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Economic Study Comparing Raman Extended GPON and Mid-span GPON Reach Extenders

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Abstract: We present an operational and capital cost study comparing newly proposed Raman amplified GPON systems with standardized, commercially available, mid-span GPON reach extenders.

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Introduction

Many network operators are already deploying or planning to deploy optical access networks with passive optical network (PON) equipment. The rate of deployment of such systems is expected to increase in the coming years and these systems will be a primary platform for the delivery of future high bandwidth services to end users. One of the leading PON technologies is GPON as standardized by the ITU [1]. A typical GPON system deployed today conforms to the 28 dB loss budget for Class B+ systems [G.984.2 Amd1] which allows for an approximate system reach up to 20 km fiber with 1:32 PON split. GPON reach extenders (GPON-REs) have been standardized by the ITU-T (G.984.6) and these enable the exploitation of the 60 km logical fiber reach of GPON and the 128 maximum addressable optical network terminations (ONTs).

The standardized reach extenders described in G.984.6 are deployed mid-span and contain optical amplifiers or OEO repeaters. These units therefore require electrical power to be supplied in the access network which can negate some of the advantages of entirely passive PON systems. The provision of power may present deployment issues and costs for a network operator and it may not always be practical in some remote or rural locations. Consequently, if the reach of a PON could be increased whilst maintaining passive outside plant, this could prove very attractive for network operators. One such approach uses distributed Raman amplification to improve the GPON loss budget [2, 3]. Put simply, this requires the provision of Raman pump lasers at the GPON head-end where electrical power is readily available. A pump at 1400 nm will provide gain for the GPON downstream signal band (1480-1500 nm) and a pump at 1240 nm will provide gain for the upstream signal band (1300-1320 nm). We assume that the narrow upstream wavelength option as defined in ITU G.984.5 is employed.

Here we examine from an operator perspective whether the Raman amplification approach to GPON reach extension offers cost benefits over existing mid-span reach extension solutions. We compare the capital cost of both approaches and consider operational costs associated with each.

Deployment Scenarios

Our assumptions are that powered GPON-REs will be deployed in underground footway boxes as described in our previous work [4]. This gives a network operator the future opportunity to reduce real estate as the central offices (COs) are by-passed. We therefore require the GPON-RE to be fitted within a hardened enclosure to withstand water ingress as these footway boxes are liable to flooding. The GPON-RE will also need to be powered and this will be supplemented by battery back-up to support lifeline telephony services in the event of a power outage. The operator will need to attend to the remote site for the initial installation of the GPON-RE and to investigate and repair faults. These requirements are captured in the illustration in Fig. 1.

With Raman extended GPON, the only additional equipment that is needed is installed at the CO and consists of a Raman pump module and WDM coupler to add the pump wavelengths to the feeder fiber. In this case an engineering visit for installation or maintenance will be carried out at the manned CO site and in a benign environment. This enables the service turn-up time to be shorter and mean repair times to be improved. This scenario is illustrated in Fig. 2.

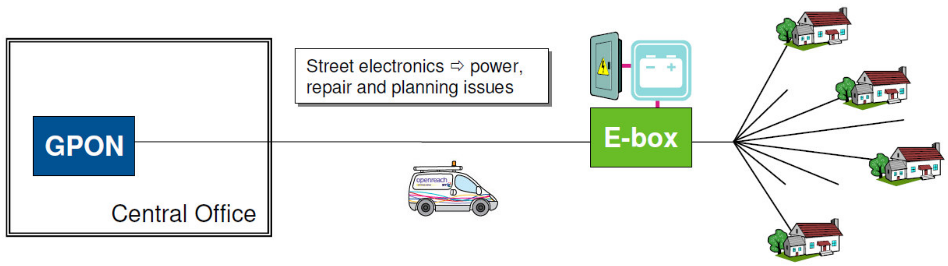

Fig. 1. Standard mid-span GPON extender box deployment scenario

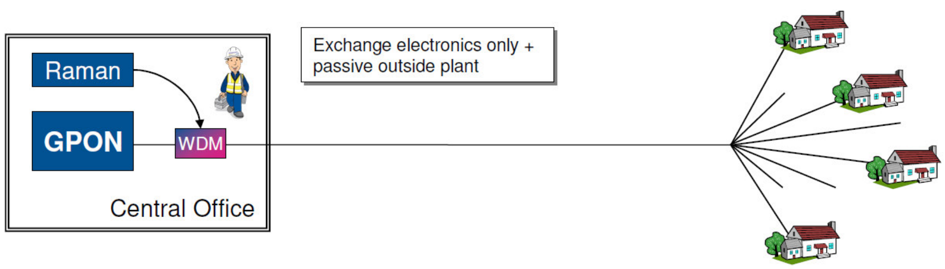

Fig. 2. Possible Raman amplified GPON deployment scenario

Cost Models

In this modeling exercise we assume a whole United Kingdom customer base consisting of residential sites only. The minimum required number of OLT headend COs is calculated give coverage with 60 km GPON technology to 98% of the residential premises. Reach extension technology is only deployed where necessary because the loss budget is beyond GPON Class C+ transceivers: 13% of premises in this scenario require reach extension. The whole customer base is assumed to be served by FTTP using 32-way split GPON systems with an average PON fill of 78%. We calculate only extra costs associated with each respective reach extension technology i.e. we do not include the common elements to both scenarios such as the ONTs and access fiber and duct. We only show in this analysis the average costs incurred by those customers actually requiring the reach extension technology.

