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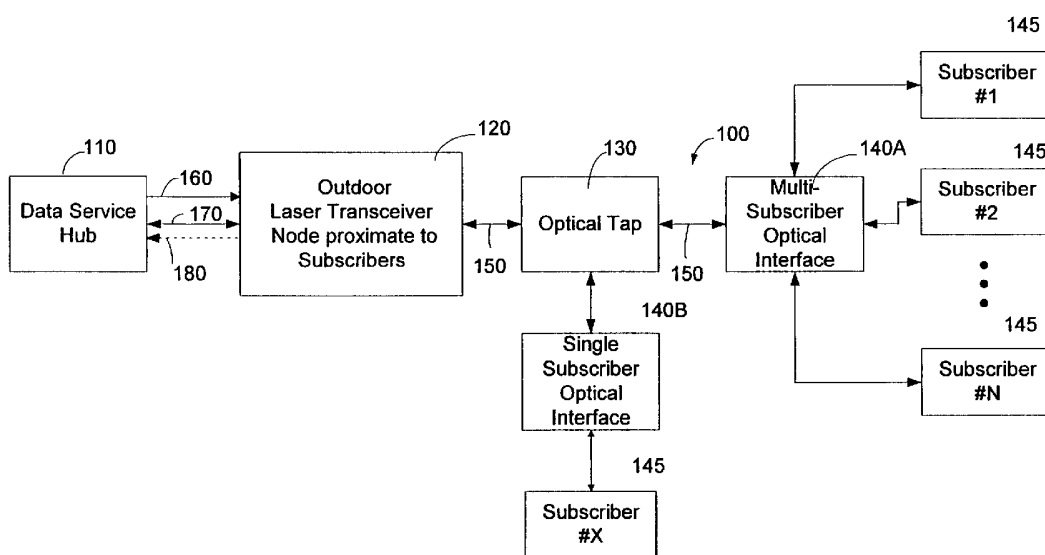
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(54) Title: SYSTEM AND METHOD FOR COMMUNICATING OPTICAL SIGNALS TO MULTIPLE SUBSCRIBERS HAVING VARIOUS BANDWIDTH DEMANDS CONNECTED TO THE SAME OPTICAL WAVEGUIDE



(57) Abstract: The present invention is generally drawn to optical network architecture that can include a multi-subscriber optical interface that can service a plurality of subscribers that are located in close proximity relative to one another. For example, the multi-subscriber optical interface can service multiple dwelling units such as an apartment complex that has many different subscribers to the optical network system. Further, the invention can also service subscribers over the same optical waveguide who may have different bandwidth needs, such as businesses, personal/home users and the like.



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**SYSTEM AND METHOD FOR COMMUNICATING OPTICAL SIGNALS TO
MULTIPLE SUBSCRIBERS HAVING VARIOUS BANDWIDTH
DEMANDS CONNECTED TO THE SAME OPTICAL WAVEGUIDE**

5 **PRIORITY CLAIM TO PROVISIONAL AND NON-PROVISIONAL
APPLICATIONS**

The present application is a continuation-in-part of non-provisional patent application entitled "System and Method for Communicating Optical Signals between a Data Service Provider and Subscribers," filed on July 5, 2001 and assigned U.S.
10 Application Serial No. 09/899,410. The present application also claims priority to provisional patent application entitled, "Fiber-to-the-Curb Communications System," filed on August 14, 2001 and assigned U.S. Application Serial No. 60/311,840. The entire contents of both the non-provisional patent application and the provisional patent application mentioned above are hereby incorporated by reference.

15

TECHNICAL FIELD

The present invention relates to video, voice, and data communications. More particularly, the present invention relates to a fiber-to-the-curb (FTTC) system that is capable of supporting several different subscribers having various degrees or levels of
20 bandwidth on the same optical waveguide.

BACKGROUND OF THE INVENTION

The increasing reliance on communication networks to transmit more complex data, such as voice and video traffic, is causing a very high demand for bandwidth.
25 To resolve this demand for bandwidth, communication networks are relying more upon optical fibers to transmit this complex data. Conventional communication architectures that employ coaxial cables are slowly being replaced with communication networks that comprise only fiber optic cables. One advantage that optical fibers have over coaxial cables is that a much greater amount of information
30 can be carried on an optical fiber.

While carrying a greater amount of information is a tremendous advantage for optical fibers, this advantage does come with a price: sophisticated optical network architectures. One problem faced by many conventional optical network architectures is servicing subscribers that have various degrees or levels of demand for bandwidth.

5 For example, in a conventional optical network architecture, if a home or personal use based subscriber is located adjacent to a business subscriber who has a greater need for bandwidth, conventional optical network architectures will provide the home subscriber with and business subscriber with different fiber optic cables. In other words, each subscriber in this scenario will be provided with its own separate fiber

10 optic cable.

Such conventional optical network architectures using separate fiber optic cables for each customer because of bandwidth concerns adds to the complexity as well as the cost of such a system since separate hardware and software components are usually required to service two different fiber optic cables.

15 Unrelated to the multiple service/multiple bandwidth problems faced by many conventional optical network architectures, another problem faced by optical network architectures is the attenuation of video service signals. Specifically, when analog video optical signals are converted to the electrical domain for propagation over a coaxial cable, the higher frequencies of the video service signal typically lose signal strength faster than lower frequencies as the signals are propagated through the

20 cable.

In order to compensate for this phenomenon, conventional optical network architectures sometimes place a tilt network at fiber optic nodes and RF amplifiers in their plant. Alternatively, some conventional optical network architectures increase

25 the magnitude of their video signal strength at the head-end in order to overcompensate for this attenuation of high frequencies for the video service signal over the coaxial cables proximate to the subscribers. Placing a tilt network at the head-end can cause problems for individual subscribers such as personal or home use subscribers, since coaxial cables interfacing with an optical network typically have a

30 relatively short length.

Another problem faced by conventional optical network architectures is servicing conventional set top terminals that require a return RF path to the head-end. A conventional RF return path typically comprises two-way RF distribution amplifiers with coaxial cables and two-way fiber optic nodes being used to interface
5 with fiber optic cables. A pair of fiber optic strands can be used to carry the radio frequency signals between the head-end and node in an analog optical format. Each optical cable of the pair of fiber optic strands carries analog RF signals: one carries analog RF signals in the downstream direction (toward the subscriber) while the other fiber optic cable carries analog RF signals in the reverse or upstream direction (from
10 the subscriber). In a more recent embodiment, the upstream spectrum (typically 5-42 MHz in North America) is digitized at the node. The digital signals are transmitted to the headend, where they are converted back to the analog RF spectrum of 5-42 MHz. This process typically uses high data rates (at least 1.25 Gb/s) and a fiber or wavelength dedicated to return traffic from one or two nodes.

15 Conventional optical network architectures typically do not comprise a return RF path from the subscriber to the data service hub because most of the return paths comprise only fiber optic cables that propagate digital data signals as opposed to analog RF signals. In conventional fiber-to-the-home (FTTH) and fiber-to-the-curb (FTTC) systems, a downstream RF path is usually provided because it is needed for
20 the delivery of television programs that use conventional broadcast signals. This downstream RF path can support RF modulated analog and digital signals as well as RF modulated control signals for any set top terminals that may be used by the subscriber. However, as noted above, conventional FTTH systems do not provide for any capability of supporting a return RF path for RF analog signals generated by a
25 legacy set top terminal.

Accordingly, in light of the problems identified above, there is a need in the art for a method and system for communicating optical signals to multiple subscribers having various bandwidth demands on a single optical waveguide. In other words, there is a need in the art for an optical network architecture that can service multiple
30 subscribers along the same optical waveguide irrespective of the demand for bandwidth imposed by each subscriber of the network. Another need exists in the art

for an optical network architecture that provides a central service disconnection point for a plurality of subscribers in a centralized location.

There is a further need in the art for positioning tilt networks in a centralized location outside a data service hub when servicing multiple subscribers of an optical network. A further need exists in the art for a method and system that provides a return path for RF signals that are generated by legacy video service terminals. A further need exists in the art for a method and system for communicating optical signals between a data service provider and subscriber that preserves the functioning of legacy set top converters using RF to communicate upstream to the headend.

Another need exists in the art for an optical network system that lends itself to efficient upgrading that can be performed entirely on the network side. In other words, there is a need in the art for an optical network system that allows upgrade to hardware to take place and locations between and within a data service hub and an active signal source disposed between the data service hub and a subscriber.

An additional need exists in the art for an optical network architecture that can take advantage of relatively inexpensive hardware components that typically service shorter distances than their expensive counterparts that service optical signals over large distances. There is a further need in the art for a system and method that can allocate additional or reduced bandwidth based upon the demand of one or more subscribers on an optical network.

SUMMARY OF THE INVENTION

The present invention is generally drawn to a system and method for efficient propagation of data and broadcast signals over an optical fiber network. More specifically, the present invention is generally drawn to optical network architecture that can include a multi-subscriber optical interface that can service a plurality of subscribers that are located in very close proximity relative to one another. For example, the multi-subscriber optical interface can service multiple dwelling units such as an apartment complex that has many different subscribers of the optical network system.

One inventive aspect of the present invention is that in addition to servicing multiple subscribers that are located in very close proximity relative to one another, the present invention can also service many different types of subscribers with the same multi-subscriber optical interface. That is, the multi-subscriber optical interface
5 can service personal-use subscribers with relatively modest bandwidth demand while servicing businesses that may have relatively high bandwidth demand. For example, a multiple subscriber optical interface can service a personal or home subscriber who desires only a bandwidth of 500 kilobits per second while the multi-subscriber optical
10 interface can also service a business that needs a bandwidth of at least a DS1 level (1.544 Megabits per second).

The multi-subscriber optical interface can be part of an optical network system that also employs single subscriber optical interfaces. In other words, the multi-subscriber optical interface can be combined with a single subscriber optical
15 interfaces that are designed to handle the optical communications for a single subscriber to the network.

According to one exemplary aspect of the present invention, to handle subscriber video services, the multi-subscriber optical interface can comprise an optical diplexer, an analog optical receiver, a tilt network, an amplifier, an RF splitter, and a service disconnect switch. For data services, the multi-subscriber optical
20 interface can comprise the optical diplexer, a bidirectional optical signal splitter, a digital optical receiver, a processor, a tilt network, and a digital optical transmitter.

According to another exemplary aspect, the processor of a multi-subscriber optical interface can comprise a switch, a microcomputer, a digital signal processor, a data router, a subscriber line audio-interface circuit (SLAC), and a subscriber line
25 interface circuit (SLIC). The SLAC and SLIC devices can assist in providing subscriber telephone services while the data router can support data services for each subscriber. With the data router, improved management of individual accounts for each subscriber in of a multi-subscriber optical interface can be achieved.

According to a further exemplary aspect of the present invention, the multi-subscriber optical interface can comprise an RF return path. The RF return path
30 supports RF signals produced by subscribers who interact with the video services

being supplied by the multi-subscriber optical interface. The RF return path according to one exemplary embodiment comprises an RF diplexer, an analog-to-digital (A/D) converter, a data reduction circuit, and a time stamp circuit. According to another exemplary aspect, the RF return path can comprise an RF diplexer, an RF presence detector, an electrical to optical converter, and an optical triplexer.

The multi-subscriber optical interface is but one part of the present invention. The present invention also comprises an efficient coupler, referred to as an optical tap, between a laser transceiver node and a respective single or multi-subscriber optical interface. The optical tap can divide optical signals between a plurality of subscribers and can be simple in its design. For example, each optical tap can comprise an optical splitter that may feed one or more subscribers. Optical taps can be cascaded or they can be connected in a star architecture from the laser transceiver node.

The optical tap can also route signals to other optical taps that are downstream relative to a respective optical tap. The optical tap can also connect to a small number of optical waveguides so that high concentrations of optical waveguides are not present at any particular laser transceiver node. In other words, the optical tap can connect to a predetermined number of optical waveguides at a point remote from the laser transceiver node so that high concentrations of optical waveguides at the laser transceiver node can be avoided.

