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Assessing the Implementation of FBG Sensing Systems in Smart Hotels

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Abstract:
In response to hotel industry feedback a simulated power analysis of a fibre Bragg grating (FBG) wavelength division multiplexed (WDM) sensing system integrated within a passive optical local area network (POLAN) for remote structural health monitoring (SHM) is assessed. (john.canning@uts.edu.au, 13031051@student.uts.edu.au). © 2020 The Author(s)

1. Introduction

The attractiveness of smart sensing within buildings has recently been emphasised by a wave of significant failed new building infrastructure presently striking Australian cities [1]. In order to assess actual needs in the field, interviews with Sydney, Australia-based hotels offering premium internet and communication services to customers were carried out. Based on these discussions, a preferred view was that the sensing network would ideally be integrated within existing high end internet connections in buildings – this is because internet demand from the customer is such that in these hotels the customer will pay more for the service. Passive optical local area networks (POLAN) have been developed for the hospitality industry, hospitals, campuses and the like where guest or patient/student rooms demand more bandwidth for high-definition IPTV, imaging, voice and data services [2,3]. Such shared integration may be expected to reduce significantly lower installation and operational costs in a building which has excess bandwidth available for the sensing system.

2. Method

The proposed CWDM GPON with FBG sensors system (Figure 1) is comprised of a transmitter, multiplexer, demultiplexers (splitters), receivers, modulators and FBG sensors for sensing temperature and strain. The 8-port transmitter operates over 1490 to 1650 nm, covering the main telecommunications windows. For downstream, λ = 1490 nm is for data and voice in GPON systems while λ = 1550 nm is allocated for video services. For upstream, from the customer for example, λ = 1310 nm. The transmitter for the Optical Line Terminal (OLT) operates with non-return to zero (NRZ) modulation. The input ports of the multiplexer are connected to the transmitter (OLT) and to the broadband light source (unmodulated) which provides the light for the FBG sensors. A 32 port demultiplexer delivers services to each Optical Network Unit (ONU).

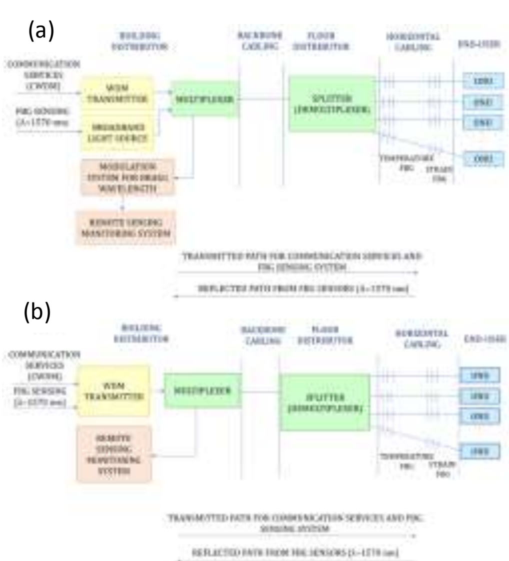

Figure 1. (a) Broadband light source ($\Delta\lambda$ ~ 100 nm) is input into the SHM system in parallel with the WDM transmitter for communications; (b) The block diagram for a laser input where NRZ modulation occurs before reflections from gratings are returned. In both these scenarios, a modulation system would be practically used to undertake TDM of sensor signals.

Uniform FBG sensors for temperature and strain sensing are modelled. In order to facilitate simulation and reduce complexity, the combined reflectivity of the gratings is set to R = 99% reflecting the extreme case of the final end grating after back reflections from the other sensors are considered – taking this scenario simplifies simulation and is more realistic. (In a practical system this would be equivalent to 100 gratings of ~ 1 dB, for example).

