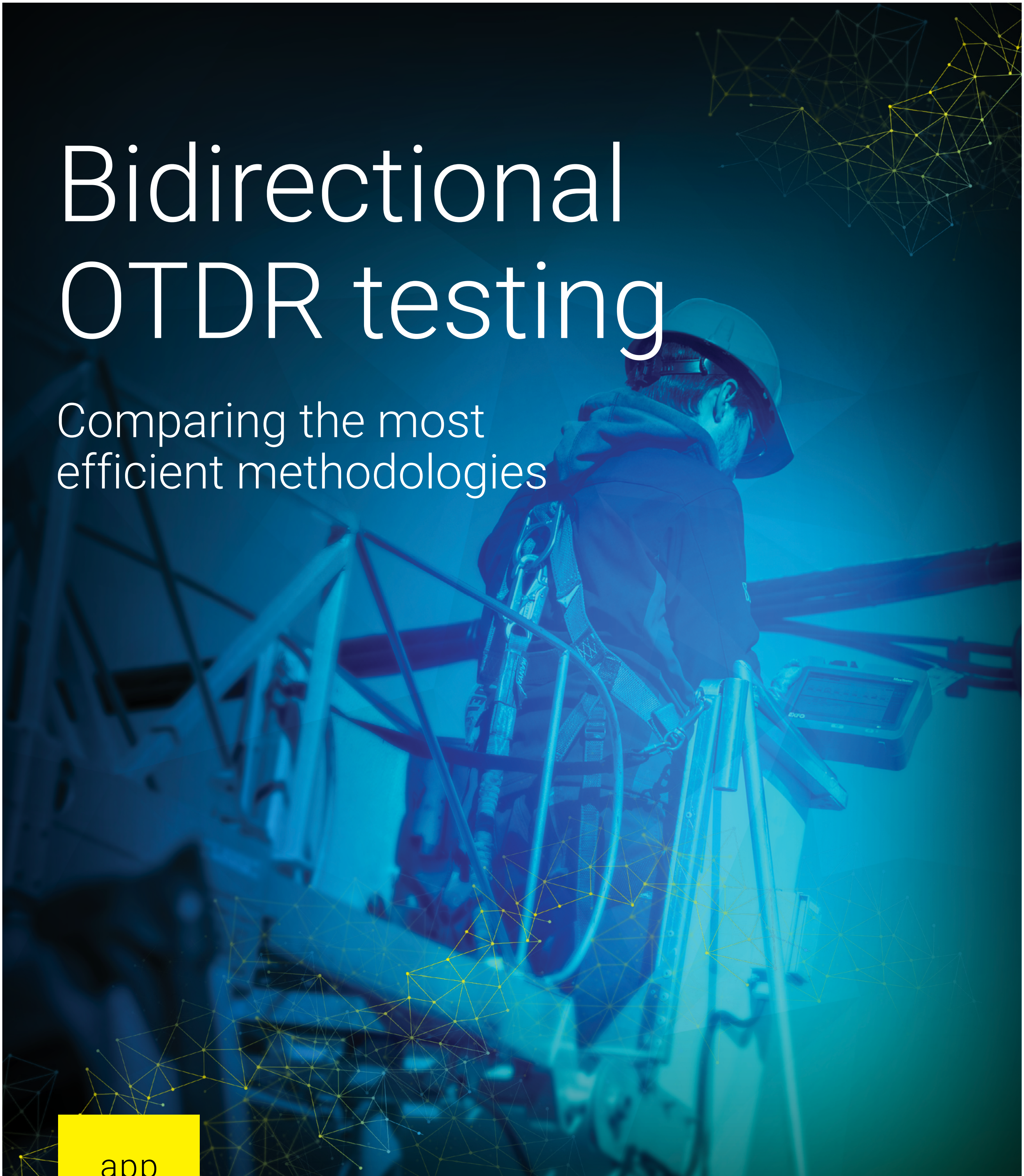
Bidirectional OTDR testing

Comparing the most efficient methodologies



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EXFO

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app note

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Bidirectional OTDR is recognized as the most accurate way to characterize a fiber link. Its main advantages are:

- The ability to neutralize the gainers/losers effect caused by a mode field diameter mismatch
- The reduction in uncertainty

However, bidirectional OTDR does come with its share of complexity and additional costs compared to unidirectional OTDR.

