MA202 PROJECT

Analysis of system failure rates due to lost or delayed messages

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Abstract

In networked communications lost or delayed messages are bound to happen. If we are unable to anticipate these losses, we might experience system failures. In this Project we are going to discuss about system failures and how we can predict it based on the likelihood of message loses. It also illustrates sources of message losses and what measures we can adopt to reduce or eliminate them.

Introduction

Any communication network can't assure us of 100% on-time message delivery. Messages can be lost due to various reasons even in properly working network hardware. These reasons can be collisions, noise, network or internet connectivity issues, hardware or software malfunctions, human error, cybersecurity attacks. The occasional loss of messages is not a big issue if the system is built to handle it. However, system failures may occur if we fail to anticipate the loss of multiple messages simultaneously. Long periods of operation multiplied by the number of units in the field can transform small potential issues into significant maintenance problems, even when message losses are relatively uncommon.

System Failure Rates

We will assume that our system is not damaged, and failures will occur only due to message loses. In this project we will assume that if a message fails means it didn't get delivered within the specified deadline. The deadline may be different for different types of messages in the system. The number of max attempts in message transmission can be given by:

$$\text{Max attempts} = \frac{\text{deadline}}{\text{retry delay}} + 1$$

The probability that the network will attempt to send a message multiple times is referred to as the system failure rate. The probability that the system will fail when sending any given message is, assuming that failures are independent of one another:

$$\mathrm{P}_{\mathrm{system\_failure}} = [\mathrm{P}_{message\_fail}]^{\mathrm{max\ \_attempts}}$$

In an embedded system that transmits hundreds of messages per second for years at a time, things can add up quickly, even though the probability of failure for any given message is typically quite low. In this perspective, the failure rate per year is:

$$\mathrm{P}_{\mathrm{failure\_per\_year}} = \mathrm{P}_{\mathrm{system\_failure}} \times \mathrm{mps} \times 31557600$$

Where mps stands for messages per second

Errors Due to Noise

When messages are transmitted on systems, there is probability that some of the bits in the message can be corrupted by noise. This probability may depend on quality and the length of the network wire. A system can get contaminated with noise from a variety of sources, including thermal noise, interference from other signals, and distortions caused by the transmission medium. Data is sent as binary bits in digital communication systems, and noise can corrupt these bits and cause errors in the data that is received. The communication channel's signal-to-noise ratio (SNR), the modulation scheme used, and the error-correction coding applied to the transmitted data all influence the likelihood of bit errors caused by noise. The number of messages lost to bit errors can be estimated by:

$$\text{message error rate} = 1 - (1 - \text{bit error rate})^{\text{bits per message}}$$

Steady State Message Losses

The loss of messages in a communication system that is operating in steady-state conditions is referred to as steady state message losses. The message traffic in these systems is relatively predictable and stable, and the system is built to handle a certain amount of message traffic.

The probability that any given transmitters all occupy the same slot k out of s slots or the probability that n transmitters will collide in the kth slot out of s slots

$$P_n = \frac{1}{s^n}$$

But if there is a combination of n transmitters out of t transmitters, then probability in that case would be:

$$P_{total} = \binom{t}{n} P_n$$

$$P_{total} = \left(\frac{t!}{n!\,(t-n)!}\right) P_n$$

Now, the remaining transmitters must select slots after the kth slot because for collision to happen kth slot must be the first selected by any transmitter.

$$P_{rest} = 1$$ (k=s and n=t)

$$P_{total} = \left(\frac{s-k}{s}\right)^{t-n}$$ (otherwise)

Probability that collision will happen in kth slot will be

$$P_{nm} = P_{total} \times P_{rest}$$

$$P_{nm} = \left(\frac{1}{s}\right)^{n}$$

(m=s and n=t)

$$P_{nm} = \left(\frac{t!}{n!(t-n)!}\right)\left(\frac{1}{s}\right)^{n}\left(\frac{s-k}{s}\right)^{t-n}$$

(otherwise, n>1)

In a system that uses collision detection, the probability of a collision is simply the sum of probabilities of a collision in each slot

$$P_{collision} = \sum_{1}^{s}\sum_{2}^{t} P_{nm}$$

The average number of messages lost per transmission attempt will be

$$\text{Average msg lost} = \sum_{1}^{s}\sum_{2}^{t} \mathrm{n}\,\mathrm{P}_{nm}$$

