eCPRI Radio Access Network Fronthaul Physical Reach Increase by using Hollow Core Fibre

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Abstract *We report how hollow core fibres low latency can be used to increase the physical distance on an eCPRI based Radio Access Network (RAN) fronthaul link. We show an increase out to 43km on a commercial open RAN system.*

Introduction

Hollow Core Fibres (HCF) are now commercially available[1] in environmentally robust cables and in lengths that are attractive to access networks, in addition Nested Anti-resonant Nodeless Fibers (NANF) attenuation is dropping[2] to comparable levels as single mode fibres (SMFs). In this work we explore the benefit of a NANF hollow core cable at a system level in an access network that can take full advantage of its unique properties. Operators are building 5G networks at scale, and as always cost is of concern, the transport layer protocol of choice is eCPRI[3] allowing scalable data rates and packet-based switching. In addition, a RAN lower layer split utilising eCPRI promises the ability to retain expensive processing deeper in the network whilst having cost reduced radio units at the edge. The depth that the processing can take place is limited by the Hybrid Automatic Repeat request (HARQ) latency. The minimum HARQ latency[4] of 100µs in standard fibre restricts this distance to a theoretical maximum of 20km[5]. In practice this distance and the HARQ loop latency is set by the design implantation of the RAN by the manufacture and will vary depending upon loading. Any technique that can either increase the fronthaul physical distance without increasing latency or reducing latency for the same distance will be of benefit to operators. HCF has ~1.5µs/km latency saving over SMF allowing the theoretical minimum geographic separation to increase to 28.5km from 20km whilst keeping the latency ≤100µs. This ability to use HCF to increase the fronthaul distance will be explored in this work.

Test Setup

The HCF cable used was a commercially available “CoreSmart® NANF™” Cable from UK manufacturer Lumenisity. The cable used a loose tube construction and was ~2.05km in length with five HCF strands to provide a 10.3km link. The cable was spliced HCF to HCF to provide a 4.1km and a 6.2km link length options. A SMF patch cord between the two HCF segments provided the 10km HCF link. The link has three HCF-HCF splices and four SMF-HCF splices. This arrangement allowed testing of a realistic 10km length of cable whilst allowing a drum small enough to be tested with ease. The cable was tested for attenuation as shown in Figure 1. The results show <1.5dB/km attenuation across the C-Band for the 10.3km link including all connectors and splices. The latency was measured using a network tester with the defined eCPRI One Way Delay[3] (OWD) method using a Global Positioning system (GPS) time stamp synchronization. This showed a latency reduction of ~32% compared to commercial single mode fibers (SMF-28e+®) as shown in Figure 2.