Two key challenges are widely acknowledged:

A. **The complexity of post-processing.** Even when using state-of-the-art post-processing software (such as FastReporter), matching the right files is not a trivial task. In the absence of proper job management, it becomes even more complex and time-consuming when file naming conventions are not consistently followed. Results may also be irrelevant if test configurations were inconsistent.

B. **The absence of a final verdict while technicians are still on site.** Bidirectional post-processing occurs after technicians leave a site. Faulty elements are diagnosed in a second step, and technician must be sent to the same site to correct them. This second visit starts another round of post-processing, which may determine that some repairs were not successful, resulting in more truck rolls until a final PASS is obtained for all fiber links.

To solve those challenges:

1. The consistency of test configurations across entire acquisitions should be ensured.
2. A bidirectional verdict should be available in the field, right after the acquisition is completed, with no manual post-processing from the technician.

This would let technicians know if the job can be closed or if any corrective actions are required prior to leaving the site. Their OTDR should also be able to export a bidirectional report along with all related SOR and native files from the field.

Several processes are available on the market and can be used to overcome those challenges and increase efficiency in bidirectional OTDR testing. This application note reviews the following four methodologies of bidirectional acquisition and analysis processes using the example of a 144-fiber cable:

1) **Loopback acquisition, two-technician job**
2) **Guided job management (asynchronous acquisitions), one-technician job**
3) **Guided job management (asynchronous acquisitions), two-technician job**
4) **Dual-ended test set (synchronous acquisitions), two-technician job**

Reviews include these four perspectives:

- Description of the test process (steps, equipment and technicians required)
- Description of the bidirectional analysis process (including how files are gathered and matched)
- Validation of continuity[1] and polarity[2]
- Hours of testing time needed (to evaluate labor cost). We will assume a 30 second acquisition time per fiber, per direction for a fair comparison across the four methodologies

The focus will be on the manipulations specific to each methodology. However, connectors must be inspected (and cleaned when needed) before any mating to prevent cross-contamination, using industry best practices.

1) Loopback acquisitions, two-technician job

Test process

This method requires one technician on Site A (Site A technician) with an OTDR and one technician on Site B (Site B technician) with a loop cable. The technicians communicate to synchronize the steps described below. The Site A technician connects a launch cable of appropriate length[3] to fiber 1 and a receive cable to fiber 2. The OTDR is connected to fiber 1 through a jumper via the launch cable. The Site B technician places a loop between fiber 1 and 2. The Site A technician starts a first acquisition that will include fiber 1 AB and fiber 2 BA (Figure 1).

For the second acquisition, the launch cable connected to fiber 1 is now the receive cable and the receive cable on fiber 2 is now the launch cable (none of them should be disconnected from the fibers under test). The Site A technician connects the OTDR to fiber 2 through the jumper (via the cable that is now the launch) to perform a second acquisition including fiber 2 AB and fiber 1 BA (Figure 2).

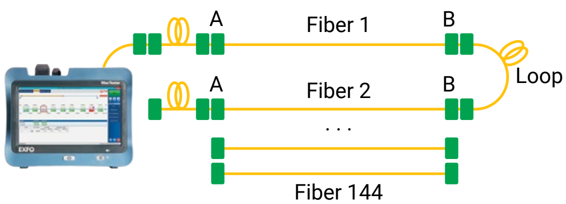


Figure 1. Step 1 of loopback acquisition. One technician performs acquisitions of fiber 1 AB and fiber 2 BA from Site A, while a second technician places the loop on Site B.

