 0.876 | 0.879 | 0.879 | 0.880 | 0.880 |
| Scoring( $S^1_{j,k}$) | 0.833 | 0.834 | 0.836 | 0.837 | 0.838 | 0.839 |

Following <Table 1> compares the analytical and the simulation results. The system is assumed to be On at time 0. The error bound of the analytical solution is less than $10^{-3}$. The simulation result is the average of $10^7$ runs after some warm-up period.

## 3. Effect of Random Task Arrival upon the Random-Request Availability

The characteristic of the random-request availability is that random task arrival is included as one of the system elements. In this section, we try to identify the role of random task arrival and see the effect of 'random task arrival' element upon the random-request availability through the simulation.

### 3.1 Task Arrival Rate

Needless to say, the random-request availability has the different value according to the task arrival rate. Varying the type $1(m_1(t))$ task arrival rate(or average number of task arrivals), the values of the random-request availability are obtained with the system parameters of Example 1. The results are shown in the <Table 2>, from which we can see that the effect of task arrival rate is different according to the operational requirements of the system.

For the perfect system, higher task arrival rate gives the lower value of availability, and vice versa. As the task arrival rate increases, the values for the $r(k)-out-of-k$ and the scoring systems can be increasing, decreasing, or even constant depending on the respective $r(k)$ value and score $S_{j,k}$ for a given $k$.

**Table 2.** Task Arrival Rate vs Random-Request Availability

| Task Arrival Rate (Average) / System | $m_1(t)=0.02t$ (1) | $m_1(t)=0.04t$ (2) | $m_1(t)=0.1t$ (5) | $m_1(t)=0.18t$ (9) | $m_1(t)=0.2t$ (10) |
|---|---|---|---|---|---|
| Perfect | 0.761 | 0.683 | 0.463 | 0.313 | 0.245 |
| *r(k)-out-of-k* | 0.884 | 0.915 | 0.958 | 0.975 | 0.982 |
| Scoring ($S^1_{j,k}=j/k$) | 0.833 | 0.834 | 0.834 | 0.833 | 0.833 |
| Scoring ($S^2_{j,k}=(j/k)^2$) | 0.802 | 0.778 | 0.736 | 0.720 | 0.716 |

Especially, in the case of the scoring system with $S^1_{j,k}=j/k$, the availability has almost constant value irrespective of the task arrival rate. This value is just the conventional interval availability which can be calculated as:

$$\int_0^{10}\left[\frac{5}{6}+\frac{1}{6}\exp(-6t)\right]\cdot\frac{m(t)}{M(T)}\,dt$$
$$=0.8334$$

### 3.2 Task Arrival Rate Pattern

Three types of task arrivals are considered: increasing, constant, and decreasing. Varying the average number of task arrivals during the mission time and the mean length of sojourn times in On and Off-states, the values of random-request availability are obtained for the perfect, the $r(k)-out-of-k$, and the scoring systems. Other system parameters are same as those of Example 1. The results are shown in <Table 3>, from which we can see that the random-request availability has different value according to the task-arrival rate patterns, even though missions have the same average task arrivals during the mission time.

Even though three types of task arrival rates produce same average number of task arrivals during the mission, the arrival rate patterns can be different from each other. That is, $m_3(t)$ ($m_1(t)$) gives a higher task arrival rate at the beginning(latter) part of the mission than at the latter(beginning) part. Therefore, if the system is in On- state at time 0, $m_3(t)$ produces higher random-request availability than $m_1(t)$ and $m_2(t)$. A similar argument shows that the assumption of the system being Off at time 0 provides higher random-request availability under $m_1(t)$ than under $m_2(t)$ and $m_3(t)$. As can be seen in <Table 3>, the above fact can be more clearly seen when the number of On-Off cycle ($M$) during the mission has small value, that is, relatively long sojourn times in On and