Probability that message is being transmitted successfully will be

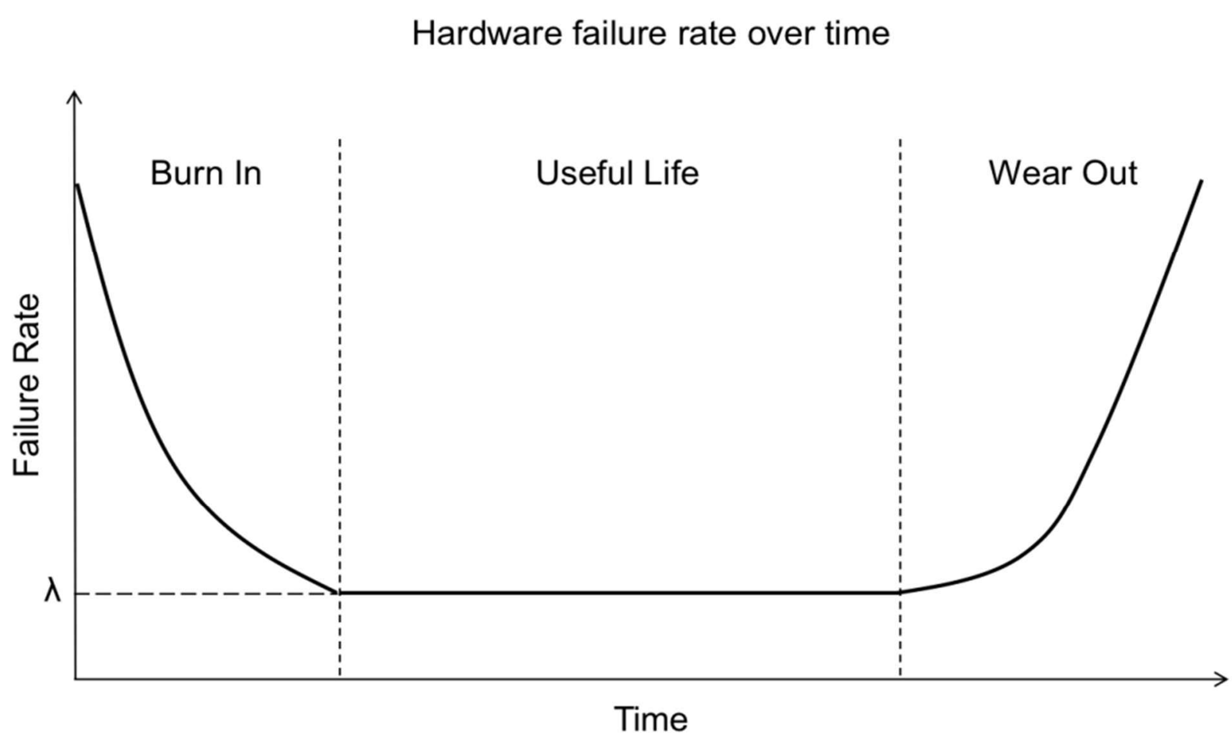
$$\mathrm{P}_{sent} = 1 - \sum_{1}^{s}\sum_{2}^{t} \mathrm{P}_{nm}$$

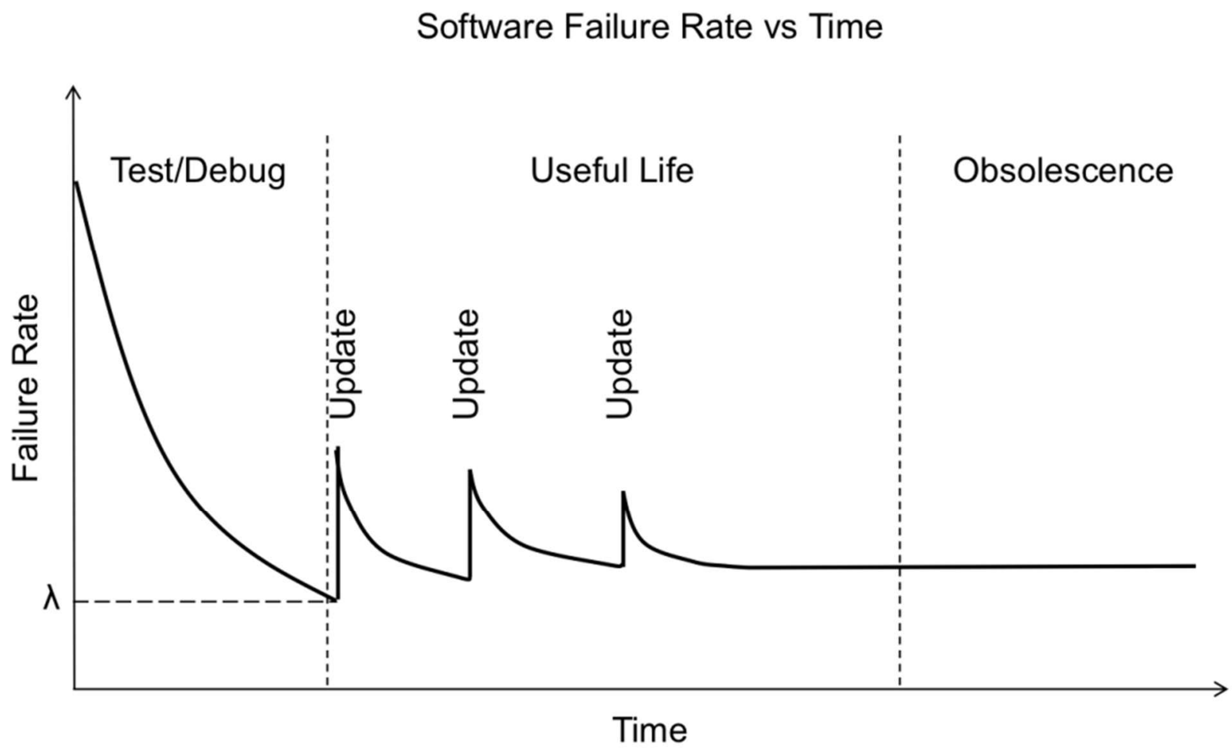
Finally, the probability of losing a message due to collisions in the transmission process will be the ratio of lost messages to total messages sent

$$\mathrm{P}_{\mathrm{loss}} = \left(\frac{\mathrm{lost}}{\mathrm{lost} + \mathrm{sent}}\right)$$

Conclusion

It is essential to design the system with fault tolerance in mind in order to avoid system failures caused by lost messages. The implementation of retry mechanisms for failed messages, the monitoring of the system for anomalies that may indicate message loss or other issues, and the use of dependable messaging protocols that guarantee message delivery are all examples of this. In the event of a failure, it is essential to have a clearly defined recovery procedure that can return the system to its original state.





To reduce the impact of steady-state message losses, communication systems often incorporate various strategies such as message buffering, redundancy, and error correction. These techniques help to ensure that lost messages are detected and retransmitted.

References

1) https://www.beningo.com/understanding-embedded-system-failure-rates/

2) https://users.ece.cmu.edu/~koopman/lost_messages/index.html

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