I-HUB Opto-Stacker Return Path

Solution Brief

Cost-effective High Performance Analog Return Path for Hub Consolidation & Node Segmentation

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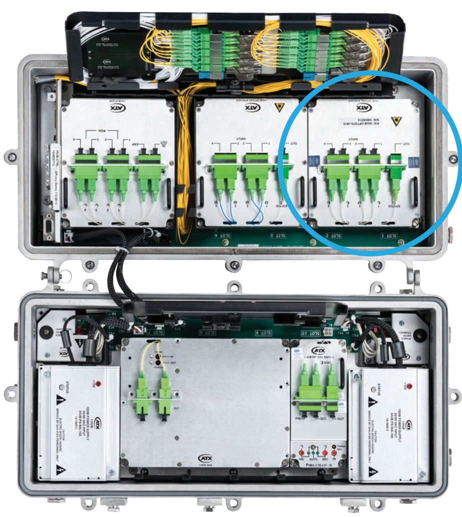
Introduction

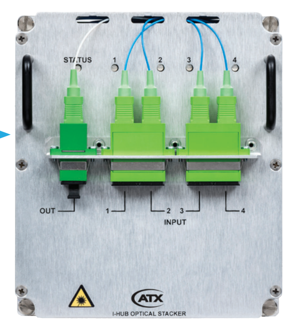
As operators consolidate or collapse hub sites to eliminate buildings and remote CMTS locations they are often faced with the challenge of how to transport an installed base of analog return transmitters from the existing nodes. Typically the analog return from these nodes terminate in the hub site with indoor return path receivers over distances of 20 km or less. The distance between the hub site being eliminated and the central headend can be 40 to over 100 kilometers and beyond the reach of the node analog return transmitters. To overcome the extended distance would normally require a forklift upgrade of the existing analog transmitter to a digital DWDM transmitter solution so as many as 40 transmitters could be multiplexed together and transported to the centralized headend.

ATX Networks offers an alternative cost effective solution to aggregate and transport existing node analog returns over 100 km from the hub collapse location to the central headend. This product brief will introduce the field hardened I-HUB Opto-Stacker solution and compare the performance and cost with upgrading nodes to digital return.

Opto-Stacker Solution

The I-HUB Opto-Stacker solution is utilized to transport a collection of node return paths upstream from an I-HUB (collapsed hub location) to a centralized headend or hub location. The Opto-Stacker is a two-slot I-HUB frequency stacker module which is configurable to support either four 5 to 85 MHz or two 5 to 204 MHz return path bands, frequency stacked and transported with a single ITU wavelength laser.





Opto-Stacker Module
Up to 5 Modules
(20 Return Segments)/Housing

Figure 1: I-HUB Housing & Opto-Stacker Module

Figure 2 is a block diagram of the Opto-Stacker. The module incorporates 4 return receivers which work with any node or RFoG analog return transmitter. An optical monitored AGC circuit balances and maintains the correct RF level for each receiver prior to being upconverted in frequency. Each return band, (4 x 85 MHz or 2 x 204 MHz) is then frequency upconverted/stacked together between 1,000 – 2,000 MHz before being modulated by the ITU C-Band laser transmitter. A FSK return channel is utilized for one-way monitoring of the I-HUB. A pilot channel is also inserted to provide link gain control for a constant RF level out of the mated De-Stacker module at the headend over the full optical range of the De-stacker. The performance rivals digital return NPR performance along with transparent phase noise performance while supporting a 204 MHz return split today.