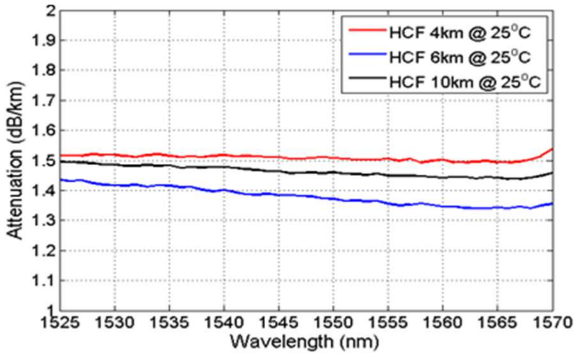

Figure 1. HCF cable attenuation including connectors

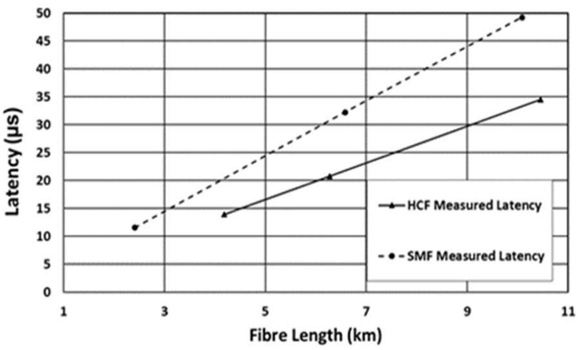

Figure 2. latency using eCPRI One Way Delay

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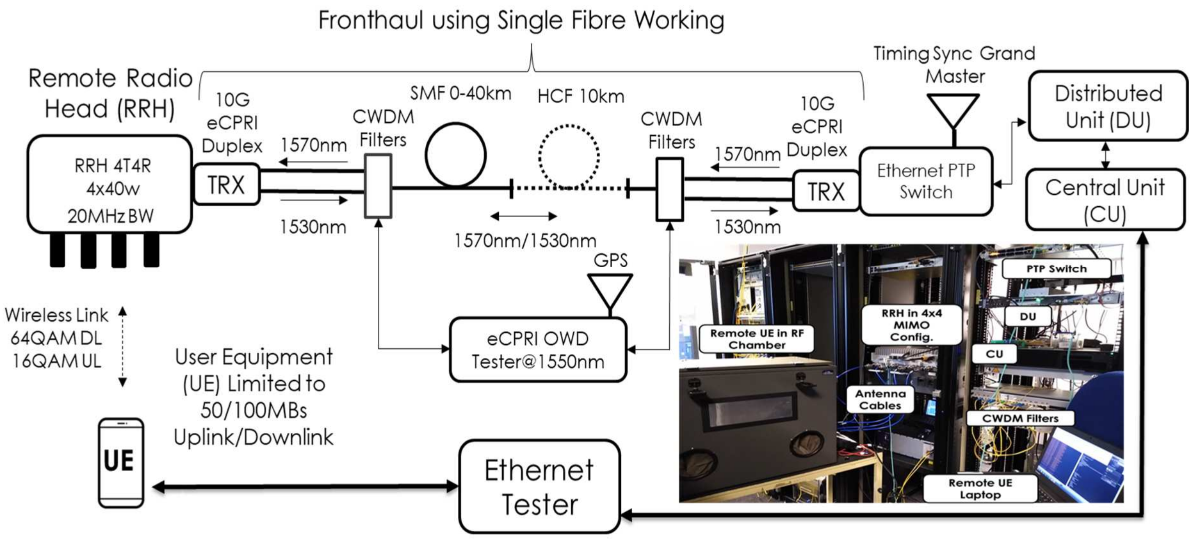


Figure 3. RAN Test schematic and photo of setup

The RAN was a commercially available Evenstar radio from MTI and an Open RAN build from Mavenir with a 7-2x low layer split as shown in figure 3. This used a 10 Gb/s eCPRI fronthaul link. We switched from standard 850nm multi-mode optics to using third party coarse wavelength division multiplexing (CWDM) single mode optical transceivers to allow operation in the C-band. Wavelengths at 1530nm and 1570nm were selected for transmission. The transceivers had a 23dB link budget, so no amplification was required to operate. Standard CWDM filters were used to facilitate single fibre working from the duplex transceivers. The fibre link length was increased incrementally, and the data rate of the user equipment measured to assess if the HARQ loop latency was introducing data loss.

Results and Discussion

The fronthaul link length was measured for two scenarios the first we will refer to as a heavy load as shown in Figure 4 for the uplink & figure 5 for the downlink. When using standard SMF the link was measured at ~160µs one way delay before the data throughput was affected. The second scenario as shown in figure 6 and 7 we will refer to as a light load and equated to a 240µs single trip delay before data throughput suffered due to the latency introducing errors. After the measurement with SMF, the test was repeated with a hybrid SMF and HCF link. Optical powers on the transceivers and equipment interfaces were monitored as were the four wireless carriers to ensure that the drop off in data throughput was due to latency and not due to link budget or wireless interface issues. In the heavy load scenario, we measured a 28.8% link length increase for the uplink, and 26.4% for the downlink. This is attributable to the lower latency of the HCF. In the light load scenario, we measured an 18.3% and a 28.7% increase for uplink and downlink respectively. The erroneous 18% result is due to the available link lengths used to increment the distance just falling short and should be discounted.