As noted above, the optical tap and laser transceiver node are parts of the present invention. The present invention can include a system that comprises the optical tap, the laser transceiver node, a data service hub, a subscriber optical interface, and optical waveguides connected between the optical taps and laser transceiver node.

25

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a functional block diagram of some core components of an exemplary optical network architecture according to the present invention.

Fig. 2 is a functional block diagram illustrating an exemplary optical network architecture for the present invention.

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Fig. 3 is a functional block diagram illustrating an exemplary data service hub of the present invention.

Fig. 4 is a functional block diagram illustrating an exemplary outdoor laser transceiver node according to the present invention.

5 Fig. 5A is a functional block diagram illustrating an optical tap connected to a subscriber interface by a single optical waveguide according to one exemplary embodiment of the present invention.

Fig. 5B is a functional block diagram illustrating a multi-subscriber optical interface according to one exemplary embodiment of the present invention.

10 Fig. 5C is a functional block diagram illustrating an exemplary processor of Fig. 5B according to one exemplary embodiment of the present invention.

Fig. 5D is a functional block diagram illustrating a multi-subscriber optical interface according to an alternative exemplary embodiment of the present invention.

15 Fig. 5E is a functional block diagram illustrating a multi-subscriber optical interface according to yet another alternative exemplary embodiment of the present invention.

Fig. 6 is a functional block diagram illustrating an exemplary data service hub according to an alternative exemplary embodiment of the present invention where upstream optical signals and downstream optical signals are propagated along separate optical waveguides.

20 Fig. 7 is a functional block diagram illustrating an exemplary outdoor laser transceiver node that can accept upstream and downstream optical signals that are propagated along separate optical waveguides in addition to unidirectional signals that can be mixed with the downstream optical signals.

25 Fig. 8 is a functional block diagram illustrating yet another exemplary outdoor laser transceiver node that can accept optical signals propagating in separate upstream and downstream optical waveguides in addition to multiple optical waveguides that propagate unidirectional signals.

30 Fig. 9 is a functional block diagram illustrating another exemplary embodiment of a data service hub in which unidirectional signals such as video or RF signals are combined with downstream optical signals.

Fig. 10 is a functional block diagram illustrating another exemplary outdoor laser transceiver node that can process a combined downstream signal that comprises downstream optical signals in addition to unidirectional signals like RF transmissions or video data.

5 Fig. 11 is a functional block diagram illustrating another exemplary outdoor laser transceiver node that employs dual transceivers between tap multiplexers and respective groups of subscribers.

Fig. 12 is a functional block diagram illustrating another exemplary outdoor laser transceiver node that includes optical taps disposed within the laser transceiver
10 node itself.

Fig. 13 is a logic flow diagram illustrating an exemplary method for servicing multiple subscribers with various demands in bandwidth in accordance with the present invention.

Fig. 14 is a logic flow diagram illustrating an exemplary process for handling
15 downstream optical signals according to the present invention.

Fig. 15 is a logic flow diagram illustrating an exemplary process for conditioning the downstream electrical analog signals according to the present invention.

Fig. 16 is a logic flow diagram illustrating an exemplary process for
20 conditioning downstream electrical digital signals according to the present invention.

Fig. 17 is a logic flow diagram illustrating a method for handling upstream signals with a multiple subscriber optical interface.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

25 An optical network architecture according to the present invention can include a multi-subscriber optical interface that can service a plurality of subscribers that are located in very close proximity relative to one another. For example, the multi-subscriber optical interface can service multiple dwelling units such as an apartment complex that has many different subscribers of the optical network system. In
30 addition to servicing multiple subscribers that are located in very close proximity relative to one another, the present invention can also service many different types of

subscribers with the same multi-subscriber optical interface. That is, the multi-subscriber optical interface can service personal-use subscribers with relatively modest bandwidth demand while servicing businesses that may have relatively high bandwidth demand.

5 The multi-subscriber optical interface can be part of an optical network system that also employs single subscriber optical interfaces. In other words, the multi-subscriber optical interface can be combined with a single subscriber optical interfaces that are designed to handle the optical communications for a single subscriber to the network.

10 Referring now to the drawings, in which like numerals represent like elements throughout the several Figures, aspects of the present invention and the illustrative operating environment will be described.

Fig. 1 is a functional block diagram illustrating an exemplary optical network architecture **100** according to the present invention. The exemplary optical network architecture **100** comprises a data service hub **110** that is connected to one or more outdoor laser transceiver nodes **120**. The laser transceiver nodes **120**, in turn, are connected to an optical taps **130**. The optical taps **130** can be connected to a plurality of subscriber optical interfaces **140**. Specifically, the optical taps **130** maybe connected to one or more multi-subscriber optical interfaces **140A** or single subscriber optical interfaces **140B** or a combination thereof. Subscribers **145** can be connected to each of the respective subscriber optical interfaces **140**.

Between respective components of the exemplary optical network architecture **100** are optical waveguides such as optical waveguides **150**, **160**, **170** and **180**. The optical waveguides **150-180** are illustrated by arrows with the arrowheads of the arrows illustrating exemplary directions of the data flow between respective components of the illustrative an exemplary optical network **100**.

While only an individual laser transceiver nodes **120**, individual optical taps **130**, and individual subscriber optical interfaces **140** are illustrated in Fig. 1, as will become apparent from Fig. 2, in its corresponding description, a plurality of laser transceiver nodes **120**, optical taps **130**, and subscriber optical interfaces **140** can be employed without departing from the scope and spirit of the present invention.

Typically, many of the exemplary embodiments of the present invention, multiple subscriber optical interfaces **140** are connected to one or more optical taps **130**.

The outdoor laser transceiver node **120** can allocate additional or reduced bandwidth based upon the demand of one or more subscribers that use the subscriber optical interfaces **140**. The outdoor laser transceiver node **120** can be designed to
5 withstand outdoor environmental conditions and can be designed to hang on a strand or fit in a pedestal or "hand hole." The outdoor laser transceiver node can operate in a temperature range between minus 40 degrees Celsius to plus 60 degrees Celsius. The laser transceiver node **120** can operate in this temperature range by using passive
10 cooling devices that do not consume power.

In one exemplary embodiment of the present invention, three trunk optical waveguides **160**, **170**, and **180** (that can comprise optical fibers) can conduct optical signals from the data service hub **110** to the outdoor laser transceiver node **120**. It is noted that the term "optical waveguide" used in the present application can apply to
15 optical fibers, planar light guide circuits, and fiber optic pigtails and other like optical waveguides.

A first optical waveguide **160** can carry broadcast video and other signals. The signals can be carried in a traditional cable television format wherein the broadcast signals are modulated onto carriers, which in turn, modulate an optical
20 transmitter (not shown) in the data service hub **110**. A second optical waveguide **170** can carry downstream targeted services such as data and telephone services to be delivered to one or more subscriber optical interfaces **140**. In addition to carrying subscriber-specific optical signals, the second optical waveguide **170** can also propagate internet protocol broadcast packets, as is understood by those skilled in the
25 art.

In one exemplary embodiment, a third optical waveguide **180** can transport data signals upstream from the outdoor laser transceiver node **120** to the data service hub **110**. The optical signals propagated along the third optical waveguide **180** can also comprise data and telephone services received from one or more subscribers.
30 Similar to the second optical waveguide **170**, the third optical waveguide **180** can also carry IP broadcast packets, as is understood by those skilled in the art.

The third or upstream optical waveguide **180** is illustrated with dashed lines to indicate that it is merely an option or part of one exemplary embodiment according to the present invention. In other words, the third optical waveguide **180** can be removed. In another exemplary embodiment, the second optical waveguide **170** propagates optical signals in both the upstream and downstream directions as is illustrated by the double arrows depicting the second optical waveguide **170**.

In such an exemplary embodiment where the second optical waveguide **170** propagates bidirectional optical signals, only two optical waveguides **160, 170** would be needed to support the optical signals propagating between the data server's hub **110** in the outdoor laser transceiver node **120**. In another exemplary embodiment (not shown), a single optical waveguide can be the only link between the data service hub **110** and the laser transceiver node **120**. In such a single optical waveguide embodiment, three different wavelengths can be used for the upstream and downstream signals. Alternatively, bi-directional data could be modulated on one wavelength.

In one exemplary embodiment, the optical tap **130** can comprise an 8-way optical splitter. This means that the optical tap **130** comprising an 8-way optical splitter can divide downstream optical signals eight ways to serve eight different subscriber optical interfaces **140**. In the upstream direction, the optical tap **130** can combine the optical signals received from the eight subscriber optical interfaces **140**.

In another exemplary embodiment, the optical tap **130** can comprise a 4-way splitter to service four subscriber optical interfaces **140**. Yet in another exemplary embodiment, the optical tap **130** can further comprise a 4-way splitter that is also a pass-through tap meaning that a portion of the optical signal received at the optical tap **130** can be extracted to serve the 4-way splitter contained therein while the remaining optical energy is propagated further downstream to another optical tap or another subscriber optical interface **140**. The present invention is not limited to 4-way and 8-way optical splitters. Other optical taps having fewer or more than 4-way or 8-way splits are not beyond the scope of the present invention.

Referring now to Fig. 2, this figure is a functional block diagram illustrating an exemplary optical network architecture **100** that includes various types of

subscribers **145**. Specifically, one type of a subscriber can comprise a large business subscriber or a multi dwelling or multiple business subscribers **145A**. Another type of subscriber can comprise a home or personal-use or small business subscriber **145B**. The terms “large” and “small” are defined relative to the amount of bandwidth needed
5 or demanded by a particular subscriber **145**.

Each optical tap **130** can comprise an optical splitter. The optical tap **130** allows multiple subscriber optical interfaces **140** (such as single subscriber optical interfaces **140B** or multiple or multi-subscriber optical interfaces **140A**) to be coupled to a single optical waveguide **150** that is connected to the outdoor laser transceiver
10 nodes **120**. In one exemplary embodiment, six optical fibers **150** are designed to be connected to the outdoor laser transceiver nodes **120**. For the use of optical taps **130**, sixteen subscribers can be assigned to each of the six optical waveguides **150** that are connected to the outdoor laser transceiver nodes **120**.

In another exemplary embodiment, twelve optical fibers **150** can be connected
15 to the outdoor laser transceiver nodes **120** while eight subscriber optical interfaces **140** are assigned to each of the twelve optical waveguides **150**. Those skilled in the art will appreciate the number of subscriber optical interfaces **140** assigned to a particular waveguide **150** that is connected between the outdoor laser transceiver nodes **120** and a subscriber optical interface **140** (by way of the optical tap **130**) can
20 be varied or changed without departing from the scope and spirit of the present invention. Further, those skilled in the art recognize that the actual number of subscriber optical interfaces **140** assigned to a particular optical waveguide is dependent upon the amount of power available on a particular optical waveguide **150**.

As depicted in Fig. 2, many configurations for supplying communication
25 services to subscribers are possible. Combinations of single subscriber optical interfaces **140B** coupled with multiple subscriber optical interfaces **140A** along the same the optical waveguide is possible with the present invention. The combinations of optical taps **130** with other optical taps **130** in addition to combinations of optical taps with various types of subscriber optical interfaces **140** are limitless. With the
30 optical taps **130**, concentrations of distribution optical waveguide **150** at the laser transceiver nodes **120** can be reduced. Additionally, the total amount of fiber needed

to service the subscriber grouping attached to a single subscriber interface **140B** or a multi-subscriber optical interface **140A** can also be reduced.

With the active laser transceiver node **120** of the present invention, the distance between the laser transceiver node **120** and the data service hub **110** can
5 comprise a range between 0 and 80 kilometers. However, the present invention is not limited to this range. Those skilled in the art will appreciate that this range can be expanded by selecting various off-the-shelf components that make up several of the devices of the present system.