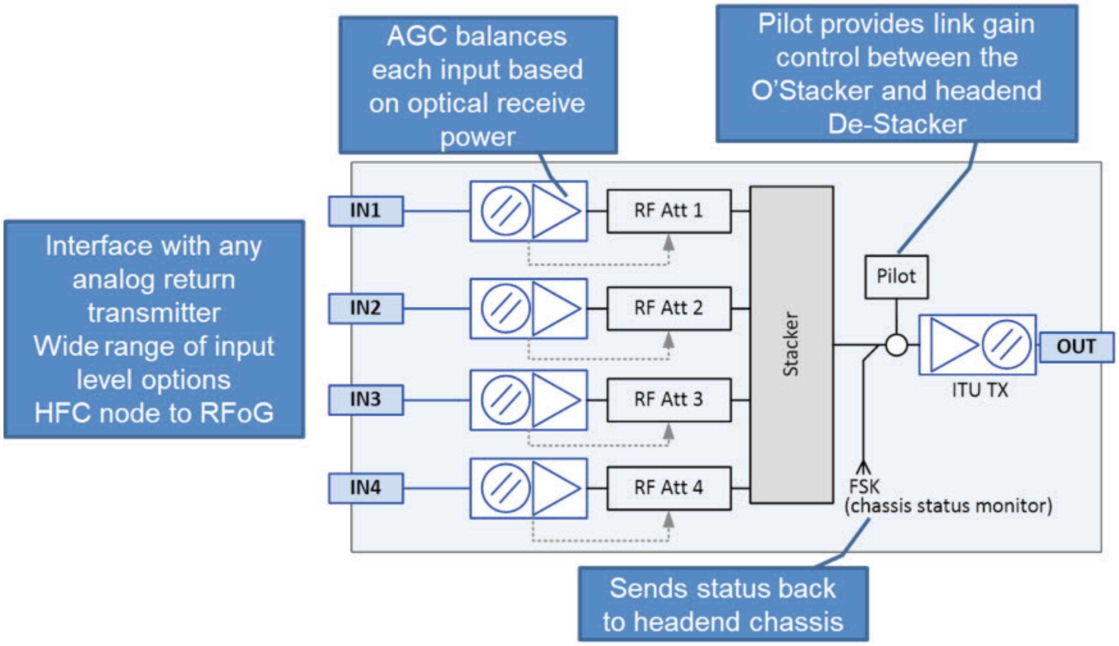


Figure 2: I-HUB Opto-Stacker Block Diagram

Hub Elimination/Collapse Return Path Topology

Up to twenty 200 GHz spaced ITU wavelengths can be utilized which supports 80 x 5 to 85 MHz return path segments or node return transmitters on a single fiber.

Figure 3 is a diagram of a hub elimination/collapse topology with 40 downstream wavelengths, or service group segments, complimented by the return path with up to 20 Opto-Stackers to support up to 80 return path service group segments. In this particular example, there is a mix of 1x1 and 4x4 nodes which may have any combination of forward and return path segmentation. Also note that the hub being eliminated incorporates forward and return path redundancy.

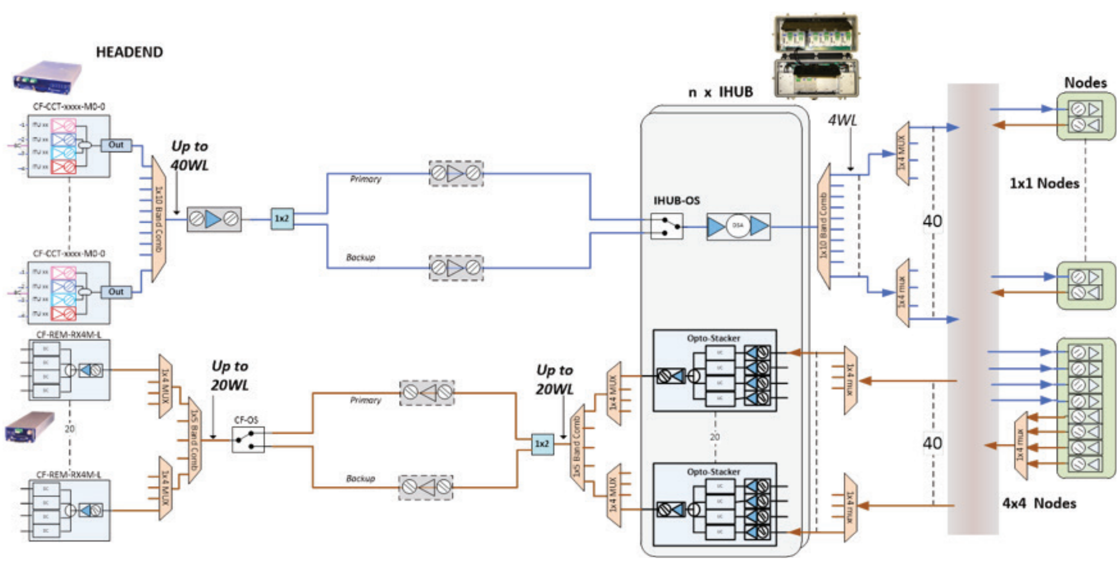


Figure 3: Diagram of 40 Wavelength Hub Elimination (Forward & Return)

