INVENTION DISCLOSURE

1. **Invention Title.**

Preventing Interference In Simultaneous RF Over Glass Transmissions

2. **Invention Summary.**
If two optical transmitters with the same wavelength transmit at the same time and if their wavelengths are close, optical beat interference occurs. This can be avoided by the CMTS performing testing for interference between optical transmitters, and the CMTS scheduler thereafter avoids simultaneous transmissions between units that are capable of interference.

3. **Invention Description**.

a. **Describe the invention in detail and/or attach a description, drawing(s) and/or diagram(s), if available.**
See below.

b. **Why was the invention developed? What problem(s) does the invention solve? How is it better?**
RFOG is considered to have problems working with DOCSIS 3. In fact it has problems working in any situation that requires simultaneous transmission on different RF frequencies. This solves the problem

c. **Briefly outline the potential commercial value and customers of the invention.**
RFOG is not yet ubiquitous, but its commercial use is significant and growing. This problem needs to be solved, as RFOG is otherwise compatible with normal Cable operations.

4. **HOW is your invention different from existing products, processes, systems?**
Not known until a search is performed.

Method to Make DOCSIS 3.0 Work Over RFOG (Radio Frequency Over Glass)

Problem:
While new HFC network builds have been limited in recent years due to the reduction in new construction, deploying FTTH has been shown to be an economical approach when building "Greenfield" networks. As capacity needs increase, fiber will continually be deployed closer to the home. As the number of homes with fiber to the home is increasing, the use of RFoG

technology is also increasing. RFoG technology enables DOCSIS and other current technologies to be leveraged with the same termination equipment and CPE equipment, CMTS and CM, and back office systems. This allows the MSO to deploy a more future-proof network architecture (FTTH), while still delivering services the same way it does on its existing network leveraging HFC. This growing deployment scenario will become an important transition technology between today's HFC and the futures FTTH with low cost digital optics.

In an RFOG system, one downstream optical signal is amplified and split and distributed to a service group that might be 32 subscribers. This part of the system works well. In the upstream direction, ideally only one home transmits an optical signal at a time. However in a DOCSIS 3.0 system, more than one home may be required to transmit at the same time, albeit on a different RF frequencies. The simultaneous RF transmissions by two cable modems generate two simultaneous laser optical transmissions which are combined. If the lasers are transmitting at almost the same wavelength, optical beat interference (OBI) is generated at the receiver and reception is impaired at all upstream frequencies. In most cases, there is enough difference in manufacture between the laser diodes to prevent identical wavelengths, but it does happen and is considered a serious problem. Upstream laser wavelength is influenced by manufacturing tolerance, temperature, and drive current. This OBI can also be generated any time two matching-wavelength lasers are on simultaneously, such as with a DOCSIS 3 transmission, simultaneous DOCSIS 2 and set-top box upstream transmissions, two simultaneous DOCSIS 2 transmissions on different frequencies, or even a noise burst that unintentionally creates an upstream optical signal.

Solution:
The scheduler in a CMTS (cable modem termination unit) has a knowledge of which cable modems were transmitting when interference was detected. It also has detection algorithms that determine if the burst signal-to-noise is poor (a.k.a. modulation error ratio), or if the signal was unintelligible (lost packet count). Furthermore, a CMTS usually has an ability to look out-of-band for an elevated noise floor using a fast Fourier transform. Out-of-band energy could indicate that there were two closely-matching lasers transmitting simultaneously. High levels of Uncorrected FEC with few Correctable FEC can also be used to determine the bursty nature of the interference. Other indicators available in the CMTS, such as equalization and spectrum analysis also exist that can be correlated to determine likelihood of OBI issues.

If the CMTS detects interference across several instances when two lasers are transmitting at the same time, it can mark them as having sufficiently close wavelengths to create OBI, and can avoid scheduling simultaneous transmissions from the two CMs. This can be validated by measuring noise and error statistics during tests of simultaneous and time separated transmissions. Additional mitigation techniques could be developed such as communication with the optical electronics in an integrated DOCSIS RFoG gateway type devices which would modify the laser operating point by a small incremental factor to reduce the impact of OBI.

This solution will also work on our upcoming Advanced Mac and Phy (AMPS) project, where RF transmissions, using OFDM (orthogonal frequency domain modulation) create an environment where the modems are even more likely to transmit simultaneously.

Although the CMTS doesn't know at what wavelengths each laser transmits, it can create a table of matching and non-matching units. For example, if unit A interferes with unit B, and unit B interferes with C, it can assume that A will interfere with C. Furthermore, the CMTS can run interference tests in an idle time period.

If the interference measurements are made and tracked over a period of time, various aging and temperature affects will result in devices being marked as being compatible that have never interfered with each other.

If a tunable laser is applied to the receiver's input and the CMTS is controlling the wavelength of the tunable laser, the CMTS can determine the wavelength of each end-point laser by introducing beats during the transmission of test or calibration packets, such as PINGs or ranging requests.

Preferred Embodiment Description - Fig. 1

Fig. 1 is a flow diagram of a process. In a first step the process is started. In a second step a 32 by 32 matrix is created. Each element in the matrix will be marked a 0 or 1, so 1024 is the size of the matrix. Each row number represents an optical transmitter number and each column in the matrix also represents said transmitter number. In a third step, the optical transmitters are turned on, two at a time by scheduling simultaneous test transmissions. In a DOCSIS 2 system the transmissions could be scheduled on neighboring RF frequencies. If interference is detected between two optical transmitters because their wavelengths are too close, the corresponding elements are marked with a 1. Otherwise a 0 is marked. Thus if unit 14 interferes with unit 30, unit 30 also interferes with unit 14, so two 1's will be marked in the matrix. This testing is repeated until every optical transmitter is tested with every other unit. The diagonal of the matrix is marked with all 1's.

In a fifth step, units with interference with any other unit are formed into groups. In a preferred embodiment, one possible group-forming rule would be: if unit A interferes with unit B, and unit B interferes with unit C, A and C are considered to be capable of interfering with each other, and are marked as interfering (even though they possibly did not interfere in one test). This will allow for wavelength drift over time and temperature. In a sixth step the matrix groups are made available to a CMTS scheduler to prevent scheduling of transmissions of units that are in the same groups. If an optical transmitter is not in a group, it can be scheduled to transmit at any time.
In a seventh step the matrix is updated, if necessary, to keep the data current. If the update was performed recently, a delay is used to prevent continuous testing. For example, updating could be done hourly to daily.

Thus, the CMTS can avoid interference in an RFOG system by keeping track of which lasers are matched too closely, and scheduling them to not transmit simultaneously.

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