Those skilled in the art will appreciate that other configurations of the optical
10 waveguides disposed between the data service hub **110** and outdoor laser transceiver node **120** are not beyond the scope of the present invention. Because of the bi-directional capability of optical waveguides, variations in the number and directional flow of the optical waveguides disposed between the data service hub **110** and the outdoor laser transceiver node **120** can be made without departing from the scope and
15 spirit of the present invention.

Referring now to Figure 3, this functional block diagram illustrates an exemplary data service hub **110** of the present invention. The exemplary data service hub **110** illustrated in Figure 3 is designed for a two trunk optical waveguide system. That is, this data service hub **110** of Figure 3 is designed to send and receive optical
20 signals to and from the outdoor laser transceiver node **120** along the first optical waveguide **160** and the second optical waveguide **170**. With this exemplary embodiment, the second optical waveguide **170** supports bi-directional data flow. In this way, the third optical waveguide **180** discussed above is not needed.

The data service hub **110** can comprise one or more modulators **310**, **315** that
25 are designed to support television broadcast services. The one or more modulators **310**, **315** can be analog or digital type modulators. In one exemplary embodiment, there can be at least 78 modulators present in the data service hub **110**. Those skilled in the art will appreciate that the number of modulators **310**, **315** can be varied without departing from the scope and spirit of the present invention.

The signals from the modulators **310**, **315** are combined in a combiner **320** where they are supplied to an optical transmitter **325** where the radio frequency signals generated by the modulators **310**, **315** are converted into optical form.

The optical transmitter **325** can comprise one of Fabry-Perot (F-P) Laser Transmitters, distributed feedback lasers (DFBs), or Vertical Cavity Surface Emitting Lasers (VCSELs). However, other types of optical transmitters are possible and are not beyond the scope of the present invention. With the aforementioned optical transmitters **325**, the data service hub **110** lends itself to efficient upgrading by using off-the-shelf hardware to generate optical signals.

The optical signals generated by the optical transmitter (often referred to as the unidirectional optical signals) are propagated to amplifier **330** such as an Erbium Doped Fiber Amplifier (EDFA) where the unidirectional optical signals are amplified. The amplified unidirectional optical signals are then propagated out of the data service hub **110** via a unidirectional signal output port **335** which is connected to one or more first optical waveguides **160**.

The unidirectional signal output port **335** is connected to one or more first optical waveguides **160** that support unidirectional optical signals originating from the data service hub **110** to a respective laser transceiver node **120**. The data service hub **110** illustrated in Figure 3 can further comprise an Internet router **340**. The data service hub **110** can further comprise a telephone switch **345** that supports telephony service to the subscribers of the optical network system **100**. However, other telephony service such as Internet Protocol telephony can be supported by the data service hub **110**.

If only Internet Protocol telephony is supported by the data service hub **110**, then it is apparent to those skilled in the art that the telephone switch **345** could be eliminated in favor of lower cost Voice over Internet Protocol (VoIP) equipment. For example, in another exemplary embodiment (not shown), the telephone switch **345** could be substituted with other telephone interface devices such as a soft switch and gateway. But if the telephone switch **345** is needed, it may be located remotely from the data service hub **110** and can be connected through any of several conventional means of interconnection.

The data service hub **110** can further comprise a logic interface **350** that is connected to a laser transceiver node routing device **355**. The logic interface **350** can comprise a Voice over Internet Protocol (VoIP) gateway when required to support such a service. The laser transceiver node routing device **355** can comprise a
5 conventional router that supports an interface protocol for communicating with one or more laser transceiver nodes **120**. This interface protocol can comprise one of gigabit or faster Ethernet or SONET protocols. However, the present invention is not limited to these protocols. Other protocols can be used without departing from the scope and spirit of the present invention.

10 The logic interface **350** and laser transceiver node routing device **355** can read packet headers originating from the laser transceiver nodes **120** and the internet router **340**. The logic interface **350** can also translate interfaces with the telephone switch **345**. After reading the packet headers, the logic interface **350** and laser transceiver node routing device **355** can determine where to send the packets of information.

15 The laser transceiver node routing device **355** can supply downstream data signals to respective optical transmitters **325**. The data signals converted by the optical transmitters **325** can then be propagated to a bi-directional splitter **360**. The optical signals sent from the optical transmitter **325** into the bi-directional splitter **360** can then be propagated towards a bi-directional data input/output port **365** that is
20 connected to a second optical waveguide **170** that supports bi-directional optical data signals between the data service hub **110** and a respective laser transceiver node **120**. Upstream optical signals received from a respective laser transceiver node **120** can be fed into the bi-directional data input/output port **365** where the optical signals are then forwarded to the bi-directional splitter **360**.

25 From the bi-directional splitter **360**, respective optical receivers **370** can convert the upstream optical signals into the electrical domain. The upstream electrical signals generated by respective optical receivers **370** are then fed into the laser transceiver node routing device **355**. Each optical receiver **370** can comprise one or more photoreceptors or photodiodes that convert optical signals into electrical
30 signals.

When distances between the data service hub **110** and respective laser transceiver nodes **120** are modest, the optical transmitters **325** can propagate optical signals at 1310 nm. But where distances between the data service hub **110** and the laser transceiver node are more extreme, the optical transmitters **325** can propagate the optical signals at wavelengths of 1550 nm with or without appropriate amplification devices.

Those skilled in the art will appreciate that the selection of optical transmitters **325** for each circuit may be optimized for the optical path lengths needed between the data service hub **110** and the outdoor laser transceiver node **120**. Further, those skilled in the art will appreciate that the wavelengths discussed are practical but are only illustrative in nature. In some scenarios, it may be possible to use communication windows at 1310 and 1550 nm in different ways without departing from the scope and spirit of the present invention. Further, the present invention is not limited to a 1310 and 1550 nm wavelength regions. Those skilled in the art will appreciate that smaller or larger wavelengths for the optical signals are not beyond the scope and spirit of the present invention.

Referring now to Figure 4, this Figure illustrates a functional block diagram of an exemplary outdoor laser transceiver node **120** of the present invention. In this exemplary embodiment, the laser transceiver node **120** can comprise a unidirectional optical signal input port **405** that can receive optical signals propagated from the data service hub **110** that are propagated along a first optical waveguide **160**. The optical signals received at the unidirectional optical signal input port **405** can comprise broadcast video data. The optical signals received at the input port **405** are propagated to an amplifier **410** such as an Erbium Doped Fiber Amplifier (EDFA) in which the optical signals are amplified. The amplified optical signals are then propagated to a splitter **415** that divides the broadcast video optical signals among diplexers **420** that are designed to forward optical signals to predetermined groups of subscribers.

The laser transceiver node **120** can further comprise a bi-directional optical signal input/output port **425** that connects the laser transceiver node **120** to a second optical waveguide **170** that supports bi-directional data flow between the data service

hub **110** and laser transceiver node **120**. Downstream optical signals flow through the bi-directional optical signal input/output port **425** to an optical waveguide transceiver **430** that converts downstream optical signals into the electrical domain. The optical waveguide transceiver further converts upstream electrical signals into the optical domain. The optical waveguide transceiver **430** can comprise an optical/electrical converter and an electrical/optical converter.

Downstream and upstream electrical signals are communicated between the optical waveguide transceiver **430** and an optical tap routing device **435**. The optical tap routing device **435** can manage the interface with the data service hub optical signals and can route or divide or apportion the data service hub signals according to individual tap multiplexers **440** that communicate optical signals with one or more optical taps **130** and ultimately one or more subscriber optical interfaces **140**. It is noted that tap multiplexers **440** operate in the electrical domain to modulate laser transmitters in order to generate optical signals that are assigned to groups of subscribers coupled to one or more optical taps.

Optical tap routing device **435** is notified of available upstream data packets as they arrive, by each tap multiplexer **440**. The optical tap routing device is connected to each tap multiplexer **440** to receive these upstream data packets. The optical tap routing device **435** relays the packets to the data service hub **110** via the optical waveguide transceiver **430**. The optical tap routing device **435** can build a lookup table from these upstream data packets coming to it from all tap multiplexers **440** (or ports), by reading the source IP address of each packet, and associating it with the tap multiplexer **440** through which it came. This lookup table can then be used to route packets in the downstream path. As each packet comes in from the optical waveguide transceiver **430**, the optical tap routing device looks at the destination IP address (which is the same as the source IP address for the upstream packets). From the lookup table the optical tap routing device can determine which port is connected to that IP address, so it sends the packet to that port. This can be described as a normal layer 3 router function as is understood by those skilled in the art.

The optical tap routing device **435** can assign multiple subscribers to a signal port. More specifically, the optical tap routing device **435** can service groups of

subscribers with corresponding respective signal ports. The optical taps **130** logically coupled to respective tap multiplexers **440** can supply downstream optical signals to pre-assigned groups of subscribers who receive the downstream optical signals with the subscriber optical interfaces **140**.

5 In other words, the optical tap routing device **435** can determine which tap multiplexer **440** is to receive a downstream electrical signal, or identify which of a plurality of optical taps **130** propagated an upstream optical signal (that is converted to an electrical signal). The optical tap routing device **435** can format data and implement the protocol required to send and receive data from each individual
10 subscriber connected to a respective optical tap **130**. The optical tap routing device **435** can comprise a computer or a hardwired apparatus that executes a program defining a protocol for communications with groups of subscribers assigned to individual ports.

Exemplary embodiments of programs defining the protocol is discussed in the
15 following copending and commonly assigned non-provisional patent applications, the entire contents of which are hereby incorporated by reference: "Method and System for Processing Downstream Packets of an Optical Network," filed on October 26, 2001 in the name of Stephen A. Thomas et al. and assigned U.S. Serial No. 10/045,652; and "Method and System for Processing Upstream Packets of an Optical
20 Network," filed on October 26, 2001 in the name of Stephen A. Thomas et al. and assigned U.S. Serial No. 10/045,584.

The signal ports of the optical tap routing device are connected to respective tap multiplexers **440**. With the optical tap routing device **435**, the laser transceiver node **120** can adjust a subscriber's bandwidth on a subscription basis or on an as-needed or demand basis. The laser transceiver node **120** via the optical tap routing device **435** can offer data bandwidth to subscribers in pre-assigned increments. For example, the laser transceiver node **120** via the optical tap routing device **435** can offer a particular subscriber or groups of subscribers bandwidth in units of 1, 2, 5, 10, 20, 50, 100, 200, and 450 Megabits per second (Mb/s). Those skilled in the art will
30 appreciate that other subscriber bandwidth units are not beyond the scope of the present invention.

Electrical signals are communicated between the optical tap routing device 435 and respective tap multiplexers 440. The tap multiplexers 440 propagate optical signals to and from various groupings of subscribers. Each tap multiplexer 440 is connected to a respective optical transmitter 325. As noted above, each optical transmitter 325 can comprise one of a Fabry-Perot (F-P) laser, a distributed feedback laser (DFB), or a Vertical Cavity Surface Emitting Laser (VCSEL). Other laser technologies may be used within the scope of the invention. The optical transmitters produce the downstream optical signals that are propagated towards the subscriber optical interfaces 140. Each tap multiplexer 440 is also coupled to an optical receiver 370. Each optical receiver 370, as noted above, can comprise photoreceptors or photodiodes. Since the optical transmitters 325 and optical receivers 370 can comprise off-the-shelf hardware to generate and receive respective optical signals, the laser transceiver node 120 lends itself to efficient upgrading and maintenance to provide significantly increased data rates.

Each optical transmitter 325 and each optical receiver 370 are connected to a respective bi-directional splitter 360. Each bi-directional splitter 360 in turn is connected to a diplexer 420 which combines the unidirectional optical signals received from the splitter 415 with the downstream optical signals received from respective optical transmitter 325. In this way, broadcast video services as well as data services can be supplied with a single optical waveguide such as a distribution optical waveguide 150 as illustrated in Figure 2. In other words, optical signals can be coupled from each respective diplexer 420 to a combined signal input/output port 445 that is connected to a respective distribution optical waveguide 150.