In the return path, the fiber from each node that was connected to a port on a return path receiver now connects to one of the ports of an Opto-Stacker. For the nodes with a single transmitter this might be a 1310 nm analog transmitter. The 4x4 node might have two or four CWDM analog return path transmitters multiplexed together on a single fiber and then demultiplexed with each CWDM wavelength connected to a port of the Opto-Stacker. The optical output of each Opto-Stacker is multiplexed and transported to the central headend or hub. Optical EDFA amplifiers may be placed if needed depending on the distance. An ATX Networks destacker module is utilized at the headend which performs the opposite function of the Opto-Stacker.

Figure 4 is a block diagram of a ChromaFlex CF-REM destacker module. The destacker module incorporates an optical receiver followed by the downconverters to separate the four original 5 to 85 MHz segments that where connected to the Opto-Stacker. The module can utilize the Opto-Stacker pilot to work as an AGC in case of optical level fluctuations.

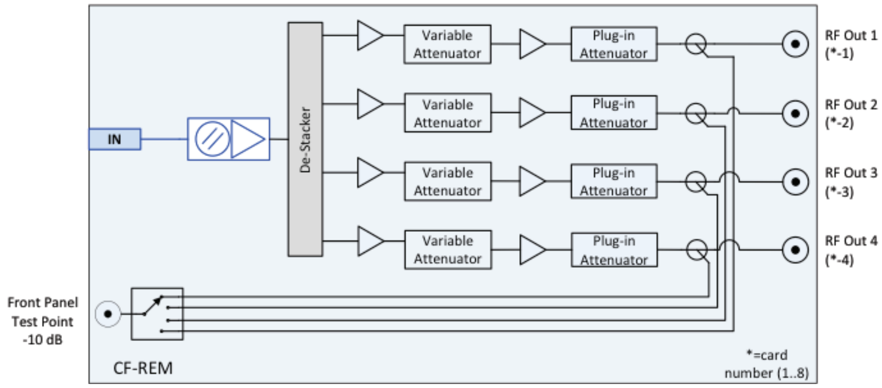


Figure 4: ChromaFlex Destacker Module (CF-REM)

I-HUB Opto-Stacker Performance

The frequency upconversion of the 5 to 85 MHz band to a frequency above 1000 MHz eliminates the performance impact from fiber effects; Interferometric Intensity Noise (IIN), Stimulate Ramon Scattering (SRS) Crosstalk, and Chirp induced distortions. These effects manifest themselves most prominently as noise-like Inter Modulation Distortion products that fall in the lower RF frequency range reducing NPR performance of the return spectrum. Direct modulated transmitters are also traditionally Composite Second Order (CSO) limited in performance and this is true for the return path as well but not quite as significant as for forward path. Another aspect of the performance improvement over traditional 5 to 85 MHz transmitters is that the four 5 to 85 MHz segments are upconverted in frequency so they fall within a single octave which eliminates CSO distortion products enabling very long links >100 km as may be needed for hub-eliminations.

Comparison Between the Opto-Stacker Solution & Digital Return Transmitters

Here we compare an Opto-Stacker return path link consisting of a node equipped with a CWDM analog DFB return transmitter with a 6 dB (approximately 20 km) link loss combined with an Opto-Stacker with a 50 km fiber link (70 km total) compared to a digital return transmitter link performance. The Opto-Stacker link performance includes node transmitters with 5 to 42 MHz loading connected to each of the four input ports. With each 37 MHz of RF load upconverted, the total RF loading modulated by the transmitter is roughly 150 MHz. The digital transmitter is stated as a 2:1 so we will assume that there are two 5 to 42 MHz RF inputs connected, however this is an unknown.

