Network Management of Optical Fiber Communication

The report contains the description why a network management unit can’t be a qualified QS.

Just like all communication systems, an optical fiber communication system contains seven layers and each layer has a unit of network management. The main function of the network management is to control the signal flow or information traffic. When one channel is found over load, the network management would instruct other channels to share the load to even the signal load for each channel or when a signal traffic block is found, the network management would find other paths to bypass the block point.

The network management units in each station collects the information required by the network management and sends it to the central station by a specified fiber or a specified wavelength channel of the optical fiber communication system, the network management unit in the central station analyzes the information and sends the network management instructions to all the station through the same specified fiber or the channel. The network management is a quite expensive function because it takes one fiber or one channel and it requires some complicated hardware and software. If an optical fiber communication has a circle or a net shaped structure, the network management function is necessary, if the communication system has a tree shaped structure, the function may not necessary. Therefore some optical fiber communication systems have it, some have not.

It should be pointed out that 1) the network management is communication system dependent because the information of network management follows the same path as the signal that the communication system carries, including the optical channel. 2) the network management information is closed inside of the communication system, that means the information is only transferred between the local stations and the central station, no maintenance person can access it.

The network management unit of the physical layer has the capability to detect the optical power. On the transmitter side, the backward emitting of the laser in the transmitter is measured as the transmitter optical output power. On the receiver side, the network management unit takes the AGC (Automatic Gain Control) voltage as the
measurement of the input optical power. When the optical power is found too low, the unit will send the information to the central station, the central station will treat it as a signal traffic block and takes some reactions, for example a HDS system would change the communication path from the upper semicircle of the optical communication system to the lower semi circle or opposite way.

The network management is good for the optical fiber communication system operation, but according to the following analysis it will be seen it is not a qualified QS.

The canalization is from two different angles: management point and technical point. First in the management point of view, a quality monitor and management system must be independent from the system monitored and managed. It is a basic law for any quality monitor and management system. There are numerous facts that prove the basic law, for example, a formal manufacture factory, a product operation can have some tools and means to measure the products that the operator works on, but final product quality measurement must be performed by an independent Quality Assurance Department or Office. The situation in this example is very similar to the network management in an optical fiber communication system.

In normal situation the network management doesn’t provide any quality information mentioned in chapter 1 such as the current quality level, the decrease from the initial level, the margin above the minimum requirement and so on. In a malfunction situation, if the network management is used as a QS, the fatal problem is very obvious: when the communication system is out of order, the network management may be out of order as well because the network management of an optical fiber communication system is dependent on the communication system.

A PQM based system is entirely independent on the communication system, even if the whole communication system is crashed completely, the PQM based system still can work properly and indicate the maintenance operators to fix the problems. Here is a true story: two adjacent regions were encounter a flood, all the ground buried optical fiber cable were in water.

The optical fiber communication system in the first region had no PQM system. During the flood the network management of the SDH system could do nothing because the network management depends on the optical fiber communication system, when multi malfunctions occurred in the whole system, no any upper or lower semicircle can work, no network management information can be sent to the central station, finally the whole optical communication stopped. After the flood, it was very difficult to prepare and resume the communication system because no any malfunction information can be provided to the maintenance person to show where
are the malfunctions. Finally almost of the whole system was reinstalled. The cost is much, much higher than the cost of a PQM system.

The situation in the second region is entirely different, the optical fiber communication system is equipped a PQM system. The PQM system uses RF as the quality communication media which is completed independent from the optical communication system. During the flood, the operator in the central station was watching the PQM system information, when the PQM sent a degradation alarm for a channel or a continuous optical intensity decrease was found in a channel, the operator informed the maintenance persons to go the field for emergent water proof treatment, so that the back bone communication still kept normal in the whole flood period of time. After the flood, the PQM system indicates the maintenance group which part of the optical fiber or terminal has malfunction, how serious the malfunction is for the whole system. Only a few days the whole optical fiber communication system resume to normal operation.

In the technical point of view, the performance parameters such as laser backward emitting power, AGC voltage are necessary for communication system normal operation, for example, the laser backward emitting power can be used as the feedback signal for laser driver, the AGC voltage can be used to adjust the gain of the amplifier to avoid saturation, but in the technical point of view they can not be used for quality monitor and management. The laser backward emitting power is a typical example, a semiconductor laser internal structure diagram is shown in Fig. 1.

Fig. 1.

Usually a semiconductor laser emits two equal optical beams: forward and backward, each optical beam diameter is around 1 mm. The forward beam is focused to the single mode optical fiber with the diameter of 9 um by a collimator while the backward beam will enter a photo detector with the active area about 1 mm in diameter. The photo detector converts the optical power to electrical current to indicate the laser optical power.

If the laser die has a very small mechanical movement for any reason, for example the movement is 1 um, for the photo detector the total optical power change is only 0.1%, it can be ignored, but for the 9 um fiber, it losses 10% optical power, if the
movement is 10 um, for the photo detector, the change is 1%, it still can be ignored, but the fiber loses all the power.

The next problem is if any potential possibility of the mechanical movement exists in a semiconductor laser, the answer is positive because the high current change rate. A semiconductor laser driving peak current is not so big, around several ten mA, typically 20 mA, but the current change ratio, di/dt is huge, especially for high speed communication systems, 155 Mb/s is very popular Baud rate, the current rise/fall time of 155 Mb/s is less than 1 ns, di/dt would be greater than 2e7 A/second, twenty million amperes per second!!!

According to Maxwell principle, the current change will generate magnetic field change. Any material has more or less magnetostriction effect and electrostriction effect, the material in a semiconductor laser is quite stable with very weak magnet effect and electrostriction effect for the electrical and magnetic field changes, but when the measurement scope is down to micrometer, the mechanical spread and shrink can not be ignored. The high frequency periodic action would cause material fatigue as well. All of them are the potential causes of the laser unit mechanical movement. The detail analysis of these effects is beyond the scope of the paper.

Therefore the photo detector output can not indicate the optical power in the optical fiber.

Actually a lot of malfunction lasers were found their backward photo detectors still output normal electrical current, but the optical power from the fiber is very weak.

The conclusion is the network management is good for optical fiber communication, but it is not a qualified QS and it can not replace a PQM system.