Unlike the conventional art, the laser transceiver node 120 does not employ a conventional router. The components of the laser transceiver node 120 can be disposed within a compact electronic packaging volume. For example, the laser transceiver node 120 can be designed to hang on a strand or fit in a pedestal similar to conventional cable TV equipment that is placed within the "last," mile or subscriber proximate portions of a network. It is noted that the term, "last mile," is a generic term often used to describe the last portion of an optical network that connects to subscribers.

Also because the optical tap routing device **435** is not a conventional router, it does not require active temperature controlling devices to maintain the operating environment at a specific temperature. In other words, the laser transceiver node **120** can operate in a temperature range between minus 40 degrees Celsius to 60 degrees Celsius in one exemplary embodiment.

While the laser transceiver node **120** does not comprise active temperature controlling devices that consume power to maintain temperature of the laser transceiver node **120** at a single temperature, the laser transceiver node **120** can comprise one or more passive temperature controlling devices **450** that do not consume power. The passive temperature controlling devices **450** can comprise one or more heat sinks or heat pipes that remove heat from the laser transceiver node **120**. Those skilled in the art will appreciate that the present invention is not limited to these exemplary passive temperature controlling devices. Further, those skilled in the art will also appreciate the present invention is not limited to the exemplary operating temperature range disclosed. With appropriate passive temperature controlling devices **450**, the operating temperature range of the laser transceiver node **120** can be reduced or expanded.

In addition to the laser transceiver node's **120** ability to withstand harsh outdoor environmental conditions, the laser transceiver node **120** can also provide high speed symmetrical data transmissions. In other words, the laser transceiver node **120** can propagate the same bit rates downstream and upstream to and from a network subscriber. This is yet another advantage over conventional networks, which typically cannot support symmetrical data transmissions as discussed in the background section above. Further, the laser transceiver node **120** can also serve a large number of subscribers while reducing the number of connections at both the data service hub **110** and the laser transceiver node **120** itself.

The laser transceiver node **120** also lends itself to efficient upgrading that can be performed entirely on the network side or data service hub **110** side. That is, upgrades to the hardware forming the laser transceiver node **120** can take place in locations between and within the data service hub **110** and the laser transceiver node **120**. This means that the subscriber side of the network (from distribution optical

waveguides **150** to the subscriber optical interfaces **140**) can be left entirely in-tact during an upgrade to the laser transceiver node **120** or data service hub **110** or both.

The following is provided as an example of an upgrade that can be employed utilizing the principles of the present invention. In one exemplary embodiment of the invention, the subscriber side of the laser transceiver node **120** can service six groups of 16 subscribers each for a total of up to 96 subscribers. Each group of 16 subscribers can share a data path of about 450 Mb/s speed. Six of these paths represents a total speed of $6 \times 450 = 2.7$ Gb/s. In the most basic form, the data communications path between the laser transceiver node **120** and the data service hub **110** can operate at 1 Gb/s. Thus, while the data path to subscribers can support up to 2.7 Gb/s, the data path to the network can only support 1 Gb/s. This means that not all of the subscriber bandwidth is useable. This is not normally a problem due to the statistical nature of bandwidth usage.

An upgrade could be to increase the 1 Gb/s data path speed between the laser transceiver node **120** and the data service hub **110**. This may be done by adding more 1 Gb/s data paths. Adding one more path would increase the data rate to 2 Gb/s, approaching the total subscriber-side data rate. A third data path would allow the network-side data rate to exceed the subscriber-side data rate. In other exemplary embodiments, the data rate on one link could rise from 1 Gb/s to 2 Gb/s then to 10 Gb/s, so when this happens, a link can be upgraded without adding more optical links.

The additional data paths (bandwidth) may be achieved by any of the methods known to those skilled in the art. It may be accomplished by using a plurality of optical waveguide transceivers **430** operating over a plurality of optical waveguides, or they can operate over one optical waveguide at a plurality of wavelengths, or it may be that higher speed optical waveguide transceivers **430** could be used as shown above. Thus, by upgrading the laser transceiver node **120** and the data service hub **110** to operate with more than a single 1 Gb/s link, a system upgrade is effected without having to make changes at the subscribers' premises.

Referring now to Figure 5A, this Figure is a functional block diagram illustrating an optical tap **130** connected to a single-subscriber optical interface **140B** by a single optical waveguide **150** according to one exemplary embodiment of the

present invention. The optical tap **130** can comprise a combined signal input/output port **505** that is connected to another distribution optical waveguide that is connected to a laser transceiver node **120**. As noted above, the optical tap **130** can comprise an optical splitter **510** that can be a 4-way or 8-way optical splitter. Other optical taps
5 having fewer or more than 4-way or 8-way splits are not beyond the scope of the present invention. The optical tap can divide downstream optical signals to serve respective single subscriber optical interfaces **140B** and multi-subscriber optical interfaces **140A** (not shown). In the exemplary embodiment in which the optical tap **130** comprises a 4-way optical tap, such an optical tap can be of the pass-through
10 type, meaning that a portion of the downstream optical signals is extracted or divided to serve a 4-way splitter contained therein, while the rest of the optical energy is passed further downstream to other distribution optical waveguides **150**.

The optical tap **130** is an efficient coupler that can communicate optical signals between the laser transceiver node **120** and a respective subscriber optical
15 interface **140**. Optical taps **130** can be cascaded, or they can be connected in a star architecture from the laser transceiver node **120**. As discussed above, the optical tap **130** can also route signals to other optical taps that are downstream relative to a respective optical tap **130**.

The optical tap **130** can also connect to a limited or small number of optical
20 waveguides so that high concentrations of optical waveguides are not present at any particular laser transceiver node **120**. In other words, in one exemplary embodiment, the optical tap can connect to a limited number of optical waveguides **150** at a point remote from the laser transceiver node **120** so that high concentrations of optical waveguides **150** at a laser transceiver node can be avoided. However, those skilled in
25 the art will appreciate that the optical tap **130** can be incorporated within the laser transceiver node **120** as will be discussed in further detail below with respect to another exemplary embodiment of the laser transceiver node **120** as illustrated in Figure 12.

The single-subscriber optical interface **140B** functions to convert downstream
30 optical signals received from the optical tap **130** into the electrical domain that can be processed with appropriate communication devices. The single-subscriber optical

interface **140B** further functions to convert upstream electrical signals into upstream optical signals that can be propagated along a distribution optical waveguide **150** to the optical tap **130**. The single-subscriber optical interface **140B** can comprise an optical diplexer **515** that divides the downstream optical signals received from the distribution optical waveguide **150** between a bi-directional optical signal splitter **520** and an analog optical receiver **525**. A service disconnect switch **527** can be positioned between the analog optical receiver **525** and modulated RF unidirectional signal output **535**.

The optical diplexer **515** can receive upstream optical signals generated by a digital optical transmitter **530**. The digital optical transmitter **530** converts electrical binary/digital signals to optical form so that the optical signals can be transmitted back to the data service hub **110**. Conversely, the digital optical receiver **540** converts optical signals into electrical binary/digital signals so that the electrical signals can be handled by processor **550**.

The analog optical receiver **525** can convert the downstream broadcast optical video signals into modulated RF television signals that are propagated out of the modulated RF unidirectional signal output **535**. The modulated RF unidirectional signal output **535** can feed to RF receivers such as television sets (not shown) or radios (not shown). The analog optical receiver **525** can process analog modulated RF transmission as well as digitally modulated RF transmissions for digital TV applications.

The bi-directional optical signal splitter **520** can propagate combined optical signals in their respective directions. That is, downstream optical signals entering the bi-directional optical splitter **520** from the optical diplexer **515**, are propagated to the digital optical receiver **540**. Upstream optical signals entering it from the digital optical transmitter **530** are sent to optical diplexer **515** and then to optical tap **130**. The bi-directional optical signal splitter **520** is connected to a digital optical receiver **540** that converts downstream data optical signals into the electrical domain. Meanwhile the bi-directional optical signal splitter **520** is also connected to a digital optical transmitter **530** that converts upstream electrical signals into the optical domain.

The digital optical receiver **540** can comprise one or more photoreceptors or photodiodes that convert optical signals into the electrical domain. The digital optical transmitter can comprise one or more lasers such as the Fabry-Perot (F-P) Lasers, distributed feedback lasers, and Vertical Cavity Surface Emitting Lasers (VCSELs).

5 The digital optical receiver **540** and digital optical transmitter **530** are connected to a processor **550** that selects data intended for the instant subscriber optical interface **140** based upon an embedded address. The data handled by the processor **550** can comprise one or more of telephony and data services such as an Internet service. The processor **550** is connected to a telephone input/output **555** that
10 can comprise an analog interface.

The processor **550** is also connected to a data interface **560** that can provide a link to computer devices, set top boxes, ISDN phones, and other like devices. Alternatively, the data interface **560** can comprise an interface to a Voice over Internet Protocol (VoIP) telephone or Ethernet telephone. The data interface **560** can
15 comprise one of Ethernet's (10BaseT, 100BaseT, Gigabit) interface, HPNA interface, a universal serial bus (USB) an IEEE1394 interface, an ADSL interface, and other like interfaces.

Referring now to Fig. 5B, this figure is a functional block diagram illustrating a multi-subscriber optical interface **140A**. Only the elements of the multi-subscriber
20 optical interface **140A** that are different relative to the single-subscriber optical interface **140B** will be discussed below. The multi-subscriber optical interface **140A** comprises a tilt network **523**, an amplifier **529**, and an RF splitter **531**. These three components typically support video services for subscribers of the optical network. A tilt network **523** attenuates lower frequency signals to bring the signal strength across
25 the frequency range back into balance at the subscriber video display device **580**. As noted previously, higher frequencies lose signal strength faster than low frequencies as they are being transmitted over coaxial cable. The tilt network **523** can compensate for this additional loss of signal strength at higher frequencies.

The amplifier **529** amplifies downstream analog electrical signals while the RF
30 splitter **531** divides the downstream analog electrical signals among a plurality of

subscribers. The RF splitter feeds its downstream energy through respective disconnect switches **527** that control a service for a particular subscriber.

Coaxial cables **565** connect subscriber video display devices **580** with respective modulated RF unidirectional signal output **535** of the multi-subscriber optical interface **140A**. Further, telephone cables **570** connect subscriber telephone devices **585** to the telephone input/output device **555**.

Data cables **575** couple each subscriber data device **590** to the data interface **560**. Each subscriber data device **590** can comprise a computer, an ISDN phone, and other like devices. Each data cable can comprise an Ethernet cable, but other data cable types are not beyond the scope of the present invention.

Referring now to FIG. 5C, this figure is a functional block diagram illustrating an exemplary processor **550** that is depicted in FIG. 5B. The processor **550** as illustrated in FIG. 5C comprises a switch **501**, a microcomputer **503**, a digital signal processor **507** and a data router **513**. The switch **501** is connected to the microcomputer **503** as well as the digital optical receiver **540** and the digital optical transmitter **530**. The microcomputer **503** supplies telephone signals to the digital signal processor **507**. The microcomputer **503** can also comprise part of a RF return path as will be described in further detail below.

The digital signal processor receives and transmits telephone signals to the microcomputer **503**. The digital signal processor **507** can perform functions such as echo cancellation. The digital signal processor **507** can be connected to one or more subscriber line audio-processing circuits (SLACs) which perform various processing routines needed in telephone systems. For example, each SLAC **509** can be responsible for such functions as generating ring tones, interpreting dialing tones, and converting between digital and analog telephone signals. A single SLAC **509** may include circuitry to manage one phone line or it may contain circuitry to manage a plurality of telephone lines.

The digital signal processor **507** can interface with a plurality of SLACs **509** by way of a data bus **517**. Each SLAC **509** can also be connected to a subscriber line interface circuit (SLIC) **511**. Each SLIC **511** can include analog interface circuits

necessary converting digital signals for conventional analog telephone equipment. Each SLIC **511** can interface with one or more telephone input/output interfaces **555**.

