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Role and usage of reliability indices in computer application having a primary and secondary unit

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Abstract
A cold standby system is a type of redundancy arrangement used in different fields, including computing, healthcare, manufacturing sector and industrial processes. In a cold standby system, a secondary system is kept in a state of readiness but is not actively running or processing data. Instead, it remains in a powered-off or idle state until it is required in case of any failure or performance degradation of the main unit. In this paper, I have mentioned the role and usage of important Reliability indices like mean time to system failure, mean sojourn time, Steady State Availability, Busy period of the server due to repair, expected number of visits by the server, expected profit earned by the system in (0, t) etc. which can be used to design the complex computer application architecture. These indices can be derived when the system is exposed to different weather conditions – normal and abnormal weather. The semi-Markov process and regenerative point technique can be used to calculate the different reliability indices which helps to assess the overall performance of the system in different conditions.

Keywords: Reliability analysis, environmental conditions, cold standby system, semi-markov process, regenerative point technique, system availability and performance

1. Introduction

In today's world, the cold standby system in software industry serves important purposes in ensuring the availability, reliability, and continuity of software applications and services. The cold standby systems are commonly used in disaster recovery scenarios, where organizations need a secondary system to recover from unexpected failures. They are also used in situations where the cost of maintaining an active secondary system is very high. Some of the main characteristics that are depicted by a cold standby system –

- **Inactive State:** The secondary system is not running any processes or applications. It is typically powered off or in a low-power, dormant state.
- **Delayed Activation:** When the primary system fails or encounters a problem, the cold standby system is activated to take over its functions. This activation process can take some time, as the secondary system needs to be initialized, and configured.
- **Lower Operational Costs:** Cold standby systems are cost-effective compared to hot standby or active-standby systems because they consume fewer resources when not in use.
- **Suitable for Non-Critical Systems:** Cold standby systems are often used for systems where the downtime associated with the secondary system's activation is acceptable for a certain period.
- **Semi-Automatic Activation:** In many cases, the activation of a cold standby system requires manual intervention or human oversight. However, some systems may have automated mechanisms to detect the failure of the primary system and initiate the secondary system's activation.

Reliability is a fundamental attribute for the safe operation of any modern technological system. In reliability theory, it is proved that redundancy plays an important role in enhancing system reliability and to reduce the frequency of failure up to a desirable extent. It also plays a crucial role in assessing and optimizing the performance and effectiveness of cold standby systems. It helps to determine the following points –

- **Reliability Assessment:** It is a systematic process used to evaluate the dependability and performance of systems over time. It involves analyzing data, conducting tests, and using mathematical models and techniques to predict how reliable a system is or will be in future. In case of a cold standby system, it helps assess the probability of the system successfully taking over when the primary system fails.
- **Failure Analysis:** Reliability analysis considers various failure modes, including both primary and secondary systems. It helps identify potential failure points, their probabilities, and consequences. For a cold standby system, this analysis helps to determine the chances of failure in the primary system and the effectiveness of secondary system in case of failure.
- **Redundancy Assessment:** The cold standby systems rely on redundancy, having a secondary system in place. Reliability analysis helps to evaluate the redundancy strategy in terms of its cost-effectiveness and ability to ensure system availability. It considers multiple factors like the reliability of individual systems, the switch-over time from the primary to the secondary system, and the overall system availability.
- **Optimization:** Reliability analysis can be used to optimize cold standby systems. This includes determining the appropriate level of redundancy, selecting reliable components, and minimizing the downtime during the transition from the primary to the secondary system.
- **Maintenance Planning:** Reliability analysis can inform maintenance strategies for cold standby systems. It helps in scheduling proactive maintenance on the primary system to reduce the risk of failure and ensures that the secondary system remains in a ready state.
- **Risk Assessment:** Reliability analysis also considers risk assessment, evaluating the consequences of system failures and their impact on operations. The analysis can help quantify the risks associated with the primary system's failure and the effectiveness of the secondary system in mitigating those risks.

Scholars including Malik S and Deswal S (2012 – 2021) [1] have performed an extensive research on stochastic analysis of two non-identical systems at cold standby under different weather conditions. Later, Malik *et al*. (2012) [1] assessed the cost benefit of a two-unit cold standby system subject to degradation, inspection and priority. This research work was further extended to include the concept of priority for operation and repair between the primary and secondary system. Yadav, RK and Mailk, SC (2020-2022) [7] have evaluated the reliability of a computer system with unit wise cold standby redundancy with different aspects like priority to hardware repair subject to failure of service facility, failure of Service Facility during Software Up-gradation etc. Mundey, V.J *et al*. examined the Profit Analysis of a Computer System with Software Redundancy Subject to Hardware Inspection.