**Table 3.** Task Arrival Rate Pattern vs Random Request Availability

| Mean Sojourn Time in On and Off States | Average number of Task Arrivals / Task Arrival Rate Pattern / System | 1 | | | 5 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $m_1(t)=0.02t$ | $m_2(t)=0.1$ | $m_3(t)=0.2-0.02t$ | $m_1(t)=0.1t$ | $m_2(t)=0.5$ | $m_3(t)=1-0.1t$ | $m_1(t)=0.2t$ | $m_2(t)=1$ | $m_3(t)=2-0.2t$ |
| * $ST_{on}=0.1$ $ST_{off}=0.02$ ($M$=83.33) | Perfect | 0.758 | 0.759 | 0.758 | 0.434 | 0.436 | 0.435 | 0.195 | 0.195 | 0.196 |
| | *r(k)-out-of-k* | 0.887 | 0.887 | 0.887 | 0.967 | 0.968 | 0.968 | 0.991 | 0.992 | 0.992 |
| | Scoring ($S^1_{j,k}=j/k$) | 0.834 | 0.834 | 0.834 | 0.833 | 0.834 | 0.834 | 0.833 | 0.833 | 0.834 |
| * $ST_{on}=1$ $ST_{off}=0.2$ ($M$=8.33) | Perfect | 0.761 | 0.764 | 0.770 | 0.463 | 0.461 | 0.474 | 0.245 | 0.237 | 0.255 |
| | *r(k)-out-of-k* | 0.833 | 0.886 | 0.889 | 0.958 | 0.961 | 0.961 | 0.982 | 0.984 | 0.984 |
| | Scoring ($S^1_{j,k}=j/k$) | 0.833 | 0.836 | 0.840 | 0.834 | 0.836 | 0.839 | 0.834 | 0.836 | 0.839 |
| * $ST_{on}=50/6$ $ST_{off}=10/6$ ($M$=1) | Perfect | 0.792 | 0.808 | 0.831 | 0.619 | 0.623 | 0.671 | 0.512 | 0.507 | 0.564 |
| | *r(k)-out-of-k* | 0.873 | 0.891 | 0.903 | 0.904 | 0.929 | 0.936 | 0.910 | 0.938 | 0.943 |
| | Scoring ($S^1_{j,k}=j/k$) | 0.841 | 0.857 | 0.874 | 0.841 | 0.857 | 0.874 | 0.841 | 0.857 | 0.874 |
| ** $ST_{off}=10/6$ $ST_{on}=50/6$ ($M$=1) | Perfect | 0.739 | 0.632 | 0.546 | 0.529 | 0.353 | 0.27 | 0.394 | 0.198 | 0.138 |
| | *r(k)-out-of-k* | 0.840 | 0.772 | 0.692 | 0.877 | 0.822 | 0.723 | 0.884 | 0.837 | 0.711 |
| | Scoring ($S^1_{j,k}=j/k$) | 0.799 | 0.716 | 0.634 | 0.800 | 0.718 | 0.633 | 0.800 | 0.717 | 0.633 |

( * : The system is On at time 0, * * : The system is Off at time 0)

Off-states compared to the mission time. For large $M$, the random-request availability has almost same value irrespective of the arrival rate pattern. Above <Table 3> also shows that the effect of arrival rate pattern upon random-request availability is more significant in the perfect system than in the $r(k)-out-of-k$ and the scoring systems. On the while, the effect of arrival rate pattern on the availability does not change as the arrival rate increases, and seems to be independent of the arrival rate. For the scoring system with $S^1_{j,k}=j/k$, the random-request availability is just the conventional interval availability. From <Table 3>, we can see that this value depends on the task arrival rate pattern, not the average number of task arrivals.

# 4. Approximation of the Random-Request Availability

As mentioned in 1. Introduction, the computational complexity for deriving the random-request availability becomes extremely high if the mean number of task arrivals grows. In this section, some approximation methods are discussed. For the perfect system, the approximation formula suggested by Finkelstein(1999) is introduced and the level of accuracy is estimated. Some simple approximation methods are provided for the $r(k)-out-of-k$ and the scoring systems.

## 4.1 Approximation for the Perfect System by Finkelstein

For the perfect system, Finkelstein provided a heuristic approximation method without estimating the accuracy level. His approximation formula is given by (Finkelstein, 1999)

$$\tilde{A}_{PF}(T)=\frac{\exp\left[\int_0^T \lambda_b(\mu)\,d\mu\right]-\Pr[N(T)=0]}{1-\Pr[N(T)=0]} \quad (2)$$

where

$$\lambda_b(t)=\theta(t)\cdot f_d(t)+f_d(t)\int_0^t m(t)\frac{\theta(t-\mu)}{1-F_d(\mu)}\,d\mu$$

Varying the task arrival rate and the mean sojourn times in On and Off-states, the random-request availability is estimated using the equation (2). Other system parameters are same as those of Example 1. The estimation results are compared with the simulation results, which are shown in <Table 4>.

