Predictive Fiber Monitoring for Aging Optical Networks

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ABSTRACT

The cabling of many fiber optics early adopters has been deployed and in operation for more than 25 years, a testament to the distinct advantages of optical fiber. Over this same period of time, copper cabling has been through multiple generations. According to the Federal Communications Commission (FCC) case reports, more than one fourth of service disruptions are attributable to fiber cable problems, many of which have interrupted lifeline 911 services. Preventing these fiber related service outages has become a top priority.

To survive in today's competitive marketplace, each operator must operate an efficient, yet reliable network that provides leading edge services with minimal downtime. Due to this intense competitiveness, carriers and service providers have begun to invest strategically in their infrastructure with a significant focus on automated management, maintenance and monitoring solutions for their networks. Carriers are finding an increasing number of outages caused by fiber deterioration. By utilizing a proactive fiber maintenance process based on a remote fiber monitoring system, service providers can significantly improve network reliability, reduce blocked calls, reduce MTTR, and improve operational efficiency. With billions of dollars of global network fiber that needs to be replaced, carriers must have a proactive maintenance system to prioritize the fibers most likely to fail.

1. Introduction

A Remote Fiber Test System (RFTS) utilizing optical time-domain-reflectometer (OTDR) technology is a well-known tool for monitoring and troubleshooting optical fibers in cabled optical networks. OTDR technology identifies fiber faults and their position in the network. The fault data can then be correlated with the Geographical Information System (GIS) to isolate the fault and pin point the problem location on a map (as shown in figure 1)

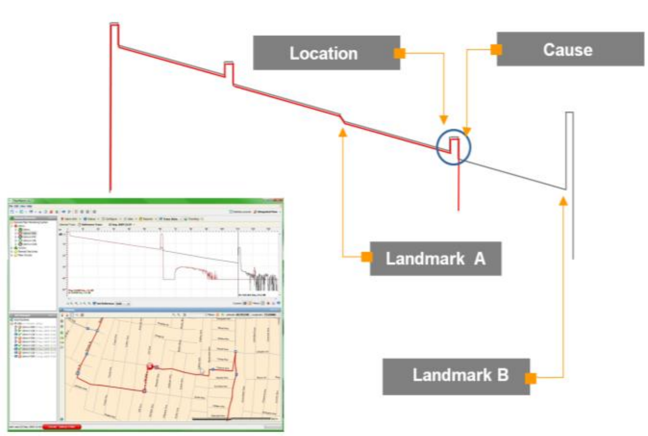


Figure 1 RFTS Graphical User Interface (GUI)

Once a network is in operation, a carrier can permanently place a remote OTDR in a rack mount configuration at a centralized location, which can be programmed to routinely test critical fibers, for early detection of degradation that may impair the signals transmitting through those same fibers.

Fiber optic cables are engineered to be highly reliable over extended periods of time. When fiber optic cables were first developed, telephone companies had abundant experience developing cables that could survive for prolonged times buried underground or suspended from poles. Applying this same know how to glass fibers, while adding materials to protect the fiber from the environment through a hermetically sealing process has led to fiber optic cables with lifetimes well over 25 years. Unfortunately, some of the early designs and manufacturing techniques have led to a growing number of fiber cable lengths degrading and are beginning to fail. Carriers must develop a maintenance strategy to deal with these aging fibers.

The historic development of complex systems maintenance efficiency solutions is shown in Figure 2 and fiber network operators have been stuck for many years at reactive maintenance.

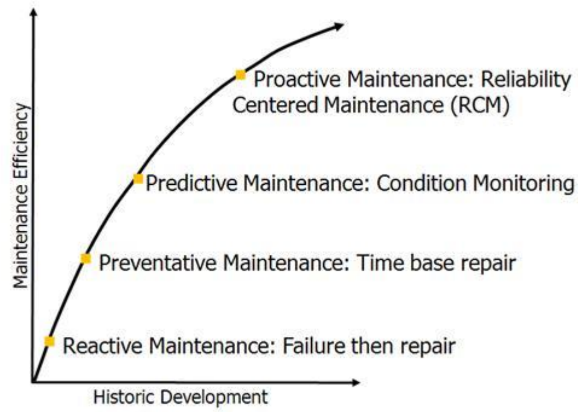


Figure 2 Historical Network Maintenance Efficiency

Although scheduled or time-based maintenance has proven to prevent some failures, many systems still experience premature and/or major failures. Unplanned failures and emergency repairs have a detrimental effect on a customer's uptime/business. By considering operating environment and application, predictive maintenance PdM delivers better control over the system health. This enables more effective services to the end customer and extended fiber life.

Unlike preventative (or periodic) maintenance, where services are based upon scheduled intervals, PdM relies upon actual fiber health to dictate when and what maintenance is required, thus reducing support costs.