Figure 5 shows the NPR performance of a typical analog transmitter with 5 to 42 MHz loading. The 40 dB NPR point has about 18 dB DR (Dynamic Range) with a peak NPR of 51 dB.

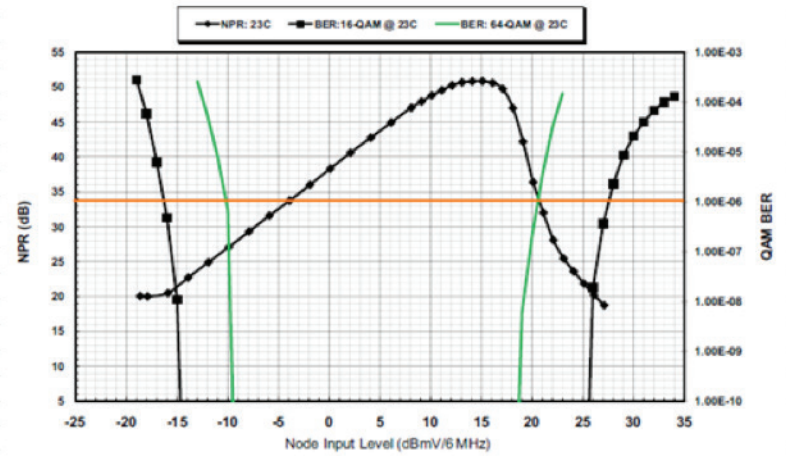


Figure 5: Analog CWDM Transmitter NPR Chart

Figure 6 shows the total end to end NPR / DR link performance of the analog DFB node transmitter (red line), an Opto-Stacker 50 km link (orange line) and the combined link (cyan line) NPR performance.