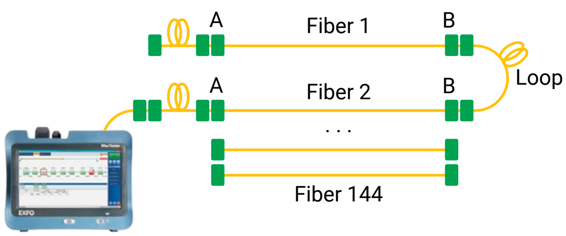


Figure 2. Step 2 of loopback acquisition (fiber 2 AB and fiber 1 BA). Then the loop is moved to the next pair, and cycles of steps 1 and 2 continue until all pairs are done.

Once the acquisition of a first pair is completed, the Site B technician can move the loop to a next pair of fibers (ex.: fiber 3 and 4) and the Site A technician can repeat the same process for fibers 1 and 2. This cycle is repeated until all 144 fibers are done.

Note: A minimum of two fibers must be available to perform the test using the loopback methodology.

Span length: as two fibers are characterized at same time, the addressable span length will be half the typical span length supported by the OTDR being used.

1. Continuity validation refers to ensuring there are no breaks in the fiber, so that a light entering from end A would exit at end B and vice versa.
2. Polarity validation refers to ensuring that what is identified as the fiber 1 port on Site A is also identified as the fiber 1 port on Site B.
3. Launch cables in this scenario also act as receive cables and vice versa.

Bidirectional analysis

With this methodology, all AB and BA unidirectional results are saved on the OTDR instrument. Since each measurement covers two fibers looped together, the OTDR has to identify the loop and separate each result in 2 individual unidirectional results. In the first acquisition from the example above, the OTDR separates fiber 1 AB from fiber 2 BA (Figure 1, Step 1). In the second acquisition, it separates fiber 2 AB from fiber 1 BA (Figure 2, Step 2). Then, for each fiber, AB and BA are analyzed bidirectionally and a verdict for each fiber is saved on the OTDR, right after the pair acquisition is completed.

First and last connector: if a receive cable is used, both connectors are characterized bidirectionally.

Validation of continuity and polarity

Continuity: Since each fiber is tested from both ends, continuity would be confirmed by reading the proper length including launch, loop and receive cables. Any break on one of the fibers of the pair being characterized would lead to length inconsistencies. Consider this simplified example: a technician tests a pair of 500-meter fibers using launch, receive and loop cables of 100 meters each. If there is no break in either length of fiber, every acquisition should present 1,300 meters of fiber (100 + 500 + 100 + 500 + 100). Should a break occur on fiber 1 at 300 meters, the first acquisition will return 400 meters of fiber (100 + 300) and the second acquisition will return 900 meters (100 + 500 + 100 + 200). This length inconsistency would prevent final processing, thus flagging a continuity issue.

Polarity: Polarity validation is only possible at the pair level. Transposition within a pair (e.g., between fiber 1 and 2) could not be identified.

Technician hours for testing

AB (fiber 1) and BA (fiber 2) acquisitions are performed during the same 30 seconds. Then AB (fiber 2) and BA (fiber 1) acquisitions are performed during the next 30 seconds. One minute of testing involving two technicians adds up to two minutes of labor in which two fiber links are tested bidirectionally. So for a 144-fiber cable that involves 77 pairs at 2 minutes of labor each, technician time adds up to 144 minutes. (The synchronization requirement may slow the pace of work to the speed of the slower technician.)

2) Guided job management (asynchronous acquisitions), two-technician job

Test process

This process involves two technicians (one at each end) with an OTDR each and internet connectivity. The OTDRs support a job management system, in which a job is defined with all 144 individual test points (fiber ID) for each site. The Site A technician selects “fiber 1” within the job as the first test point, connects the OTDR through a launch cable to this test point and launches the AB acquisition. At the same time, the Site B technician selects fiber 144 within the job as the first test point, connects the OTDR to this test point and launches the BA acquisition. With this setup, AB on fiber 1 and BA on fiber 144 can be performed at the same time. Then the technicians switch to fiber 2 and fiber 143, and so on.