Also coupled to switch **501** is data router **513**. The data router **513** can comprise a standard internet protocol router **513** that is connected between the switch **501** and a plurality of data interfaces **560**. The data router **513** can comprise a router operating at level 3 in the standard 7-layer communications model, or it may comprise a switch operating at level 2 in the standard 7-layer communications model. The data router **513** manages data services for a plurality of subscribers that are coupled to the multi-subscriber optical interface **140A**. Each subscriber data device **590** coupled to a respective data interface **560** can be managed by using a media access control (MAC) address, as known in the art. The data router is also useful to provide data to each individual subscriber, while not sending data intended for any other subscribers to his location, preventing “snooping,” or hacking the system to monitor someone else’s data.

Referring now to FIG. 5D, this figure is a functional block diagram illustrating an alternate exemplary embodiment of a multi-subscriber optical interface **140A** in accordance with a present invention. The multi-subscriber optical interface **140A** FIG. 5D further comprises an RF return path. Further details of this RF return path are described in co-pending non-provisional patent application entitled, “Method and System for Providing a Return Path for Signals Generated by Legacy Terminals in an Optical Network,” filed on January 8, 2002 and assigned US Serial No. 10/041,299, the entire contents of which are hereby incorporated by reference.

The RF return path of FIG. 5D comprises another diplexer **533** that is connected between the amplifier **529** and RF splitter **531**. When a legacy video service terminal **581** generates RF signals, these RF signals are propagated through the modulated RF signal input/output **535** to the diplexer **533**. The diplexer **533** passes the upstream analog RF signals to an analog-to-digital (A/D) converter **537**. From the A/D converter **537**, the digital RF signals are passed to a data reducer **539**. Further details of a data reducer **539** are discussed in co-pending non-provisional application Serial No. 10/041,299, referenced above and which is incorporated by reference. The data reducer **539** can comprise additional components (not shown)

that removes unnecessary numbers of bits from each sampled upstream RF signal, while maintaining the maximum scaling of the data.

After reducing the upstream RF signals, the data reducer **539** passes the processed RF signals to a data conditioner **541** that can comprise a buffer such as a
5 FIFO. A FIFO, a special purpose circuit known to those skilled in the art, takes in data at a first data rate, and puts out the data (“plays it out”) at a second data rate suitable for transmission.

The FIFO can input a time stamp and identification information with the digitized upstream RF signals to form RF packets. That is, a RF packet can comprise
10 digitized and RF signals that are coupled with identification and timing information. Further details of the data conditioner **541** are discussed in co-pending non-provisional application serial no. 10/041,299, referenced above and incorporated by reference. The data conditioner **541** feeds its RF packets to the processor **550**.

Referring now to FIG. 5E this figure illustrates another alternative exemplary
15 embodiment of a multi-subscriber optical interface **140A** according to the present invention. In this particular embodiment, the RF return path comprises an inexpensive amplitude modulated (AM-analog) optical transmitter **561**. A wavelength admitted by the AM optical transmitter **561** usually must not be in the **1310** nanometer wavelength region because other users may be using data transported
20 at this wavelength.

Suitable wavelengths for the AM optical transmitter **561** include **1490** nano
meters plus/minus 10 nano meters, which is being used for some specialized applications, other wavelengths in the vicinity of **1550** nanometers not being used by
25 the analog optical transmission path, and **1625** nanometers which is sometimes used for internal communications within optical networks. However, the present invention is not limited to these wavelength regions and can include regions higher or lower than described without departing from the scope and spirit of the present invention. The RF return path illustrated in FIG. 5E further comprises an RF presence detector
30 **372** which detects the existence of RF data and turns on the transmitter **561** upon detection RF signals.

Further details of this exemplary RF return path are described in co-pending non-provisional application Serial No. 10/041,299 discussed above and incorporated by reference. The RF return path illustrated in FIG. 5E further includes an optical triplexer **519** which combines upstream data signals channeled through the bi-directional optical signals splitter **520** and emitted from the AM optical transmitter **561**. The triplexer **519** operates the same as the previously described optical bplexer **515**, except that a third input has been added, at a wavelength different from the upstream data signals emitted from the bi-directional optical signals splitter **520** and received in the downstream direction from the optical paths. Such triplexers **519** are known to those skilled in the art.

Referring now to Figure 6, this figure is a functional block diagram illustrating an exemplary data service hub **110B** according to an alternative exemplary embodiment of the present invention where upstream optical signals and downstream optical signals are propagated along separate optical waveguides such as the second optical waveguide **170** and the third optical waveguide **180** discussed above with respect to Figure 1. In other words, in this exemplary embodiment, the second optical waveguide **170** is designed to carry only downstream optical signals while the third optical waveguide **180** is designed to carry only upstream optical signals from the laser transceiver node **120**.

The exemplary data service hub **110B** further comprises a downstream optical signal output port **605** that is coupled to the second optical waveguide **170**. The data service hub **110B** further comprises an upstream optical signal input port **610** that is coupled to the third optical waveguide **180**. With the exemplary data service hub **110B** separate optical waveguides **180** and **170** carry the respective upstream and downstream optical transmissions. With this exemplary embodiment, power can be conserved since additional components that were previously used to combine and separate the upstream and downstream optical signals are eliminated.

This exemplary embodiment of the data service hub **110B** can further reduce distance limitations due to power loss and cross talk. In other words, at each end of an optical transmitter, which is supplying a lot of optical power compared with the received power, can create interference at the receiver due to incomplete isolation

between the upstream and downstream optical signal directions. By utilizing separate optical waveguides for the upstream and downstream optical signals, this interference can be substantially reduced or eliminated.

Referring now to Figure 7, this Figure illustrates a functional block diagram of an exemplary outdoor laser transceiver node **120B** that can accept upstream and downstream optical signals that are propagated along separate optical waveguides in addition to unidirectional signals that can be mixed with downstream optical signals. In other words, the laser transceiver node **120B** can be coupled to the exemplary data service hub **110B** illustrated in Figure 6.

The laser transceiver node **120B** can comprise a downstream optical signal input port **705** that is coupled to the second optical waveguide **170** as illustrated in Figure 1. The downstream optical signal input port **705** is coupled to an optical receiver **710** that converts the downstream optical signals into the electrical domain. The optical receiver **710** in turn, feeds the electrical signals to the optical tap routing device **435**.

The laser transceiver node **120B** of Figure 7 can further comprise an optical transmitter **720** that converts electrical signals received from the optical tap routing device **435** into the optical domain. The optical signals generated by the optical transmitter **720** are fed to an upstream optical signal output port **715**. The upstream optical signal output port **715** is coupled to the third optical waveguide **180** as illustrated in Figure 1.

Compared to the exemplary laser transceiver node **120A** illustrated in Figure 4, the bi-directional splitter **360** has been replaced with a second diplexer **420₂**. The optical transmitter **325** generates optical signals of a wavelength that is higher than the upstream optical signals produced by a respective subscriber optical interface **140**. For example, in one exemplary embodiment, the optical transmitter **325** can produce optical signals having wavelengths between 1410 and 1490 nm while the upstream optical signals remain at the 1310 nm wavelength region.

As noted above, those skilled in the art will appreciate that the wavelengths discussed are only illustrative in nature. In some scenarios, it may be possible to use communication windows at 1310 and 1550 nm in different ways without departing

from the scope and spirit of the present invention. Further, the present invention is not limited to the wavelength regions discussed above. Those skilled in the art will appreciate that smaller or larger wavelengths for the optical signals are not beyond the scope and spirit of the present invention.

5 Because of the difference in wavelength regions between the upstream and downstream optical signals, the additional diplexer **420₂** can be substituted for the previous bi-directional splitter **360** (illustrated in the exemplary embodiment of Figure 4). The additional or substituted diplexer **420₂** does not exhibit the same loss as the previous bi-directional splitter **360** that is used in the exemplary embodiment of
10 Figure 4. This substitution of the bi-directional splitter **360** with the additional diplexer **420₂** can also be applied to the subscriber optical interface **140**. That is, when the upstream and downstream optical signals are operating at respective different wavelength regions, the bi-directional optical signal splitter **520** of the subscriber optical interface **140** can be substituted with a diplexer **420₂**. The
15 substitution of the bi-directional splitter **360** with the diplexer **420** can reduce the optical loss between the laser transceiver node **120** and the subscriber optical interface **140**.

 Alternatively, if the laser transceiver node **120** is using the same wavelengths for the upstream and downstream optical signals, the optical interface **140** uses the bi-
20 directional optical signal splitter **520** with a corresponding loss in optical power as illustrated in Figure 5. Those skilled in the art will appreciate that various other substitutions for the components of the laser transceiver node **120** can be made without departing from the scope and spirit of the present invention.

 Referring now to Figure 8, this Figure illustrates another exemplary outdoor,
25 laser transceiver node **120C** that can accept optical signals propagating from separate upstream and downstream optical waveguides in addition to multiple optical waveguides that propagate unidirectional signals. In this exemplary embodiment, the laser transceiver node **120C** of Figure 8 can comprise multiple unidirectional signal input ports **805** that are coupled to a plurality of first optical waveguides **160**. In this
30 exemplary embodiment, compared to the laser transceiver node **120A** of Figure 4 and laser transceiver node **120B** of Figure 7, the amplifier **410** has been removed from the

laser transceiver node **120C** as illustrated in Figure 8. The amplifier **410** is taken out of the laser transceiver node **120C** and placed in the data service hub **110**.

The optical signals propagating from the multiple first optical waveguides **160** are combined with the upstream and downstream optical signals originating from the second set of diplexers **420₂** using the first set of diplexers **420₁**. This design to remove the amplifier **410** (that typically comprises an Erbium Doped Fiber Amplifier - EDFA) from the laser transceiver node **120C** of Figure 8 to the data service hub **110** and to include multiple first optical waveguides **160** feeding into the laser transceiver node **120C**, may be made on the basis of economics and optical waveguide availability.

Figure 9 illustrates another exemplary embodiment of a data service hub **110D** in which unidirectional signals such as video or RF signals are combined with downstream optical signals. In this exemplary embodiment, the data service hub **110D** further comprises a splitter **415** that feeds the broadcast video optical signals to respective diplexers **420**. The respective diplexers **420** combine the broadcast video optical signals with the downstream data optical signals produced by respective optical transmitters **325**. In this way, the first optical waveguide **160** as illustrated in Figure 1 can be eliminated since the broadcast video optical signals are combined with the downstream data optical signals along the second optical waveguide **170**.

Figure 10 illustrates another exemplary laser transceiver node **120D** that can be coupled to the data service hub **110D** as illustrated in Figure 9. In this exemplary embodiment, the laser transceiver node **120D** comprises a combined downstream optical signal input **1005** that is coupled to a second optical waveguide **160** that provides a combined downstream optical signal comprising broadcast video services and data service. The laser transceiver node **120D** further comprises a diplexer **420** that feeds the broadcast video or RF signals to an amplifier **410**. The broadcast video or RF optical signals are then sent to a splitter **415** which then sends the optical signals to the first set of diplexers **420₁**. The combination of the data service hub **110D** as illustrated in Figure 9 and the laser transceiver node **120D** as illustrated in Figure 10 conserves optical waveguides between these two devices.

As noted above, in another exemplary embodiment, it may be possible to use only a single fiber (not shown) to operatively link a data service hub **110** and a laser transceiver node **120**. In such an exemplary embodiment, different wavelengths could be used to propagate upstream and downstream optical signals.

5 Figure 11 is a functional block diagram illustrating another exemplary outdoor laser transceiver node **120E** that employs dual transceivers between tap multiplexers **440** and respective groups of subscribers. In this embodiment the downstream optical signals originating from each respective tap multiplexer **440** are split immediately after the tap multiplexer **440**. In this exemplary embodiment, each optical transmitter
10 **325** is designed to service only eight subscribers as opposed to sixteen subscribers of other embodiments. But each tap multiplexer **440** typically services sixteen or fewer subscribers.