Many industries have gone several steps beyond PdM and have implemented a Reliability Centered Maintenance (RCM) framework. Those industries where safety and reliability are paramount have pioneered this development. RCM has been adopted by the aerospace, military, transportation, and construction industries as a means for improving the overall availability of assets in the field.

This whitepaper will review each method of maintenance, the advantages and disadvantages and highlight why predictive and proactive RFTS maintenance strategies are recommended in all fiber optic network management operation plans in the future.

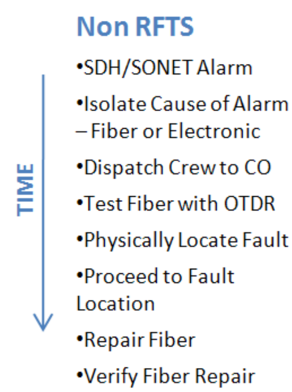
REACTIVE MAINTENANCE

Service disruptions can be caused by a myriad of things. Power outages, network element failure and fiber failure/breaks are all common problems. To combat these issues, redundancy, backup power, and network management systems have been deployed for many years. And yet many carriers have delayed the deployment of fiber monitoring solutions due to the fact that they consider that by monitoring the network elements (NE), that they are indirectly "monitoring" the fiber path. However, monitoring NEs only ensures the carrier that the information is being transmitted correctly and that the communication links are active and working properly. Although these are not optimal solutions, some carriers have considered them satisfactory. Due to the lack of fiber monitoring, downtime attributed to fiber issues has continued to increase every year. According to the FCC 25% of all network service disruptions are due to fiber optic cable outages.

In the event of a fiber related service disruption, a series of events take place that leads to final fault resolution.

In the accompanying figure, we summarize a series of events typical to many operators today.

The key element for fault resolution lies with problem identification. In the event of a fiber break, there will be transmission alarms along with other equipment alarms.



The first step upon receipt of these alarms is to diagnose the cause.

After determining that a fiber break has occurred, a technician with an OTDR must be dispatched to the closest access point with visibility to the fault in order to determine the optical distance to the fault.

Next, the optical distance must be correlated to a physical location.

Upon finding the fault location, appropriate action must be taken to remedy the fault and restore service as quickly as possible.

A customer study of 27 fiber breaks showed that reactive maintenance took an average of 9.7 hours to restore service for each outage. This has led many carriers to rethink their strategy and begin deployment of a fiber monitoring or Remote Fiber Test System (RFTS)

Fault detection and isolation represents one of the strongest features of the RFTS. In the event of a cable break, the monitoring system is able to detect the physical problem (the fault), diagnose the problem, and then correlate this information with the GIS to isolate the fault in less than a minute. This information is then broadcast to a number of systems with which the RFTS integrates (alarm manager, trouble ticketing system, direct dispatch through email or SMS, etc…) The net result is immediate dispatch of restoration personnel to the fault location..

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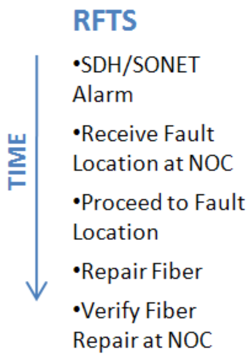


In the accompanying figure, we summarize a series of events that occur when a RFTS is utilized to automate fault diagnosis and isolation.

The key element for fault resolution lies with problem identification. In the event of a fiber break, there will be transmission alarms along with the RFTS alarm.

The RFTS will automatically diagnose and locate the fault location within a minute. This eliminates the time needed to investigate the cause and determine a search area.

Upon finding the fault location, appropriate action is taken to remedy the fault and restore service as quickly as possible. Users of Fiber Monitoring Systems often realize a 4-6 hour decrease in repair time

PREVENTATIVE MAINTENANCE

While a 60% reduction in MTTR is significant, many carriers have been looking at the advances that preventative maintenance can provide.

The primary goal of maintenance is to avoid or mitigate the consequences of failure in a system. This may be by preventing the failure before it actually occurs which planned or preventative maintenance helps to achieve. It is designed to preserve and restore network reliability by replacing degraded components before they actually fail. Preventive maintenance activities include partial or complete overhauls at specified periods. In addition, workers can record equipment deterioration so they know to replace or repair deteriorating parts before they cause system failure. The ideal preventive maintenance program would prevent all equipment failure before it occurs.