The only potential down time is when technicians cross each other at the “middle” of the cable (likely around fiber 77 if they work at same pace) and try to test the same fiber at the exact same time. This scenario can be avoided if, instead of going in reverse order, both technicians proceed from fiber 1 to 144, but offset their test launch times by a few minutes so they never launch a test in the same fiber at the same time.

Note: Acquisition from both sites does not have to be performed at the exact same moment and no synchronization is required if no receive cable is used. For example, the Site B technician could start earlier or later, or even on another day. When using a receive fiber, technicians must synchronize and communicate to ensure the receive cable is on the right fiber before they start testing.

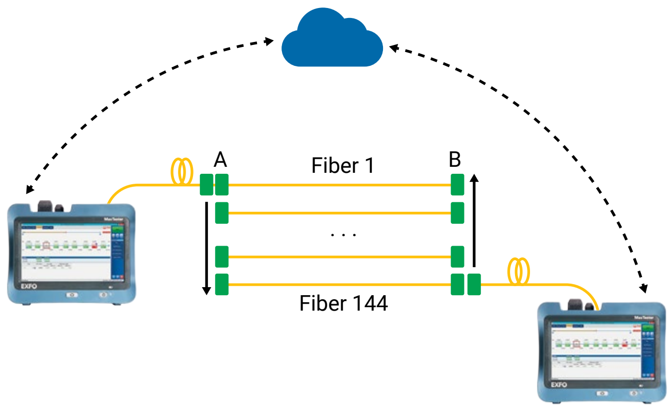


Figure 3. Asynchronous acquisitions with two technicians working in parallel on Sites A and B.

Bidirectional analysis

AB results from Site A are uploaded to the cloud during the acquisition process. Results can then be pulled from the OTDR on Site B. As the job progresses, the OTDR on Site B gathers AB and BA results. Since technicians select predefined test points with proper fiber ID before each test, the matching of AB and BA is automated by job management. As soon as a pair of AB and BA are available for a given fiber, bidirectional analysis can occur and a verdict appears on the OTDR. Verdicts and diagnoses are sent back to the cloud, where they become available to the OTDR on Site A.

First and last connector: if a receive cable is used, they will both be characterized bidirectionally.

Validation of continuity and polarity

Continuity: Within the same cable, all fibers have the same length. This length is the same whether it is measured from Site A or Site B. Any continuity issue (fiber cut) would mean an inconsistent length compared to other fibers in the cable, as well as inconsistent AB versus BA length. Inconsistent fiber length would prevent bidirectional analysis and flag a continuity issue.

Polarity: A receive cable can be used to confirm polarity. Absence of receive length in the total measured length would flag a polarity issue as it would mean the fiber path does not match expected polarity.

Technician hours for testing

At 30 seconds per fiber per direction on 144 fibers, each technician will spend 77 minutes on testing (144 × 30 seconds). This means a total of 144 minutes (77 minutes × 2 technicians) of technician time for the 144-fiber cable. If a receive cable is used, synchronization between each fiber may slow down to the speed of the slower technician.

3) Guided job management (asynchronous acquisitions), one-technician job

Test process

This process involves one technician using one OTDR. The OTDR supports a job management system in which a job is defined with all 144 individual test points (fiber ID) for each site. On Site A, the technician selects fiber 1 in the job as a first test point, connects the OTDR using a launch cable to this test point, launches the AB acquisition and repeats the process for each fiber. Then the technician goes to Site B and repeats the same sequence to acquire all 144 BA measurements.

Figure 4. Step 1 of asynchronous acquisitions with one technician. Technician tests AB from fibers 1 to 144 on Site A.