The OLT in most hotels is located at the Building Distributor (BD) where power is closest. Two connectors are used between the OLT and the fibre optic panel supporting the backbone cabling and cable termination (one connector). The floor distributor contains a 32-port splitter. The FBG sensors would be located at the horizontal cabling section, multiple drop components have been added to suppress wavelengths away from λ_B = 1570 nm in the reflected return-path section. The reflected path section contains the return path length (L = 1.45 km) and components to simulate the Bragg wavelength return to the building distributor for remote sensing. A WDM drop filter suppresses λ = 1570 nm for the communications end user.

3. Results

Figure 2 (a,b) shows the eye diagram results for the broadband source in scenario 1 (Fig 1 (a,b)). In its most basic form, a typical POLAN network has far too high a loss, arising primarily from the insertion losses associated with splitters, for detecting the returned sensing signals and the eye diagram is almost closed. Improving the broadband signal by using a higher-powered broadband source (20 dBm improvement) marginally changes this result. This indicates that a low-cost broadband source-based sensing system cannot be integrated into a current POLAN network. Another important consideration with the broadband source approach is crosstalk arising from emission overlapping with the signal communications to the customer for internet-based services. The use of an Er^{3+}-doped fibre amplifier, for example, will generate interference across the entire telecom bandwidth. When the signal level is only -80 dBm a quality factor, $Q = (VH - VL)/(\sigma H - \sigma L)$ ~ 20.3 and bit error rate BER << 10^{-13} is obtained. These are within International Telecommunications Union (ITU) standard ITU G.984.2s so will not affect the communications of the network. When the signal is raised to -60dBm, the quality factor degrades to Q ~ 8.7 affecting the potential service provided to the customer. A system based on this broadband source approach without additional power and filtering is therefore not workable.

The LED analysis points to a laser-based sensing system where there is no spectral overlap with the communications network – whilst this may be less desirable given power considerations, the deployment of an additional dedicated single wavelength laser system with TDM can make this more efficient. However, given the narrow linewidth of many sources (<0.01 nm), the integrated power returned is low and t2e eye diagram under these conditions is closed (Figure 2 (c)). Increasing this power by 20 dB opens the eye (Figure 2 (d)) cleanly and it is feasible to undertake this approach. Whilst a higher power laser source can readily overcome the losses of the integrated system, the power penalty will be significant and the integrated system overall far too costly to run from an ongoing economic and environmental perspective, likely damaging green accreditations over time. The sensing network is not customer driven so these costs are difficult to pass onto the customer.

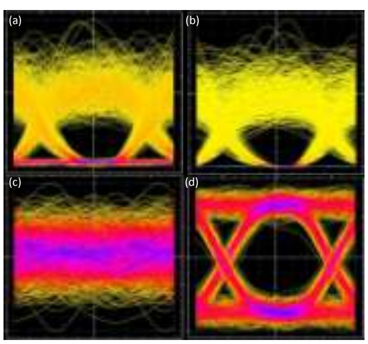

Fig. 2. The simulated eye diagrams for a broadband and laser signal transmission centred λ = 1570 nm. Broadband emission at -80 dBm through scenario 1 (a) and in (b) for a 20 dB power increase. For the narrow linewidth laser signal transmission, 9 dBm of power (c) does not open the eye diagram. Boosting this by more than 20 dB to 20 dBm (d) finally provides a clear return eye diagram.

4. Conclusions

The integration of two fibre optic systems, one communication and one sensing, has been analysed from the perspective of a smart hotel business model. Loss an energy savings are important factors that lead us to conclude it is not economically viable. By implication the study has consequences for the entire construction and real estate technology sectors and smart infrastructure more broadly – simply put, current technologies are not scalable in terms of power penalty budgets and photonic technologies are presently not able to leverage off energy harvesting being discussed for electronic sensors. It is interesting to note that whilst sensing systems have relied heavily on cost reductions introduced by telecommunications, they have evolved somewhat separately. One has been driven by interactive but sporadic customer needs and the other by perceived passive, remote and steady interrogation without customer funding. To overcome these differences and bring together potentially convergent market forces, a new research effort marrying the two is demanded.

3. References

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