Availability in Industrial Networks

Version 1.1

By Mohamed Hussein

روابـي القابضة
Rawabi Holding

Revision History

Date	Rev	Details
July 27, 2016	1.0	Release
October 25, 2016	1.1	Added wireless availability calculations

Table of Contents

1. Introduction

This document gives an introduction about the availability in industrial networks: wired and wireless. It will explain what is meant by availability, how it is calculated and what the acceptable value for different networks.

2. Availability

Availability is defined as the proportion of time a system is functioning. In other words, availability is the uptime of the system with respect of the total time the system is in operation.

2.1. Network Availability

In wired networks, the network availability of a link is defined as the reachability between its end points. It means how much percentage of time point B will receive the data sent by point A via that link. However, multiple links can connect between two points. Hence, the unavailability of the network between the two points is the product of the unavailability of the two links.

Where unavailability = 1 - availability

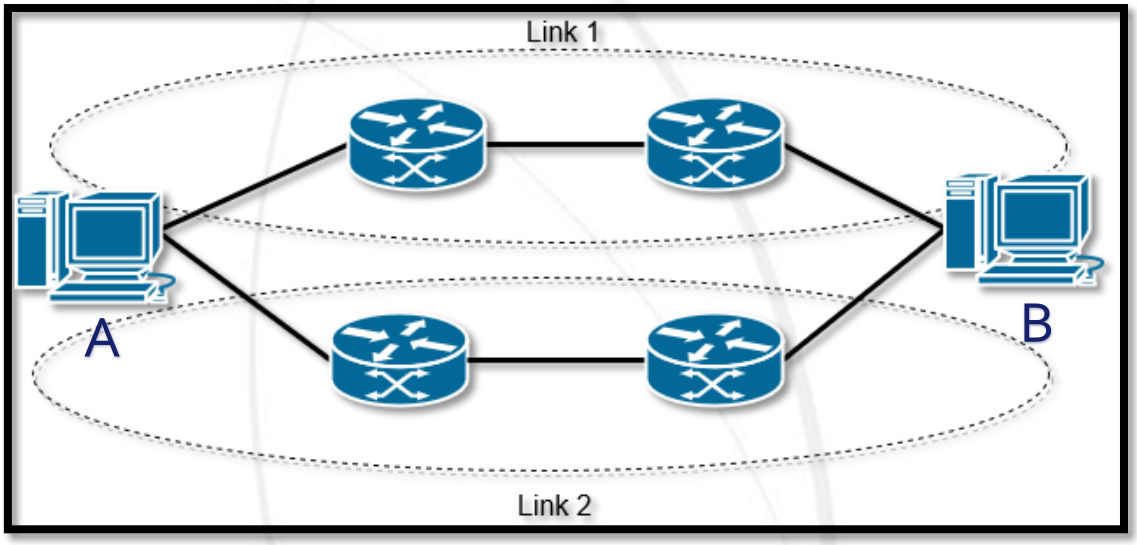

FIGURE 1

For Figure 1, the total unavailability = unavailability (link 1) x unavailability (link 2)

In general:

$$Total\ unavailability = \prod_{i=1}^{n} unavailability\ (link\ i)$$

$$Total\ availability = 1 - Total\ unavailability$$

When the network consists of multiple points, the overall availability calculated depends on the topology of the network. For wired networks, where peer-to-peer topology is applicable, the availability can be defined as the mean of the availabilities for every two links.

3. How to calculate network availability

The availability of a network link relies on several components:

The availability of different segments that a link consists of whether it is wireless or wired.

The availability on the hardware that connects the paths such as routers, wireless modems… etc. This also includes the reliability of the source powering the hardware.

The reliability of the software or firmware that operates the hardware. The device reliability usually includes both the HW and the SW availabilities.

$$Link\ Availability = \prod_{i=1}^{n} Device\ Availbility\ (i) \prod_{i=1}^{m} Path\ Availability\ (i)$$

3.1. The "nines" standard

In the industry, the availability is given by the "nines" notation which is number of "nines" before and after the decimal point. For example, a network of three nines availability has 99.9% uptime which corresponds a downtime of 8.76 hours per year and 43.8 minutes per month. Table 1 shows a list of availability values and their corresponding downtime.