The goal of the present paper is to provide applications in computer domain where the cold-standby system is used and mention the mathematical techniques used to assess certain reliability measures.

2. Cold standby setup in Computer Applications

- **Database Servers:** In a database system, a cold standby server can be set up as a backup to the primary database server. It remains in an offline or idle state until needed. When the primary server fails, data can be restored to the standby server, which is then brought online to take over as the primary database server. This minimizes data loss and downtime during a database server failure.
- **Web Servers:** For web applications, a cold standby web server can be deployed alongside the active server. The standby server is not actively serving traffic but can quickly take over if the primary server experiences issues. Load balancers or DNS failover mechanisms can be used to switch traffic to the standby server when necessary.
- **Application Servers:** In a distributed application environment, cold standby application servers can be maintained. These standby servers are not running application instances but can be activated when needed. If a primary application server fails, requests can be redirected to the standby server, which is then started and configured to handle the workload.
- **Disaster Recovery:** In a broader sense, cold standby systems can be part of a disaster recovery strategy for an entire data center or infrastructure. An entire secondary data center or cloud environment may be kept in a cold standby state. If the primary data center experiences a catastrophic failure, operations can be shifted to the secondary data center, ensuring business continuity.
- **Batch Processing:** In batch processing scenarios, where large volumes of data need to be processed periodically, a cold standby processing environment can be set up. The standby environment is not actively processing data but can be activated to handle batch jobs if the primary processing environment becomes unavailable.
- **Clustered File Systems:** Some clustered file systems use cold standby nodes that are not actively participating in file storage but can take over in case a primary node fails. This ensures data availability and redundancy in high-availability storage environments.
- **Network Equipment:** In networking, cold standby routers or switches can be used. These devices remain inactive until needed. If the primary router or switch fails, the standby device can be configured to take over network routing and switching functions.

3. Mathematics Processes for Reliability Analysis

The Reliability analysis can be done using well known semi-Markov process and regenerative point technique which are briefly described as:

Markov Process

If $\{X(t), t \in T\}$ is a stochastic process such that, given the value of $X(s)$, the value of $X(t)$, $t>s$ do not depend on the values of $X(u)$, $u<s$ Then the process $\{X(t), t \in T\}$ is a Markov process.

Semi-Markov Process

A semi-Markov process is a stochastic process in which changes of state occur according to a Markov chain and in which the time interval between two successive transitions is a random variable, whose distribution may depend on the state from which the transition take place as well as on the state to which the next transition take place.

Regenerative Process

Regenerative stochastic process was defined by Smith (1955) and has been crucial in the analysis of complex system. In this, we take time points at which the system history prior to the time points is irrelevant to the system conditions. These points are called regenerative points. Let X(t) be the state of the system of epoch. If t1, t2,... are the epochs at which the process probabilistically restarts, then these epochs are called regenerative epochs and the process {X(t), t = t1, t2.........} is called regenerative process. The state in which regenerative points occur is known as regenerative state.

4. Key Reliability Indices

The following measures of reliability for the systems are obtained:

- **Transition probabilities**

$$p_{ij} = Q_{ij}(\infty) = \int_0^\infty q_{ij}(t)dt$$

- **Mean Sojourn time in a state**

The expected time taken by the system in a particular state before transiting to any other state in known as mean sojourn time or mean survival time in that state. If Ti be the sojourn time in state i, then the mean sojourn time in state i is

$$\mu_i = \int_0^\infty \Pr(T_i > t)dt$$

- **Mean time to system failure**

Let $\emptyset_i(t)$ be the cdf of first passage time from regenerative state S_i to a failed state. Regarding failed state as absorbing state, we have following recursive relations for $\emptyset_i(t)$:

$$\emptyset_i(t)=\sum_j Q_{i,j}(t) Ⓢ \emptyset_j(t) + \sum_k Q_{i,k}(t)$$

Where S_j is the un failed regenerative state and $S_k$is the absorbed state. Taking L.S.T. of above relations and solving for $\emptyset_0^{**}(s)$,we get

$$\text{MTSF} = \lim_{s\to 0} \frac{1-\tilde{\phi}_0(s)}{s} = \frac{N_1}{D_1}$$

- **Steady State Availability**

Let $A_i(t)$ be the probability that the system is in up-state at instant 't' given that the system entered regenerative state S_i at t = 0. The recursive relations for $A_i(t)$ are given as

$$A_i(t)=M_i(t)+\sum_j q_{i,j}^{(n)}(t) © A_j(t)$$

Where S_j is any successive regenerative state to which regenerative state S_i can transits through n transitions.