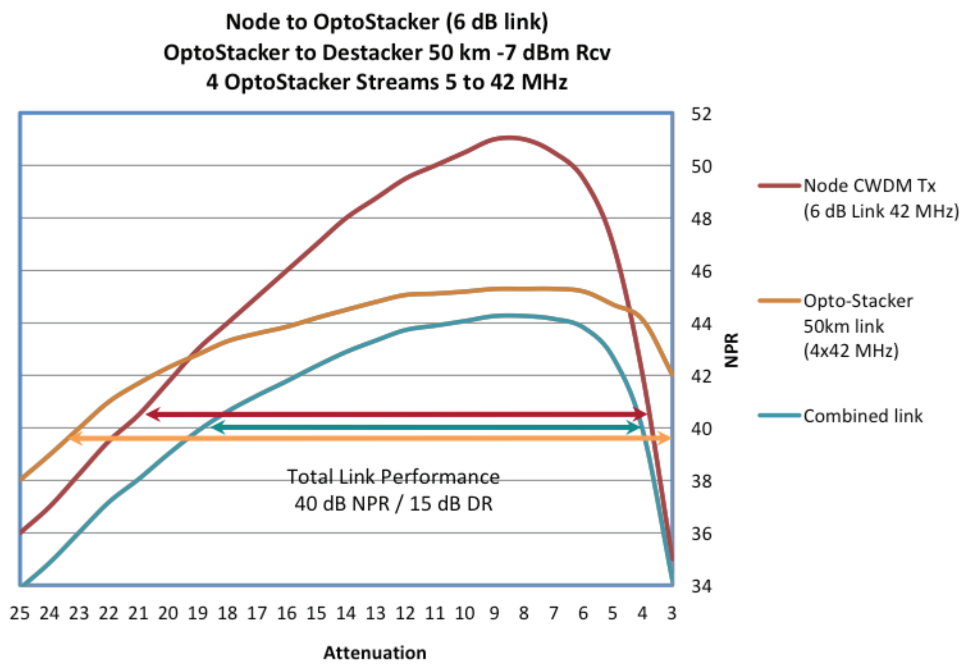


Figure 6: Node Transmitter, Opto-Stacker & Combined NPR Performance

The Opto-Stacker exhibits a much wider dynamic range due to its immunity to fiber impairments normally seen in the 5 to 42 MHz RF spectrum. At 40 dB NPR the DR is extended beyond the node transmitter NPR on both the noise and distortion side of the curve with a total of about 24 dB. The overlapping of the dynamic range provides additional tolerances for the Opto-Stacker to auto adjust each of the four optical input port RF attenuators for the correct input level to the upconverters. The peak NPR is lower compared to the node transmitter peak, about 45 dB, as the link loss is fairly lengthy along with having roughly 150 MHz of RF loading as compared to 35 MHz for the digital return transmitter. The RF loading difference equates to 5.5 dB which is what we see. The combined link performance of the node transmitter and Opto-Stacker with four node transmitters upconverted provides 15 dB DR at 40 dB NPR. Since the node transmitter has a peak NPR about 6 dB greater than the Opto-Stacker peak the combined result is reduced by only about 1 dB for a peak NPR of 44 dB. Longer distance Opto-Stacker links are supported with mid-span EDFAs with integrated dispersion compensation as would be utilized in forward path over optical links of this length. The additional NPR / DR degradation is minimal and specific to the placement of the EDFAs.

The table in figure 7 calculates the optical link performance required for differing modulation rates and for three node serving size scenarios from node plus zero to roughly a 500 HP serving area with 16 amplifiers subtended from the node. The "Avg # Amps" column is the number of amplifiers subtended by the node serving area and the "Amp CNR" column is the combined CNR of those amplifiers. By subtracting the return path amplifier CNR and the cable modem source CNR from the CMTS input CNR requirement tells us what the optical link performance needs to be for the different modulation rates.

So with the combined performance of greater than 40 dB NPR with a very good dynamic range the node transmitter and Opto-Stacker can support greater than 1024 QAM modulation and an increased passband to 204 MHz which is not supported today with digital return solutions.

Node size		D3.1 CNR Requirement / Optical Link (OL) CNR Requirement								
Avg # Amps	Amp CNR	CM CNR	QAM 256		QAM 512		QAM 1024		QAM 2048	
			CMTS	OL	CMTS	OL	CMTS	OL	CMTS	OL
N+0	62	44	29	30	32.5	33	35.5	37	39	41
7	53	44	29	30	32.5	33	35.5	37	39	41
16	50	44	29	30	32.5	33	35.5	37	39	42

Figure 7: Return Path Performace Requirements

Figure 8 is a NPR curve for a typical digital return transmitter. The 100 km link performance provides a 18 dB DR at 40 NPR, similar to the combined analog link performance of the node transmitter plus Opto-Stacker.