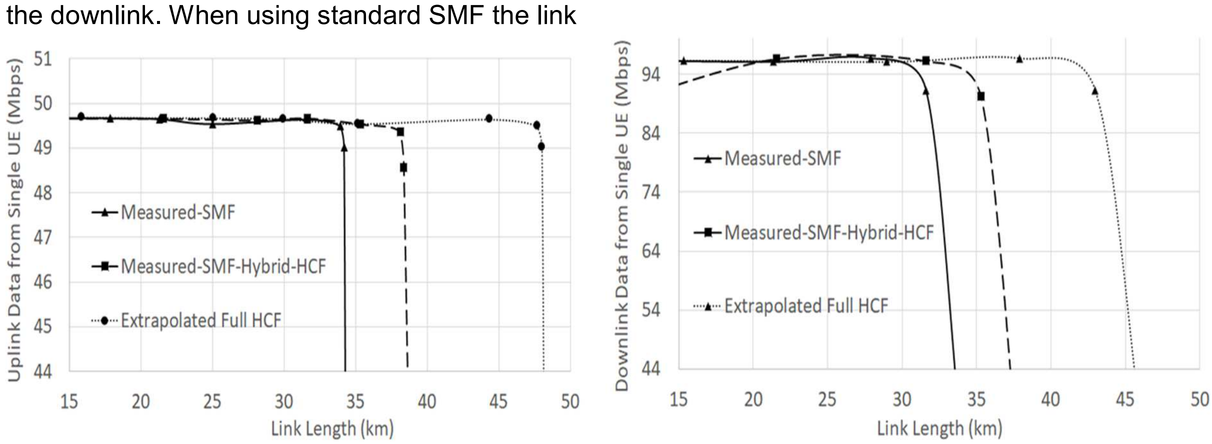
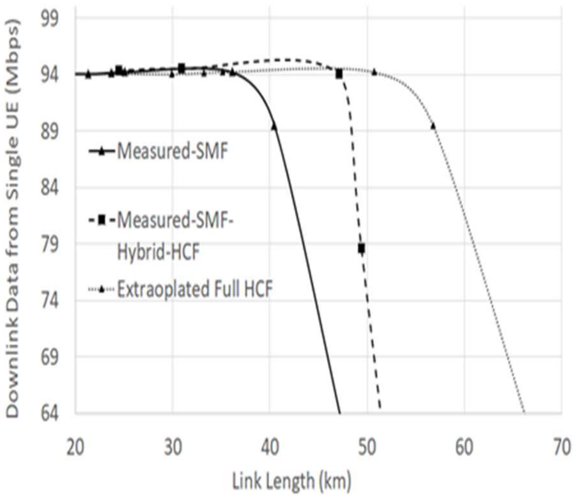


Figure 4 & 5. Uplink and downlink measurement of fronthaul link length under heavy load



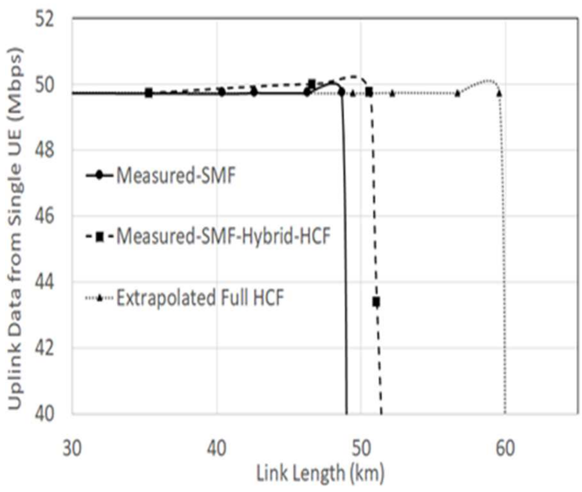


Figure 6 & 7. The downlink and uplink measurement of front haul link length under light load

In both scenarios the link length is limited by the downlink latency. The increase in physical distance by using the hybrid HCF/SMF combination was then used to calculate the length that a full hollow core link could cover whilst remaining within the error free latency bounds of the RAN system. This was extrapolated as shown on the graphs. In the two scenarios we measured, we have shown that HCF could be used to extend the distance of an eCPRI fronthaul radio access network. In the light load scenario from 40km to 56km. More importantly in the heavy load scenario, which would be used to plan a RAN's deployment, the link length can be increased from 31.6km to 43km. The measurements come close to the theoretical latency reduction of 32%. The 3.2% difference equates to ~6.4μs or ~1.3km of SMF and is well within the measurement error of the setup.

Conclusions

Hollow core fibre can be used to increase a RAN's fronthaul distance whilst keeping the latency within the HARQ loops bounds. The Mavenir RAN tested has a latency tolerance in excess of the eCPRI minimum specification and so can benefit even more by increasing its practical heavy load link length out to >40km. The benefits of this increase will be by serving a higher density of RRH units from a single central office lowering costs and improving base station coordination. An alternative option is to maintain the link length as per a SMF deployment but reduce the overall latency of the RAN system for the delivery of ultra-low latency services.

Acknowledgements

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