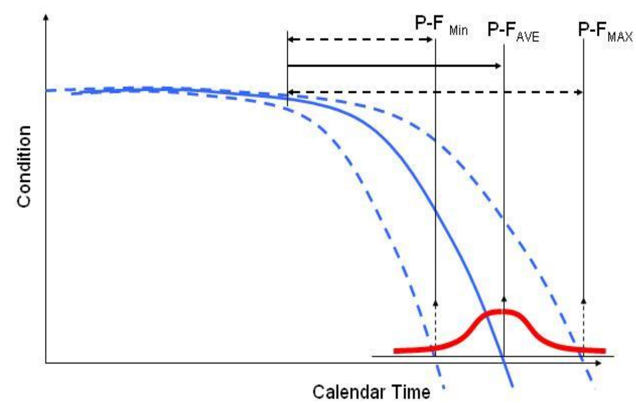
For many years, we have heard the preventative maintenance message for minimizing automobile failures. Every 3000 miles or every 3 months you should have your oil changed. While this is true in some cases, it has been determined that there are many other variables such as the type of oil and the environment the vehicle is driving in. A recent study showed that a fleet of 1000 vehicles was "over-servicing" their fleet by $770,000 a year. Time-based maintenance is labor intensive, ineffective in identifying problems that develop between scheduled inspections, and is not cost-effective. New automobiles have since moved on to a predictive maintenance solution (described in the next section)

Many carriers have seen major issues with the fiber optic cables that were deployed in the early adopter phase of fiber deployment. One carrier decided it was time to begin a preventative maintenance program to replace this aging fiber. To their chagrin, their analysis estimated it would cost them hundreds of millions of dollars to replace all of this fiber. Since the fiber is still functional, there has been resistance to replace it but they are worried about the unexpected failures. If only they could predict which fibers will fail first and replace those.

PREDICTIVE MAINTENANCE

Today, RFTS provides the foundation to predict which fibers are the most likely to fail. Each fiber can be prioritized and a realistic budget put in place that can essentially eliminate fiber disruptions due to aging fiber or fibers that were poorly installed.

PdM, or condition-based maintenance, attempts to evaluate the condition of the network by performing periodic or continuous fiber cable condition monitoring. Maintenance is performed after one or more indicators show that the fiber is going to fail or that performance is deteriorating. The ultimate goal of PdM is to perform maintenance at a predicted point in time when the maintenance activity is most cost-effective and before the equipment loses performance within a threshold. As the figure below shows, a fiber cable can be monitored and the remaining life can be accurately determined.



This is in contrast to time- or preventative -based maintenance, where a fiber gets replaced whether it is close to failing or not.

The "predictive" component of predictive maintenance stems from the goal of predicting the future trend of the fiber cable's condition. This approach uses principles of statistical process control to determine at what point in the future failure will occur. Adoption of PdM can result in substantial cost savings and higher system reliability.

With networks becoming larger and more complex, network operators are faced with the daunting task of maintaining the network with fewer resources. As designed, the RFTS provides a time stamped characterization of the network segments. In particular, the OTDR trace provides a measure of attenuation, reflectance and discontinuities along the entire length of the cable for the fibers under surveillance. This data, from day one of system deployment, provides a benchmark from which a predictive maintenance system can continually assess network quality.

PROACTIVE MAINTENANCE

Reliability-centered maintenance (RCM) or Proactive Maintenance is a process to ensure that assets continue to do what their users require in their present operating context.

RCM sets out the minimum evaluation criteria that any process should meet[i]. This begins with the 7 questions below, worked through in the order that they are listed:

1. What is the item supposed to do and its associated performance standards?
2. In what ways can it fail to provide the required functions?
3. What are the events that cause each failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What systematic task can be performed proactively to prevent the consequences of the failure?
7. What must be done if a suitable preventive task cannot be found?

RCM is an engineering discipline that facilitates the definition of a complete maintenance process. Maintenance is regarded as the means to maintain the functions a user may require of a system in a specific operating context. It enables system stakeholders to monitor, assess and predict the future functionality of the network asset. This is contained in the initial section of the RCM process which is to identify the operating context of the system, and write a Failure Mode Effects and Criticality Analysis (FMECA). The second part of the analysis is to apply the "RCM logic engine", which helps determine the maintenance tasks appropriate for the identified failure modes in the FMECA. When the logic is completed for all elements in the FMECA, the resulting maintenance list is prepared for the operations team, so that the task schedules are configured into work packages. Lastly, RCM is kept active throughout the "in-service" life of the system, where the effectiveness of the maintenance is kept under constant review and adjusted based on network experience.

The standard outcomes of an RCM analysis

An RCM analysis results in three tangible outcomes:

- Schedules to be performed by the maintenance group
- Revised operating procedures for the network operators
- A list of areas where changes can be made to the installation procedures

CONCLUSION

Fiber-cable breaks and degradations are one of the top causes of network service disruptions. In order to truly offer a reliable fiber service, network operators, must have total control over service disruptions, by using all means available in order to minimize their occurrence as well as their durations. When network data is available in real-time, in a clear, coherent and customized application, its value stretches beyond daily network operations and creates business intelligence. Operation Managers, planners, and product managers all profit. Your fiber monitoring data is your competitive advantage. The best way to achieve this is to develop a proactive maintenance system utilizing RFTS. Remember that taking action before end-user services are impacted is better than a quick cure.

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[i] Society of Automotive Engineers. SAE JA1011- Evaluation Criteria for Reliability Centered Maintenance (RCM) Processes, 1998.