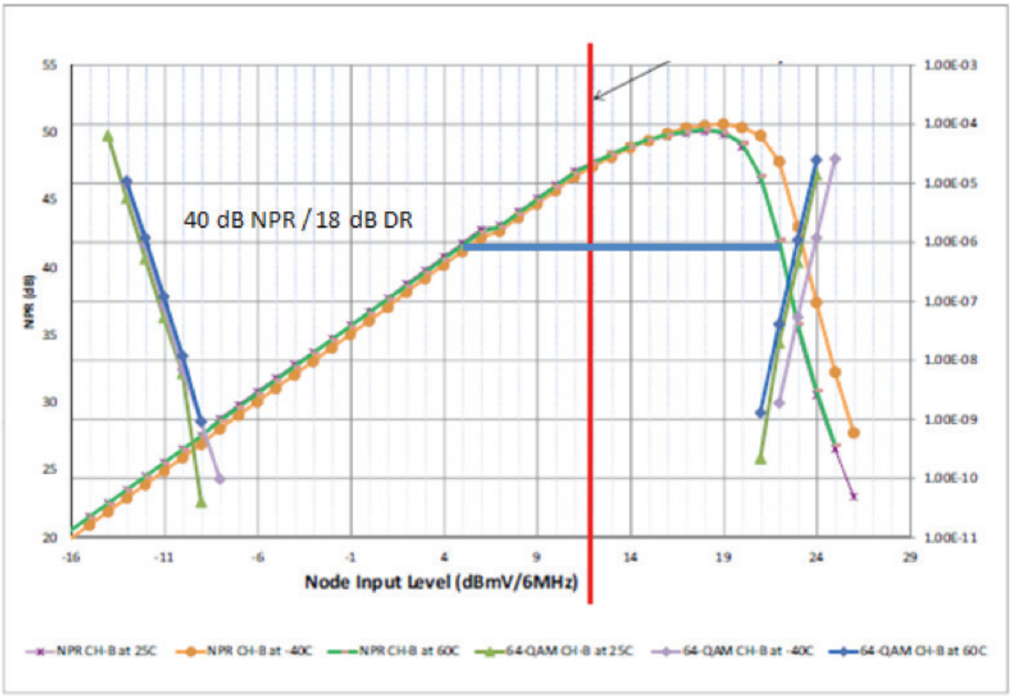


Figure 8: Digital Return Transmitter NPR

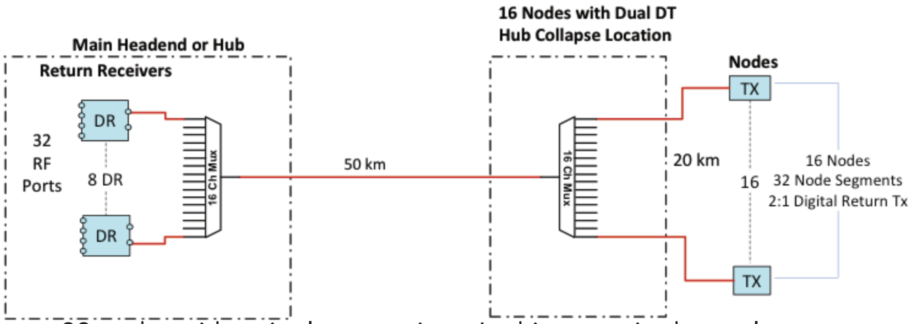
However the Opto-Stacker is transporting four return path segments per wavelength compared to the digital return with one or two return segments. The digital return transmitter is also limited to supporting 5 to 85 MHz.

Economics

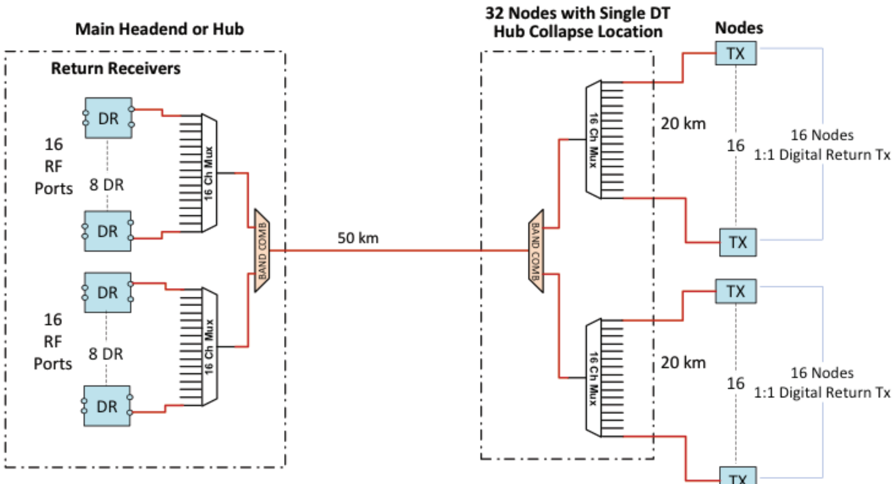
Here we will compare the typical cost between a digital return and Opto-Stacker solution for transporting 32 node return path segments from a hub collapse with an installed base of analog node return path transmitters.

For the digital return we will look at two scenarios:

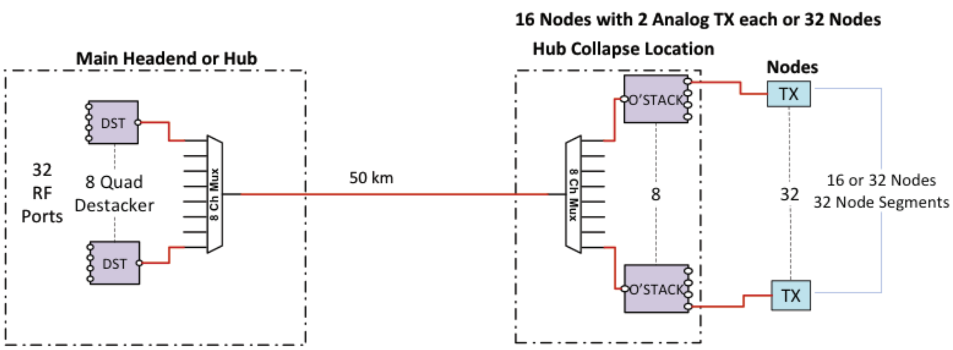
1. There are 16 2x2 nodes where a single 2:1 digital transmitter can be installed which takes advantage of the digital return technology. In this scenario the analog return transmitters at the 16 nodes are replaced with a 2:1 digital return transmitter with an 80 km SFP to support the two return path segments for each node. The 16 DWDM wavelengths are multiplexed at the old hub location and transported to the headend. Eight dual input, four RF output digital return receivers reconstruct the 32 return path segments.



2. There are 32 nodes with a single transmitter. In this scenario the analog return transmitters at the 32 nodes are replaced with a 1:1 digital return transmitter with an 80 km SFP to support the return path for each node. The 32 DWDM wavelengths are multiplexed at the old hub location and transported to the headend. Sixteen dual input, two RF output digital return receivers reconstruct the 32 return path segments.



The two digital return scenarios are compared to just leaving the 32 analog return transmitters in place and installing the Opto-Stacker solution to transport the return segments from the hub being eliminated to the headend.



Each of the 32 analog transmitters is connected to one of the four Opto-Stacker ports. Each Opto-Stacker upconverts four of the node transmitter inputs and modulates onto a DWDM transmitter. Eight Opto-Stackers handles the 32 node transmitters. The wavelength of the node transmitters does not matter. The eight wavelengths are multiplexed and transported to the headend. Eight de-stacker modules reconstruct the 32 return path segments.

The table in figure 9 compares the cost of the two scenarios described above to replace the existing analog return transmitters with digital return transmitters against leaving the analog return transmitters in place using the Opto-Stacker technology.

	Replace Analog Node Tx to Digital TX						Keep Analog Tx with Opto-Stacker		
	16 Node 2:1 DT			32 Node 1:1 DT			16 (2x2) or 32 Nodes		
	QTY	Price	Ext Price	QTY	Price	Ext Price	QTY	Price	Ext Price
IHUB Housing							2	$ 1,600	$ 3,200
Opto-Stacker							8	$ 2,400	$ 19,200
8 CH Mux/Dmux							1	$ 900	$ 900
16 CH Mux/Dmux	1	$ 2,100	2100	2	$ 2,100	$ 4,200			
Band Combiner				1	$ 500	$ 500			
2:1 Digital TX	16	$ 350	5600						
81 km 4.2 Gb SFP	16	$ 850	$ 13,600						
1:1 Digital TX				32	$ 300	$ 9,600			
80 km 2.1 Gb SFP				32	$ 750	$ 24,000			
OSP total			$ 21,300			$ 38,300			$ 23,300
HE Chassis	1	$ 1,800	$ 1,800	2	$ 1,800	$ 3,600	1	$ 1,800	$ 1,800
DR Dual in 4 RF Out	8	$ 1,400	$ 11,200						
DR Dual in 2 RF Out				16	$ 1,200	$ 19,200			
8 CH Mux/Dmux							1	$ 900	$ 900
16 CH Mux/Dmux	1	$ 2,100	$ 2,100	2	$ 2,100	$ 4,200			
Band Combiner				1	$ 500	$ 500			
Quad Destacker							8	$ 1,000	$ 8,000
HE Total			$ 15,100			$ 27,500			$ 10,700
Total			**$ 36,400**			**$ 65,800**			**$ 34,000**

Figure 9: Cost Comparison of Digital Return & Opto-Stacker Technology

The analysis does not include the labor component of changing nodes or the additional service interruptions. The Opto-Stacker proves to be more cost effective than either transmitter replacement scenario with the 32 node scenario being about half the cost of the digital return equipment.

Conclusion

In summary the ATX Networks Opto-Stacker provides a cost effective and high performance (rivaling or exceeding digital return) return path solution for hub elimination and node segmentation applications where an installed base of node analog transmitters exists.

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