From <Table 4>, we can see that the approximation using equation (2) is relatively accurate over the quite range of system parameters. And it can be also seen that the estimation accuracy becomes higher for larger $M$ and lower task arrival rate.

## 4.2 Approximation Based on the Interval Availability

It seems to be difficult to get approximation methods for the $r(k)-out-of-k$ and the scoring systems. One of the simple intuitive method is to use the conventional interval availability. Taking the task arrival rate into consideration, it can be expressed as

$$\bar{A}(T)=\int_0^T \Pr[z(t)=1]\cdot\frac{m(t)}{M(T)}\,dt$$

**Table 4.** Comparison of the Finkelstein Approximation and the Simulation Results

| Task Arrival Rate (Average) / Result / Mean Sojourn Time in On and Off-States | $m_2(t)=0.1$ (1) | | $m_2(t)=0.5$ (5) | | $m_2(t)=1$ (10) | |
|---|---|---|---|---|---|---|
| | Estimation Using Equation (2) | Simulation | Estimation Using Equation (2) | Simulation | Estimation Using Equation (2) | Simulation |
| $ST_{on}=0.1$, $ST_{off}=0.02$ ($M=83.33$) | 0.758 | 0.759 | 0.434 | 0.436 | 0.195 | 0.195 |
| $ST_{on}=1$, $ST_{off}=0.2$ ($M=8.33$) | 0.764 | 0.764 | 0.465 | 0.461 | 0.245 | 0.237 |
| $ST_{on}=50/6$, $ST_{off}=10/6$ ($M=1$) | 0.809 | 0.808 | 0.634 | 0.623 | 0.518 | 0.507 |

Then, the approximate values for the perfect, the $r(k)-out-of-k$, and the scoring systems can be respectively expressed as follows.

$$\widetilde{A}_p(T)=\frac{\sum_{k=1}^{\infty}\{\overline{A}(T)\}^k\cdot \Pr[N(T)=k]}{1-\Pr[N(t)=0]} \quad (3)$$

$$\widetilde{A}_r(T)=\frac{\sum_{k=1}^{\infty}\left\{\sum_{j=r(k)}^{k}\binom{k}{j}\{\overline{A}(T)\}^j\{1-\overline{A}(T)\}^{k-j}\right\}\cdot \Pr[N(T)=k]}{1-\Pr[N(t)=0]} \quad (4)$$

$$\widetilde{A}_s(T)=\frac{\sum_{k=1}^{\infty}\left\{\sum_{j=0}^{k}\binom{k}{j}\{\overline{A}(T)\}^j\{1-\overline{A}(T)\}^{k-j}\cdot S_{j,k}\right\}\cdot \Pr[N(T)=k]}{1-\Pr[N(t)=0]} \quad (5)$$

Using above equations (3), (4), and (5), the approximation values for the random-request availability are obtained under various system parameter values. The approximate results are compared with the simulation results in <Table 5>.

For the perfect system, the approximation accuracy is low compared to that using Finkelstein's formula. We can see that the approximation inaccuracy grows quickly as the $M$ becomes small and task arrival rate increases. The approximation results for the $r(k)-out-of-k$ and the scoring systems are more accurate than those for the perfect system. They show better accuracy for larger $M$ and lower task arrival rate. Given the value of $M$, we try to find out maximum number of average task arrivals which satisfies the accuracy requirement, | simulation result − approximation result | $\leq 10^{-2}$. <Table 6> shows the results. The task arrival rates for all the systems are assumed to be decreasing function, that is, such as type 3 task arrival of Example 1. For example, average one task arrival corresponds to $m_3(t)=0.2-0.02t$. Other system parameters are same as those of Example 1. From <Table 6>, we can see that the $r(k)-out-of-k$ and the scoring systems can satisfy the approximation accuracy requirement with higher task arrival rate than the perfect system.