In this way, the splitting loss attributed to the optical taps **130** can be substantially reduced. For example, in other exemplary embodiments that do not split
15 the downstream optical signals immediately after the tap multiplexer **440**, such embodiments are designed to service sixteen or fewer subscribers with a corresponding theoretical splitting loss of approximately 14 dB (including an allowance for losses). With the current exemplary embodiment that services eight or fewer subscribers, the theoretical splitting loss is reduced to approximately 10.5 dB.

20 In laser transceiver node **120E**, the optical receivers **370** cannot be paralleled because at all times one receiver **370** or the other is receiving signals from respective subscribers, while the other receiver **370** is not receiving signals. The receiver **370** not receiving any upstream optical signals could output noise which would interfere with reception from the receiver **370** receiving upstream optical signals. Therefore, a
25 switch **1105** can be employed to select the optical receiver **370** that is currently receiving an upstream optical signal. The tap multiplexer can control the switch **1105** since it knows which optical receiver **370** should be receiving upstream optical signals at any given moment of time.

Figure 12 is a functional block diagram illustrating another exemplary outdoor
30 laser transceiver node **120F** that includes optical taps **130** disposed within the laser transceiver node **120F** itself. In this architecture, optical waveguides **150** from each

subscriber optical interface 140 can be connected to the laser transceiver node 120F. Typically, the number of optical waveguides 150 that may conveniently be brought to one location is such that at least two laser transceiver nodes 150 are needed to support the number of optical waveguides 150. But when less than a maximum number of subscribers exist, one laser transceiver node 120F can be used to service the existing service base. When the service base expands to a number requiring an additional laser transceiver node 120, the additional laser transceiver nodes can be added.

By placing the optical taps 130 within the laser transceiver node 120F, two or more laser transceiver nodes 120F can be co-located with one another for the reason discussed above. In other words, this exemplary embodiment enables two or more laser transceiver nodes 120F to be placed in close proximity to one another. Such placement of laser transceiver nodes 120F can conserve power and result in significant cost savings. Furthermore, with such a co-location design, future expansion of the optical architecture 100 can easily be obtained. That is, one laser transceiver nodes 120F can be installed until more subscribers join the optical network architecture 100 requiring the laser transceiver node. Optical waveguides 150 can be connected to the co-located laser transceiver nodes as more subscribers join the optical network architecture 100.

Referring now to FIG. 13, this figure illustrates an exemplary method for communicating optical signals to multiple subscribers with various bandwidth demand on a single optical wave guide. In other words, FIG. 13 illustrates a fiber to the curb (FTTC) processing overview.

The description of the flow charts in the this detailed description are represented largely in terms of processes and symbolic representations of operations by conventional computer components, including a processing unit (a processor), memory storage devices, connected display devices, and input devices. Furthermore, these processes and operations may utilize conventional discrete hardware components or other computer components in a heterogeneous distributed computing environment, including remote file servers, computer servers, and memory storage devices. Each of these conventional distributed computing components can be accessible by the processor via a communication network.

The processes and operations performed below may include the manipulation of signals by a processor and the maintenance of these signals within data structures resident in one or more memory storage devices. For the purposes of this discussion, a process is generally conceived to be a sequence of computer-executed steps leading to a desired result. These steps usually require physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, compared, or otherwise manipulated. It is convention for those skilled in the art to refer to representations of these signals as bits, bytes, words, information, elements, symbols, characters, numbers, points, data, entries, objects, images, files, or the like. It should be kept in mind, however, that these and similar terms are associated with appropriate physical quantities for computer operations, and that these terms are merely conventional labels applied to physical quantities that exist within and during operation of the computer.

It should also be understood that manipulations within the computer are often referred to in terms such as creating, adding, calculating, comparing, moving, receiving, determining, identifying, populating, loading, executing, etc. that are often associated with manual operations performed by a human operator. The operations described herein can be machine operations performed in conjunction with various input provided by a human operator or user that interacts with the computer.

In addition, it should be understood that the programs, processes, methods, etc. described herein are not related or limited to any particular computer or apparatus. Rather, various types of general purpose machines may be used with the following process in accordance with the teachings described herein.

The present invention may comprise a computer program or hardware or a combination thereof which embodies the functions described herein and illustrated in the appended flow charts. However, it should be apparent that there could be many different ways of implementing the invention in computer programming or hardware design, and the invention should not be construed as limited to any one set of computer program instructions.

Further, a skilled programmer would be able to write such a computer program or identify the appropriate hardware circuits to implement the disclosed invention without difficulty based on the flow charts and associated description in the application text, for example. Therefore, disclosure of a particular set of program code instructions or detailed hardware devices is not considered necessary for an adequate understanding of how to make and use the invention. The inventive functionality of the claimed computer implemented processes will be explained in more detail in the following description in conjunction with the remaining Figures illustrating other process flows.

Certain steps in the process described below must naturally precede others for the present invention to function as described. However, the present invention is not limited to the order of the steps described if such order or sequence does not alter the functionality of the present invention. That is, it is recognized that some steps may be performed before or after other steps without departing from the scope and spirit of the present invention.

Step **1305** is the first step in the exemplary Fiber-to-the-curb processing overview. In step **1305**, downstream RF and data optical signals are propagated from a data service hub **110** through a laser transceiver node **120**. Next, in step **1310**, the downstream RF and data optical signals are propagated from the laser transceiver node **120** toward one or more optical tap **130**. However, those skilled in the art will appreciate that optical tap **130** in this particular step in process **1300** could be eliminated without departing from the scope and spirit of the present invention.

In step **1315**, the downstream RF and data optical signals are divided between subscriber optical interfaces **140** at the tap **130**. In step **1320**, the downstream optical signals at multi-subscriber optical interfaces **140A** are further divided between various types of subscribers that may include businesses as well as home or personal-use subscribers. A business subscriber may comprise a small or large business that typically has bandwidth demands that are greater than those of a home or personal-use subscriber. A personal use or home subscriber may comprise a household or single family dwelling unit that may include a personal computer.

In step **1325**, the downstream RF and data optical signals can also be propagated through single subscriber optical interfaces **140B** to individual dwelling units. Individual dwelling units may comprise single family homes that are physically separate from one another compared to a multiple dwelling unit such as an apartment
5 complex.

In step **1330**, each subscriber optical interface **140** can receive upstream digital and analog electrical signals from respective subscribers. In step **1335**, the upstream analog electrical signals can be converted to digital signals. For example, RF return signals from Legacy terminals **581** can be digitized as discussed above. Similarly,
10 analog phone signals from a subscriber telephone device **585** may be converted from analog signals to digital form.

In step **1340**, upstream electrical signals from multiple subscribers can be combined together at a multi-subscriber optical interface. For example, upstream telephone signals from different subscriber telephone units can be combined.
15 Similarly, the RF return paths for various subscribers can be combined into a single input. Also, upstream data can be combined from multiple subscribers with the data router **513** as discussed above.

In step **1345**, each of the converted or digitized electrical upstream signals can then be converted to the optical domain by either the digital optical transmitter **530** or
20 the AM optical transmitter **561**. In step **1350**, the upstream optical signals can be propagated to an optical tap **130** or to the laser transceiver node **120** directly.

Referring now to FIG. 14, this figure illustrates an exemplary method for downstream multi-subscriber processing. Step **1405** is the first step in the process in which downstream RF and data optical signals are received from the laser transceiver
25 node **120** or an optical tap **130**. Next, in step **1410**, the downstream optical signals are separated from the downstream digital signals in the optical diplexer **515**. Next, the analog optical signals are converted into the electrical domain with the analog optical receiver **525**. Subsequently, and in routine **1420**, the downstream electrical analog signals are conditioned and then propagated to respective subscribers. Further details
30 of routine **1420** will be discussed below with respect to FIG. 15.

After routine 1420, in step 1425, the downstream digital optical signals are converted into the electrical domain with the digital optical receiver 540. Next, in routine 1430, the downstream electrical digital signals are conditioned and propagated to respective subscribers. Further details of routine 1430 will be discussed below with respect to FIG. 16.

Referring now to FIG. 15, this figure illustrates an exemplary method for conditioning the downstream electrical analog signals received by a multi-subscriber optical interface 140A. Routine 1420 begins with step 1505 in which the analog electrical downstream signals are tilted with a tilt network 531. The tilt network 531 attenuates lower frequency signals to bring the signal strength across the frequency range back into balance. As noted above, higher frequencies lose signal strength faster than lower frequencies as they are being transmitted through coaxial cables. The tilt network of 531 balances frequencies by attenuating the lower frequencies.

Next, in step 1510, the analog electrical downstream signals are amplified with an amplifier 529. Next, in step 1515, the analog downstream electrical signals are divided among a plurality of subscribers with a RF splitter 531. In step 1520, service to individual subscribers can be controlled with disconnect switches 527. In step 1525, the analog downstream electrical signals can be displayed on a video display device 580. A process then returns to step 1425 of FIG. 14.

Referring now to FIG. 16, this figure illustrates an exemplary method 1430 for conditioning the downstream electrical signals. Specifically, routine 1430 begins with step 1605 in which the downstream electrical data signals are processed with a microcomputer 503 and sent to a data processing system such as a data router 513. Microprocessor 513 can process data signals associated with a telephone system as well as data signals destined for subscriber optical interface computers. The microprocessor 513 can control switch 501 that is coupled to the digital optical transmitter 30. Next, in step 1610, the downstream electrical signals are converted to telephone formatted signals in microcomputer 503. The telephone formatted signals are then distributed between a plurality of audio processing circuits 509 with a digital signal processor 507.

In step **1620**, the telephone signals are further processed with one or more subscriber line audio circuits (SLICs) **509**. In step **1625**, the telephone signals can be adapted to standard analog telephone equipment with subscriber line interface circuits **511**. In step **1630**, data signals received from the switch **501** can be routed between a plurality of subscriber data interfaces **560** with the data router **513**.

Referring now to FIG. 17, this figure illustrates an exemplary method for upstream multi-subscriber optical interface processing. Method **1700** begins with step **1705** in which upstream analog telephone signals are converted to digital signals with subscriber line interface circuits **511**. Next, in step **1710**, upstream digital telephone signals can be combined with one or more telephone signals from other subscribers in a subscriber line audio circuit **509**.

In step **1715**, upstream digital telephone signals can be further combined and processed with other groups of subscribers with a digital signal processor **507**. Next, in step **1720**, a digital telephone signals received from the digital signal processor **507** can be formatted further by a micro-computer **503** for transmission over an optical network.

In step **1725**, upstream RF return analog signals can be converted to digital signals with an analog-to-digital converter **537**. In step **1730**, upstream digital data signals received from subscriber data devices **590** can be combined with a data router **513**. In step **1735**, RF return signals and telephone signals can be processed together in a micro-computer **503**. In step **1740**, the upstream digital telephone, RF return, and data signals can be converted to the optical domain with a digital optical transmitter **530**. In step **1745**, the upstream optical signals can be propagated towards a laser transceiver node **120** or an optical tap **130**.

The present invention provides a method and system for communicating optical signals to multiple subscribers having various bandwidth demands on a single optical waveguide. The present invention services multiple subscribers along the same optical waveguide irrespective of the demand for bandwidth imposed by each subscriber of the network. The optical network architecture of the present invention provides a central service disconnection point for a plurality of subscribers in a centralized location.

Further, the present invention positions tilt networks in a centralized location when servicing multiple subscribers of an optical network. In addition to the centralized tilt network, the present invention also provides a return path for RF signals that are generated by legacy video service terminals. The method and system
5 for communicating optical signals between a data service provider and subscriber preserves the upstream transmission timing scheme that is controlled by a legacy video service controller.