Taking L.T. of above relations and solving for $A_0^*(s)$, we obtain

$$A_0(\infty) = \lim_{s\to 0} sA_0^*(s) = \frac{N_2}{D_2}$$

- **Busy period of the server due to repair**

Let $B_i(t)$ be the probability that the server is busy in repairing the unit at an instant 't' given that the system entered regenerative state S_i at t=0.The recursive relations for $B_i(t)$ are as follows:

$$B_i(t) = W_i(t) + \sum_j q_{i,j}^{(n)}(t) © B_j(t)$$

Taking L.T. of above relations and solving for $B_0^*(s)$,

$$B_0^*(\infty) = \lim_{s\to 0} sB_0^*(s) = \frac{N_3}{D_2}$$

- **Expected number of visits by the server**

Let $N_i(t)$ be the expected number of visits by the server in (0,t] given that the system entered the regenerative state S_i at t=0. The recursive relations for $N_i(t)$ are given as:

$$N_i(t) = \sum_j Q_{i,j}^{(n)}(t) Ⓢ [\delta_i + N_j(t)]$$

The expected numbers of visits per unit time by the server are given by

$$N_0(\infty) = \lim_{s\to 0} sN_0^{**}(s) = \frac{N_4}{D_2}$$

- **Expected profit earned by the system in (0, t)**

The profit incurred to the system Model in steady state can be obtained as

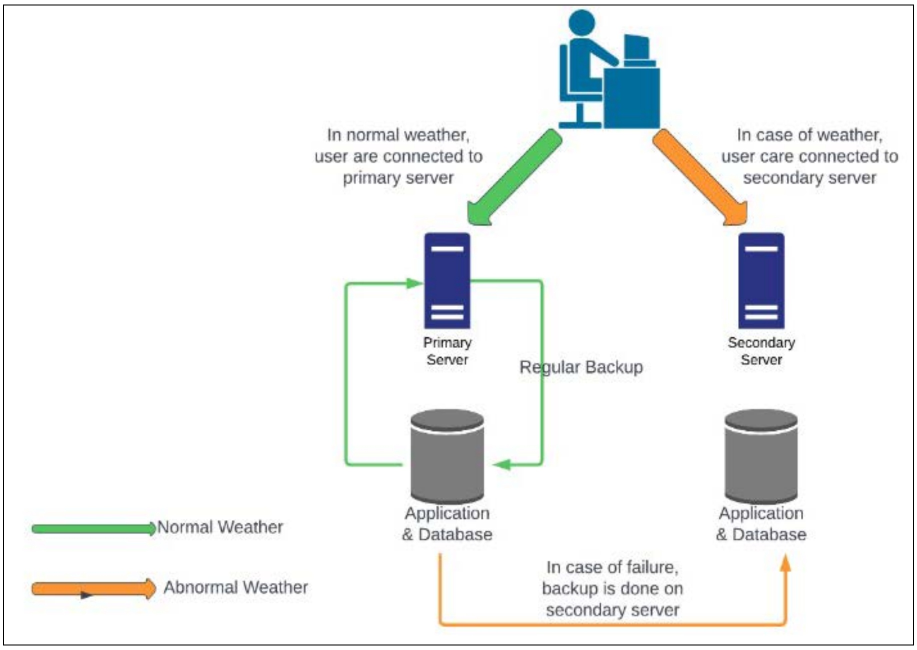
$P_i=K_0A_0-K_1B_0-K_2N_0$;K_0=Revenue per unit up-time of the system

K_1=Cost per unit for which server is busy

K_2= Cost per unit visit by the server and A_0, B_0, N_0 are already defined.

5. Cold Standby Implementation for Computer Applications

This is a sample Cold Standby implementation, which utilizes two servers, each acting as a primary (active) and secondary (backup) server respectively. The secondary server will remain dormant and will only be called upon if the primary server fails.



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