For the $r(k)-out-of-k$ and the scoring systems, the approximation accuracy also depends on the respective $r(k)$ value and score $S_{j,k}$ for a given $k$. We can see low accuracy in the perfect system, which is the most strict case of the $r(k)-out-of-k$ system ($r(k)=k$ for all $k$) or the scoring system ($S_{j,k}=1$ for $j=k$, and 0, otherwise). Therefore, the more strict the

**Table 5.** Comparison of the Approximation and the Simulation Results

| System | Task Arrival Rate (Average) \ Results \ Mean Sojourn Time in On and Off States | $ST_{on}=0.1$, $ST_{off}=0.02$ ($M=83.33$) Approximation | $ST_{on}=0.1$, $ST_{off}=0.02$ ($M=83.33$) Simulation | $ST_{on}=1$, $ST_{off}=0.2$ ($M=8.33$) Approximation | $ST_{on}=1$, $ST_{off}=0.2$ ($M=8.33$) Simulation | $ST_{on}=50/6$, $ST_{off}=10/6$ ($M=1$) Approximation | $ST_{on}=50/6$, $ST_{off}=10/6$ ($M=1$) Simulation |
|---|---|---|---|---|---|---|---|
| Perfect | $m_2(t)=0.1$ (1) | 0.758 | 0.759 | 0.761 | 0.764 | 0.788 | 0.808 |
| | $m_2(t)=0.5$ (5) | 0.431 | 0.436 | 0.437 | 0.461 | 0.484 | 0.623 |
| | $m_2(t)=1$ (10) | 0.189 | 0.195 | 0.194 | 0.237 | 0.238 | 0.507 |
| $r(k)$-out-of-$k$ | $m_1(t)=0.02t$ (1) | 0.887 | 0.887 | 0.887 | 0.884 | 0.892 | 0.873 |
| | $m_1(t)=0.1t$ (5) | 0.969 | 0.967 | 0.969 | 0.958 | 0.971 | 0.904 |
| | $m_1(t)=0.2t$ (10) | 0.993 | 0.992 | 0.993 | 0.982 | 0.994 | 0.910 |
| Scoring ($S_{j,k}=(j/k)^2$) | $m_3(t)=0.2-0.02t$ (1) | 0.802 | 0.802 | 0.807 | 0.810 | 0.847 | 0.855 |
| | $m_3(t)=1-0.1t$ (5) | 0.731 | 0.732 | 0.738 | 0.743 | 0.791 | 0.814 |
| | $m_3(t)=2-0.2t$ (10) | 0.711 | 0.712 | 0.719 | 0.724 | 0.775 | 0.802 |

**Table 6.** Maximum Number of Average Task Arrivals Satisfying the Accuracy Requirement

| System | Sojourn Times in On and Off-States | Maximum Number of Average Task Arrivals Satisfying the Accuracy Requirement, $10^{-2}$ |
|---|---|---|
| Perfect | $ST_{on}=0.1$, $ST_{off}=0.02$ ($M=83.33$) | ∞ |
| | $ST_{on}=1$ $ST_{off}=0.2$ ($M=8.33$) | 2 |
| | $ST_{on}=50/6$ $ST_{off}=10/6$ ($M=1$) | 0.5 |
| *r*(*k*)-*out-of-k* | $ST_{on}=0.1$, $ST_{off}=0.02$ ($M=83.33$) | ∞ |
| | $ST_{on}=1$ $ST_{off}=0.2$ ($M=8.33$) | 10 |
| | $ST_{on}=50/6$ $ST_{off}=10/6$ ($M=1$) | 1 |
| Scoring ($S_{j,k}=(j/k)^2$) | $ST_{on}=0.1$, $ST_{off}=0.02$ ($M=83.33$) | ∞ |
| | $ST_{on}=1$ $ST_{off}=0.2$ ($M=8.33$) | ∞ |
| | $ST_{on}=50/6$ $ST_{off}=10/6$ ($M=1$) | 2 |

operational requirement is, the lower the approximation accuracy for the $r(k)-out-of-k$ and the scoring system is, and vice versa.

## 5. Conclusions

The characteristic of the random-request availability is that the random task arrival is included as one of the system elements. Using the simulation method, the effect of 'random task arrival' element on the random-request availability has been investigated.

If the mean number of task arrivals grows, the computational complexity for deriving the random-request availability becomes extremely high. Some approximation methods are discussed. For the perfect system, the Finkelstein's heuristic approximation method turns out to be accurate over the significant range of system parameters. Simple approximation based on the interval availability is suggested. Even though this method seems to be rudimentary, it gives accurate results for the $r(k)-out-of-k$ and the scoring systems under some range of system parameters.

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