The optical network system according to the present invention lends itself to efficient upgrading that can be performed entirely on the network side. The
10 upgrading can comprise replacing off-the-shelf parts with other off-the-shelf parts to reduce costs that may be associated with repairs.

The optical network architecture of the present invention can take advantage of relatively inexpensive hardware components that typically service shorter distances than their expensive counterparts that service optical signals over large distances. The
15 system comprises a computer system and method that can allocate additional or reduced bandwidth based upon the demand of one or more subscribers on an optical network.

It should be understood that the foregoing relates only to illustrate the embodiments of the present invention, and that numerous changes may be made
20 therein without departing from the scope and spirit of the invention as defined by the following claims.

CLAIMS

What is claimed is:

5

1. An optical network system comprising:
a data service hub;
at least one optical tap;
at least one multi-subscriber optical interface connected to the

10 optical tap for servicing two or more subscribers;

a laser transceiver node disposed between the data service hub and the optical tap, for communicating optical signals between the data service hub and the optical tap, and for apportioning bandwidth between subscribers of the optical network system, and

15

one or more optical waveguides connected between that at least one optical tap, the laser transceiver node, and the least one multi-subscriber optical interface, for carrying the upstream optical signals and the downstream optical signals, whereby optical bandwidth for subscribers is controllable by at least one of the laser transceiver node and multi-subscriber optical interface in response to

20 subscriber demand.

2. The optical network system of claim 1, wherein the multi-subscriber optical interface further comprises a tilt network.

3. The optical network system of claim 1, wherein the multi-subscriber optical interface further comprises an RF splitter and a service disconnect switch disposed between an RF splitter and a signal output port.

5 4. The optical network system of claim 1, wherein the multi-subscriber optical interface further comprises a data router.

5. The optical network system of claim 1, wherein the multi-subscriber optical interface further comprises an RF return path.

10

6. The optical network system of claim 1, wherein the laser transceiver node comprises passive cooling devices in order to operate in a temperature range between -40 degrees Celsius to 60 degrees Celsius.

15 7. The optical network system of claim 1, wherein the laser transceiver node is mountable on a strand in an overhead plant environment.

8. The optical network system of claim 1, wherein the laser transceiver node is housed within a pedestal in an underground plant environment.

20

9. The optical network system of claim 1, wherein a distance between the laser transceiver node and the data service hub comprises a range between zero and eighty kilometers.

25 10. The optical network system of claim 1, wherein the laser transceiver node comprises at least one optical transmitter, each optical transmitter comprises one of a Fabry-Perot laser, a distributed feedback laser, and a vertical cavity surface emitting laser (VCSEL).

11. The optical network system of claim 1, wherein the laser transceiver node further comprises an optical tap routing device that allocates additional or reduced optical bandwidth to at least one subscriber optical interface
5 relative to other subscriber optical interfaces in the optical network system.

12. The optical network system of claim 1, wherein the laser transceiver node comprises an optical tap routing device that manages upstream and downstream optical signal protocols.
10

13. The optical network system of claim 11, wherein one of the protocols comprises a time division multiple access protocol.

14. The optical network system of claim 1, wherein data bit rates
15 for the upstream and downstream optical signals are substantially symmetrical.

15. The optical network system of claim 1, wherein each optical waveguide handles data rates of at least 450 Mb/s.

20 16. The optical network system of claim 1, wherein each optical tap comprises at least one optical splitter.

17. The optical network system of claim 1, wherein one of the optical taps servicing a particular group of subscriber optical interfaces is connected
25 to another optical tap.

18. The optical network system of claim 1, wherein each optical tap propagates upstream and downstream optical signals in addition to downstream RF modulated optical signals.
30

19. The optical network system of claim 1, wherein the multi-subscriber optical interface comprises an analog optical receiver, a digital optical receiver, and a digital optical transmitter.

5 20. The optical network system of claim 1, wherein the optical waveguides are a first set of optical waveguides, the optical network system further comprising a second set of optical waveguides disposed between the data service hub and laser transceiver node, the second set comprising a first waveguide for carrying upstream optical signals to the data service hub, and a second optical waveguide for
10 carrying downstream optical signals to the laser transceiver node.

 21. The optical network system wherein the multi-subscriber optical interface comprises a processor for managing one of data and telephone signals.
15

 22. The optical network system of claim 21, wherein the processor further comprises at least one of a microcomputer and a switch.

 23. The optical network system of claim 21, wherein the processor
20 further comprises at least one of a digital signal processor, a subscriber line audio-processing circuit for digital telephone signal processing, and a subscriber line interface circuit for analog telephone signal to digital telephone signal conversion.

24. An optical network system comprising:
a data service hub;
at least one optical tap;
a least one single-subscriber optical interface connected to the
5 optical tap for servicing a subscriber;
at least one multi-subscriber optical interface connected to the
optical tap for servicing two or more subscribers;
a laser transceiver node disposed between the data service hub
and the optical tap, for communicating optical signals between the data service hub
10 and the optical tap, and for apportioning bandwidth between subscribers of the optical
network system, and
one or more optical waveguides connected between respective
optical taps, the laser transceiver node, the at least one single-subscriber optical
interface, and the at least one multi-subscriber optical interface, for carrying the
15 upstream optical signals and the downstream optical signals, whereby optical
bandwidth for subscribers is controllable by one of a laser transceiver node and the at
least one multi-subscriber optical interface in response to subscriber demand.

25. The optical network system of claim 24, wherein the multi-
20 subscriber optical interface further comprises a tilt network.

26. The multi-optical network system of claim 24, wherein the
multi-subscriber optical interface further comprises an RF splitter and a service
disconnect switch disposed between the RF splitter and a signal output port.

25

27. The optical network system of claim 24, wherein the multi-
subscriber optical interface further comprises a data router.

28. The optical network system of claim 24, wherein the multi-
30 subscriber optical interface further comprises an RF return path.

29. The optical network system of claim 24, wherein the at least one optical tap comprises an optical splitter.

30. The optical network system of claim 24, wherein the at least
5 one optical tap services a particular group of subscribers and is connected to another optical tap.

31. A method for communicating optical signals to multiple subscribers with various bandwidth demands connected to the same optical waveguide, comprising:

5 receiving upstream analog telephone signals from one or more subscribers;

converting analog optical signals into a digital domain;

combining upstream digital telephone signals originating from a first group of subscribers;

10 combining upstream digital telephone signals originating from the first group of subscribers with a second group of subscribers;

converting upstream RF analog signals into digital domain; and propagating the upstream signals along an optical waveguide.

32. The method of claim 31, further comprising the step of
15 combining at least two streams of upstream digital data signals with a router.

33. The method of claim 31, wherein the step of combining upstream digital telephone signals originating from a first group of subscribers comprises the step of combining the upstream digital telephone optical signals with a
20 subscriber line audio circuit.

34. An optical network system comprising:
a data service hub;
at least one optical tap;
at least one multi-subscriber optical interface connected to the
5 optical tap for servicing two or more subscribers, the at least one multi-subscriber
optical interface comprising an RF return path;
a laser transceiver node disposed between the data service hub
and the optical tap, for communicating optical signals between the data service hub
and the optical tap, and for apportioning bandwidth between subscribers of the optical
10 network system, and
one or more optical waveguides connected between respective
optical taps and the laser transceiver node, and the at least one multi-subscriber
optical interface, for carrying the upstream optical signals and the downstream optical
signals, whereby optical bandwidth for subscribers is controllable by one of the laser
15 transceiver node and a multi-subscriber optical interface in response to subscriber
demand.

35. The optical network system of claim 34, wherein the multi-
subscriber optical interface further comprises a tilt network.
20

36. The optical network system of claim 34, wherein the multi-
subscriber optical interface further comprises an RF splitter and a service disconnect
switch disposed between the RF splitter and a signal output port.

37. The optical network system of claim 34, wherein the multi-
subscriber optical interface further comprises a data router.
25

38. The optical network system of claim 34, wherein the RF return
path comprises at least one of a diplexer and an analog-to-digital (A/D) converter.
30

39. The optical network system of claim 34, wherein the RF return path comprises at least one of a data reducer and a data conditioner.

40. The optical network system of claim 34, wherein the RF return
5 path comprises at least one of a diplexer and an RF presence detector.

41. The optical network system of claim 34, wherein the RF return path comprises amplitude modulated optical transmitter.

10 42. The optical network system of claim 1, wherein the at least one multi-subscriber optical interface services both business subscribers and single subscribers.