Figure 5. Step 2, technician tests BA from fibers 1 to 144 on Site B.

Bidirectional analysis

AB results are already stored in the OTDR, so after each BA a bidirectional analysis is processed automatically and a verdict appears on the OTDR (fully offline). Since technicians select predefined test points with proper fiber ID before each test, the matching of AB and BA is automated. If two different OTDRs are used on Sites A and B, AB results can be transferred to the OTDR on Site B via the cloud (internet connection required). This transfer can happen before the BA acquisition job on Site B starts.

As soon as a pair of AB and BA are available for a given fiber, bidirectional analysis is processed automatically and a verdict appears on the OTDR.

First and last connector: since a receive cable is typically not used with this method, both connectors are characterized from one direction only. A technician could still perform bidirectional characterization of first and last connectors by driving back and forth between sites to pre-install launch and receive cables on both ends of each fiber prior to performing acquisitions. This latter option only makes sense where there are few fibers to characterize since it would involve too many costly launch and receive cables (1 pair per fiber).

Validation of continuity and polarity

Continuity: Within the same cable, all fibers have the same length. This length is the same whether it is measured from Site A or Site B. Any continuity issue (fiber cut) would mean an inconsistent length compared to other fibers in the cable, as well as inconsistent AB versus BA length. Inconsistent fiber length would prevent bidirectional analysis and flag a continuity issue.

Polarity: Not available with this methodology.

Technician hours for testing

At 30 seconds per acquisition, measuring all AB (144 fibers x 30 seconds) takes 77 minutes. Add another 77 minutes for all BA and this adds up to 144 minutes (77 + 77) of technician time.

4) Dual-ended test set (synchronous acquisitions), two-technician job

Test process

This process involves two technicians (one at each end), each with an OTDR capable of exchanging data over the cable under test. The technicians communicate to synchronize and confirm when they are ready to start testing.

They connect their OTDRs using launch cables of appropriate lengths[4], to fiber 1 on both ends. One technician launches the acquisition process, then each OTDR performs a unidirectional acquisition on the fiber under test. Once both unidirectional acquisitions are completed, technicians are advised they can move the OTDRs to the next fiber.

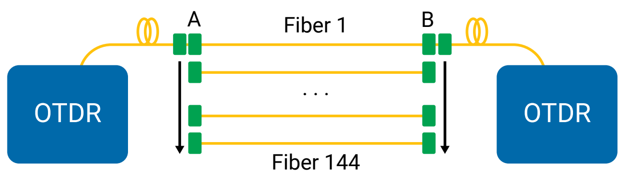


Figure 6. Two OTDRs are connected through launch cables on the same fiber on both ends. They sequentially perform unidirectional acquisitions AB and BA, transfer results, then automatically perform bidirectional analysis. The verdict appears on the OTDRs.

Bidirectional analysis process

Results are exchanged between OTDRs using the cable under test. The OTDR on site B gathers AB and BA results and processes the information for a bidirectional analysis. A verdict appears on both OTDRs.

First and last connector: they are both characterized bidirectionally since each fiber is tested using a launch and receive fiber.

Validation of continuity and polarity

Continuity and polarity: when both OTDRs are connected to the same fiber on both ends, communication is attempted. If successful, this confirms there is continuity. It also means polarity is as expected on this fiber. Unidirectional acquisitions can now start.

If communication is not successful, the OTDRs launch unidirectional tests from both ends to help diagnose the issue. A fiber cut (continuity issue) would lead both unidirectional acquisitions to be shorter than the expected length and each direction is likely to have a different length than the other direction. If both unidirectional measurements return the length expected for the cable minus the receive length, this indicates a polarity issue.