TABLE 1

Availability %	Downtime per year	Downtime per month
90 "one nine"	36.5 days	72 hours
95	18.25 days	36 hours
98	10.96 days	21.6 hours
99 "two nines"	7.3 days	14.4 hours
99.5	1.83 days	3.60 hours
99.9 "thee nines"	8.76 hours	43.8 minutes
99.99 "four nines"	52.56 minutes	4.38 minutes
99.999 "five nines"	5.26 minutes	25.9 seconds
99.9999 "six nines"	31.5 seconds	2.59 seconds

3.2. Availability factors

The availability of a path or a device depends on two factors: Mean Time Between Failures (MTBF) and Mean Time Between Repairs (MTTR). The MTBF for a device is usually listed in its specifications whereas the MTTR is a service provider advantage.

The availability from for a device is calculated from the MTBF and the MTTR as follows:

$$availability = \frac{MTBF}{MTBF + MTTR}$$

For example, for a device with a MTBF of 45,000 hours a MTTR of 4 hours, the availability is 45,000/(45,000+4)= 99.991% with a downtime of 0.7788 hours per year.

By increasing the MTBF (better design) or deceasing the MTTR (better operations and procedures) or both, the availability improves.

3.3. Availability in wired networks

There are multiple methodologies to measure the availability in wired networks. For example:

1. Periodic pings: pinging each device of the network to collect statistical availability data for each segment of the network.
2. Service assurance agent (SAA): an embedded software in Cisco IOS devices that performs active monitoring of the network connecting Cisco devices and other network application servers. The monitoring generates reports of network statistics such as network delay or latency, packet loss, network delay variation (jitter), availability, one-way latency, website download time…etc.
3. Remote network MONitoring (RMON): a flow-based algorithm that collects traffic patterns to generate network health statistics.

Nowadays, providers target a network availability of three nines (99.9%) or higher.

3.4. Availability in wireless networks

In wireless networks, it is rather difficult to collect availability information in real time due to the fact of limited bandwidth. However, statistical methods are utilized to estimate the availability of the network. A common method is based on the Received Signal Strength. By continuously monitoring the received signal strength from the neighboring nodes, an estimation of the wireless link availability to these nodes can be calculated based on a statistical model. One of the most common and conservative models is Rayleigh distribution.

The worst case of multipath fading is modeled as a Rayleigh distribution function which relates the fade margin to link availability. Table 2 below shows the "nines standard" availability vs the required fade margin assuming Rayleigh distribution. Other values of availability can be extrapolated from the table.

TABLE 2

Availability (%)	Fade Margin (dB)
90	8
99	18
99.9	28
99.99	38
99.999	48

Other empirical methods are used to calculate availability for a certain distance and fade margin. These methods classify paths by terrain and climate. Path Classification method 1 relates the frequency, the fade margin and the link distance to path unavailability. It also accounts for climate of the area of interest. The formula for this method for flat coastal areas is:

$$Path\ Unavailability = 2 \times 10^{-7} \times f \times d^3 \times 10^{\frac{FM}{12}}$$

f: frequency in GHz

d: path length in km

FM: Fade margin in dB

Path Classification method 2 has a generalized formula but it its results were only verified within the US. This formula is:

$$Path\ Unavailability = 6 \times 10^{-5} \times (ab) \times f \times d^3 \times 10^{\frac{FM}{10}}$$

Where:

a can take values of 4, 1 or 0.25 for smooth, average and rough terrains respectively.

B can take values of 0.5, 0.25 or 0.125 for coastal, normal or dry climate respectively.

To calculate a theoretical availability for a wireless link, a certain method is determined based on the terrain, climate and system specifications. Rayleigh distribution will give the worst case for multipath which is expected in an environment with many obstacles. Therefore, it can be used as a first step to roughly estimate the expected availability before applying other methods. The system should continuously monitor the received signal strength for each link as well as the Bit Error Rate (BER) or the Packet Error Rate (PER) which are the actual indications of availability of the wireless link.

4. References

1. https://en.wikipedia.org/wiki/High_availability
2. http://www.cisco.com/c/dam/en/us/products/collateral/ios-nx-os-software/high-availability/prod_presentation0900aecd8031069b.pdf
3. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3279241/
4. Radio System Design for Telecommunications by Roger Freeman.