For OPEX modeling we include electricity costs and costs for repair and maintenance. Electricity is consumed, in the case of the GPON-RE, by both the reach extender and by float charge current to the back-up batteries. Furthermore, in the case of the Raman pump, the power consumption is variable in proportion to the gain (in dB) required. In calculating the cost of faults, we have made the assumption that both approaches have the same FIT rate as they both rely on optoelectronic device technology. We also assume that the cost of attending a fault in the field rather than a CO is five times higher.

The modeled Raman pumping unit is illustrated in Fig. 3 and consists of up to two semiconductor pump lasers, a pump combiner (PBS) and control electronics. It is assumed that just one pump will be used in the case of shorter length systems and so Pump 2 is optional.

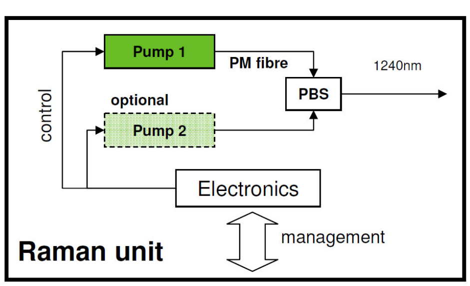

Fig. 3. Modelled Raman extender module configuration

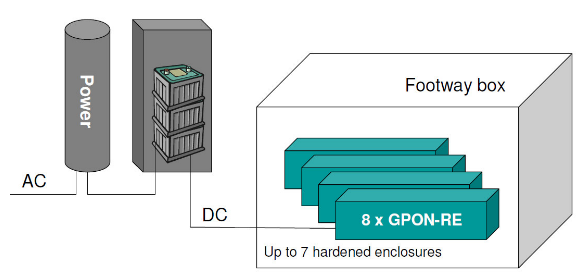

Fig. 4. Modelled GPON-RE configuration

The GPON-RE configuration is illustrated in Fig. 4 which shows GPON-REs in hardened enclosures sited underground in footway boxes and fed with a local power converter and back-up batteries. Up to seven GPON-REs modules, each containing eight reach extender units, are considered to be practical to site in each footway box. This allows room for servicing, fiber cable storage and adequate heat dissipation. Where possible, existing footway boxes will be used if there is enough room, otherwise they will be newly provisioned. For simplicity, we assume in the cost model that all footway boxes are new build. The footway boxes are clustered in groups of four and each cluster served by a single AC power feed. The AC power feed must be metered if the power consumption for the cluster exceeds 500 W and this incurs an installation and ongoing maintenance cost. The back-up batteries take a float current which adds to the power consumed and the batteries also require replacement every 3 years. The power installation requires an annual safety and maintenance check which we include in the OPEX model.

Results

In Fig. 5 we summarize the results of our study by showing the cumulative differential cost for each year after installation for both technology options. This shows that the initial capital costs of each solution are broadly similar with Raman amplification slightly less expensive by 5 %. However, year on year the GPON-RE approach adds extra cost due to annual OPEX at 250 % of the Raman approach. The main items impacting OPEX for the GPON-RE are fault attendance and power supply maintenance and for the Raman it is the power consumption.

The Raman approach to GPON reach extension seems attractive from a cost perspective in the deployment scenarios we have considered. However, the technology for the Raman pumps at this wavelength is not as mature as the components of a GPON-RE; hence reliability and manufacturability are yet to be proven. Furthermore, there are safety issues regarding the handling of high optical power. Effective automatic laser shutdown must be present and fiber damage due to high power at tight bends [5] must be eliminated by good quality fiber management at the CO.

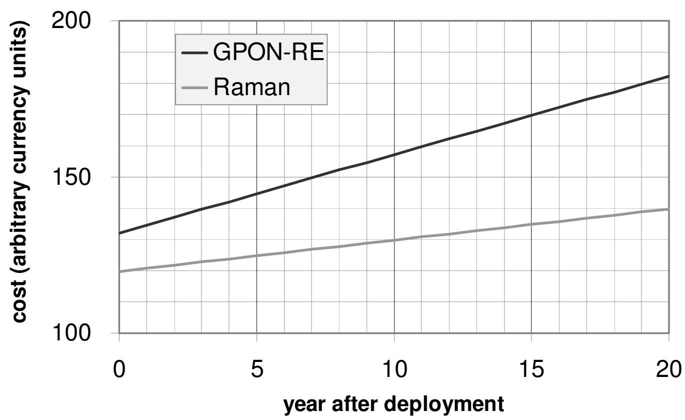

Fig. 5. Cumulative cost per customer vs. year after deployment for Raman extended GPON compared to standard GPON reach extender

Conclusions

Raman amplification has been recently proposed as a technology to enable the reach extension of GPON. We have studied this approach from a network operator's perspective and found that, in comparison to standardized GPON reach extenders, the Raman approach offers advantages from both a CAPEX and OPEX perspective. There are still many challenges to overcome before Raman amplification becomes a compelling proposition in this application but it remains an area worthy of further study.

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