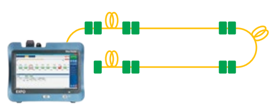
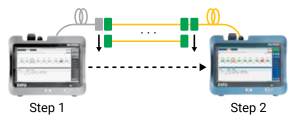
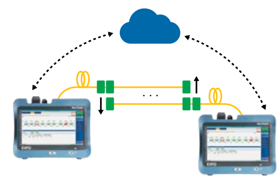
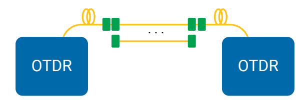
Technician hours for testing

When fiber 1 is under test, AB acquisition takes 30 seconds, then BA takes another 30 seconds, adding up to a full, uninterrupted 1-minute sequence. While AB and BA acquisitions take place in sequence for a fiber, both technicians have to wait for both directions to be completed. The Site A technician waits for 30 seconds for AB, but also has to wait for the next 30 seconds for BA. The Site B technician experiences inverse wait times. Thus, 1 minute per fiber on the clock means two technicians each spend 1 minute, for a total of 2 minutes per fiber. Testing time for a 144-fiber cable can be calculated as 144 fibers x 2 minutes/fiber = 288 minutes of technician time to be paid.

The synchronization requirement at every step also slows the pace down to the speed of the slower technician, so overall testing time will be higher and should be planned and budgeted accordingly.

4. Launch cables in this scenario also acts as receive cables. For example, the launch cable of the OTDR on Site B acts as the receive cable when the OTDR on Site A performs the AB acquisition.

5) Summary

Bidirectional measurement technique	Loopback acquisition	Guided job management (1 technician)	Guided job management (2 technicians)	Dual-ended testing
				
Number of technicians	2	1	2	2
Number of OTDRs	1	1	2	2
Technicians' synchronization (each test can only start when both technicians are ready and working on the same fiber at both ends)	Required	Not required	Optional (required only if using receive cables)	Required
Span length	Half the typical capacity of the OTDR being used	Full typical capacity of the OTDR being used	Full typical capacity of the OTDR being used	Full typical capacity of the OTDR being used
Bidirectional verdict and reports in the field	Yes	Yes	Yes	Yes
Cloud connectivity (for verdict on testing site)	Not required	Not required	Required	Not required
First and last connector measurements	Bidirectional	Unidirectional (or bidirectional with launch and receive cables pre-installed)	Unidirectional or bidirectional (if using receive cables)	Bidirectional
Continuity	Yes	Yes	Yes	Yes
Polarity	By pair	No	Optional (if using receive cables)	Yes
Technician time for testing a 144-fiber cable* (minutes)	144	144	144	288

* Assuming 30 seconds per acquisition per direction, excluding inspection, cleaning and manipulations. See detailed calculations in respective sections.

6) Conclusion

Each methodology offers different benefits and cost profiles (technician hours, number of OTDRs) to be reviewed carefully by operators to make optimal choices, fitting their business goals. The dual-ended testing approach might be appealing for its ability to guarantee polarity, and to ensure the entry connectors are both measured bidirectionally. However, from an OPEX perspective it costs at least twice as much as other methodologies. The asynchronous approach through guided job management (one technician) is much more efficient, to the point that it could reduce testing time (part of OPEX) beyond the minimum expected factor of 2. Indeed, the constraint to synchronize technicians' work on both ends can lead to further time wasted, and any delay on either end translates into time wasted for two technicians instead of one.

Beyond the efficiency of the acquisition and bidirectional analysis process, accuracy of the results is another key factor to consider for overall efficiency. Greater accuracy means fewer false alarms driving unnecessary repair costs or leaving faulty elements unnoticed (which may necessitate additional truck rolls later on). Such state-of-the art accuracy can be achieved using the iOLM patented multipulse acquisition and patented intelligent bidirectional analysis, which uses all data available from all acquisitions from original unidirectional acquisitions. Finally, to make it easier to review results later, all bidirectional data relative to a given fiber link should be available through a single bidirectional file, preventing the need for manual post-processing even in the case of a future audit.