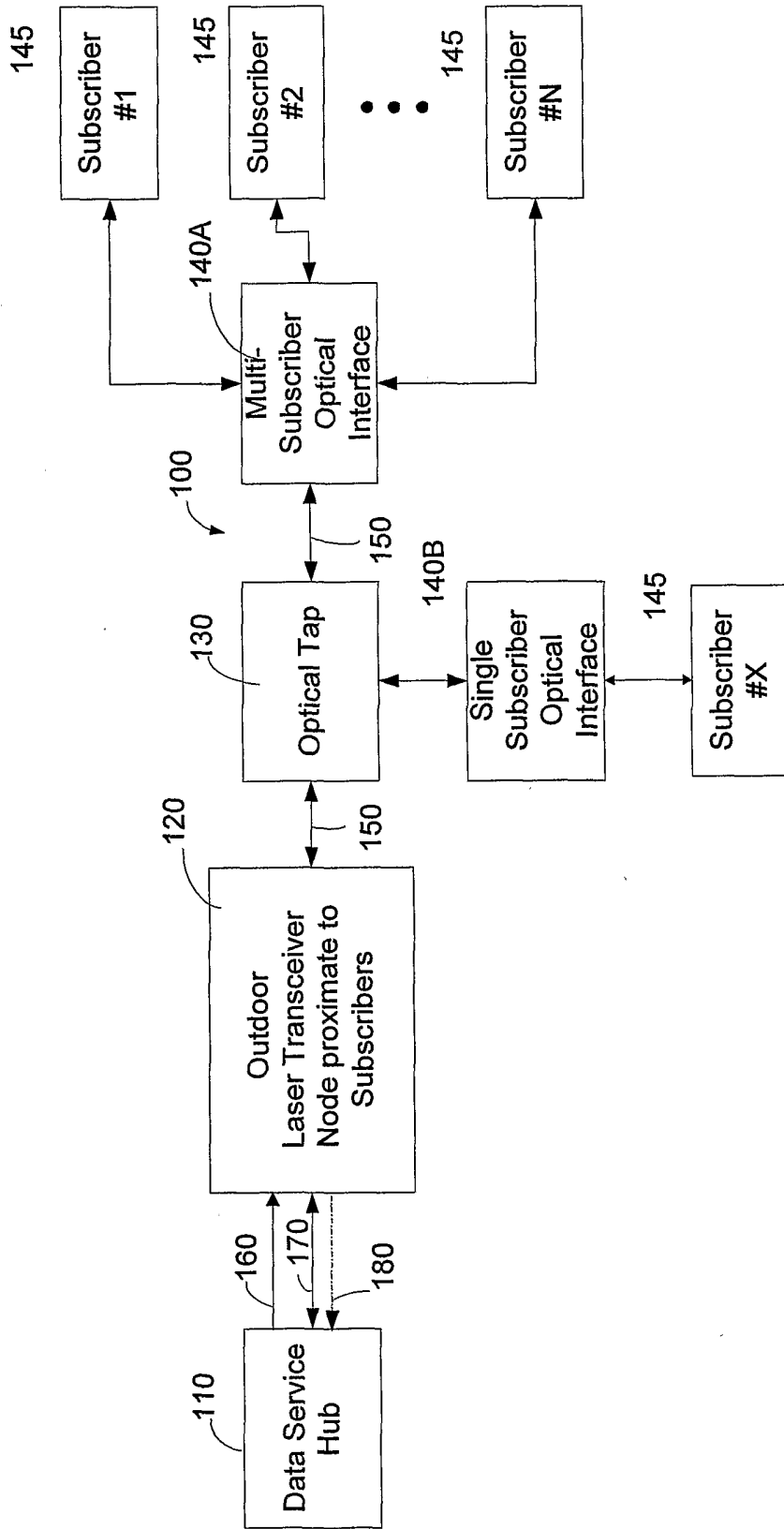


FIG. 1

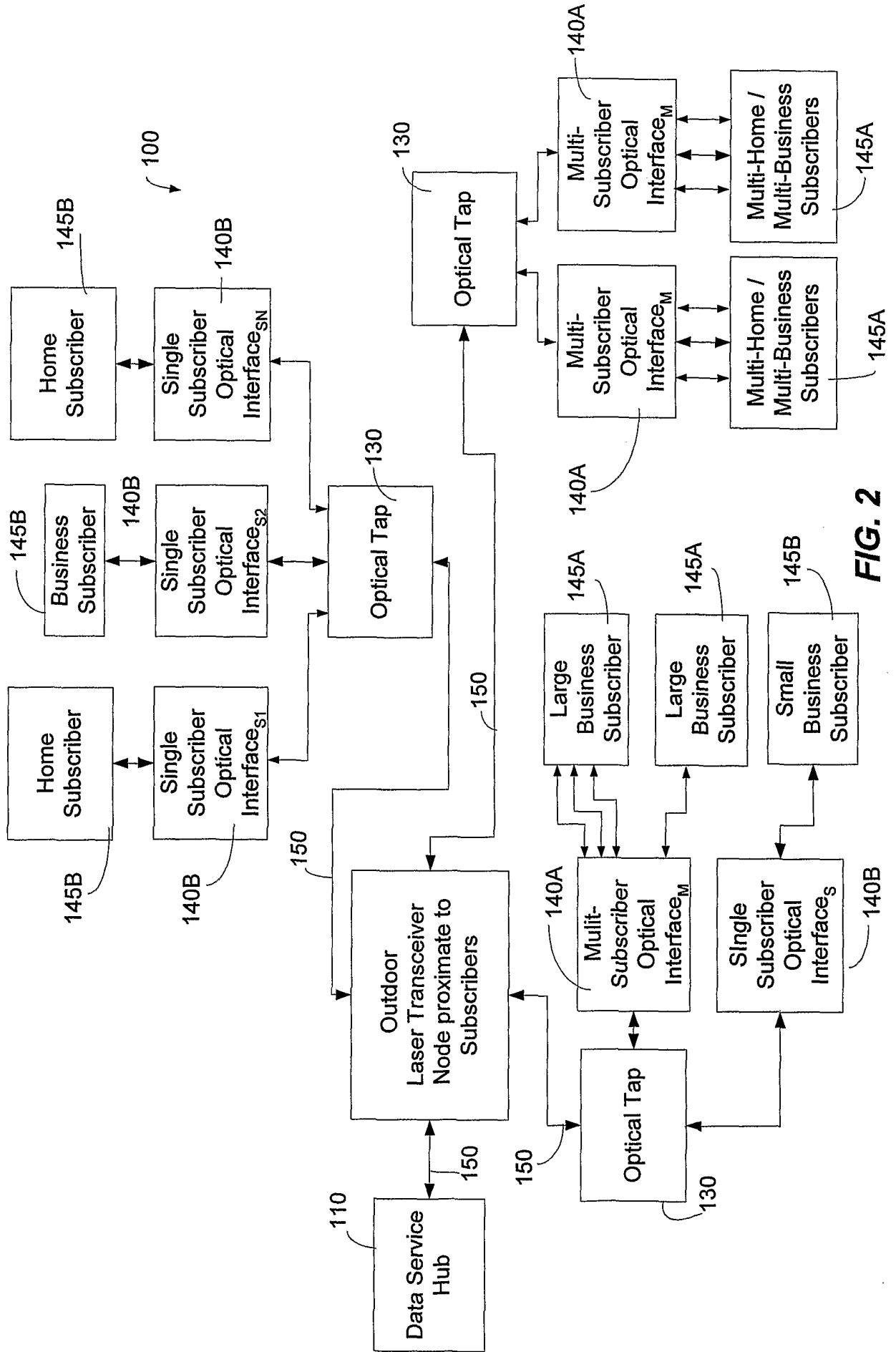


FIG. 2

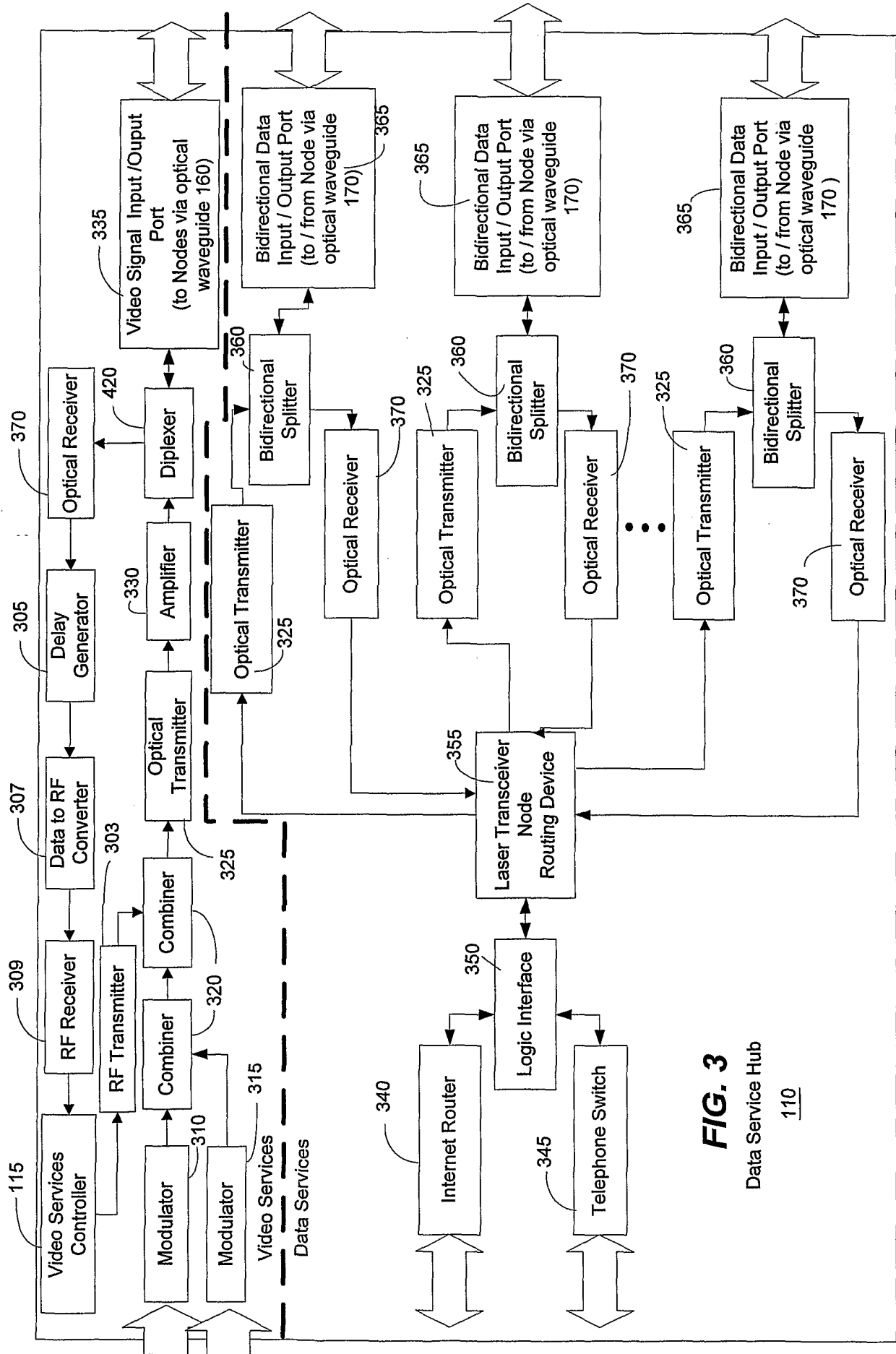


FIG. 3

Data Service Hub

110

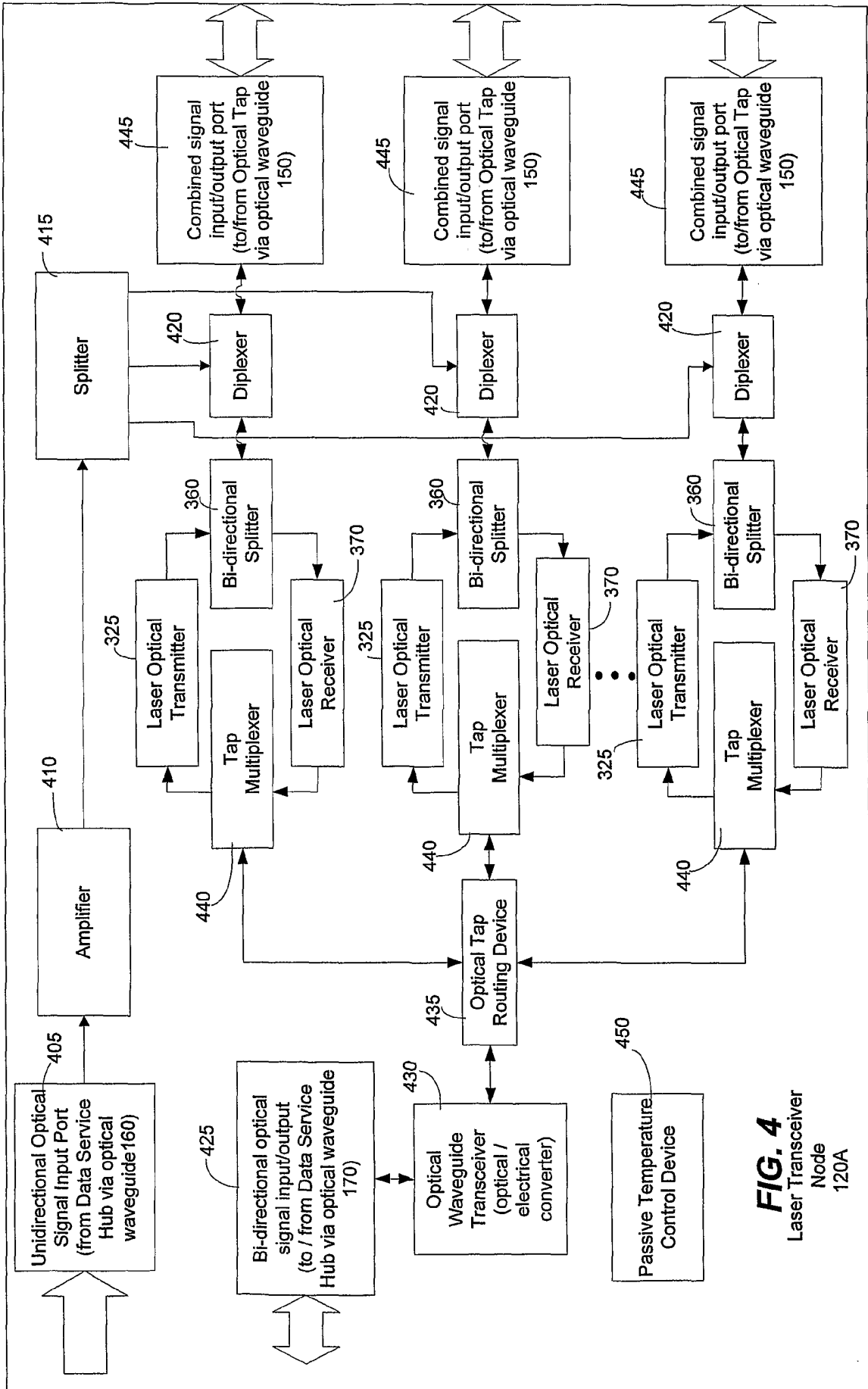


FIG. 4
Laser Transceiver Node 120A

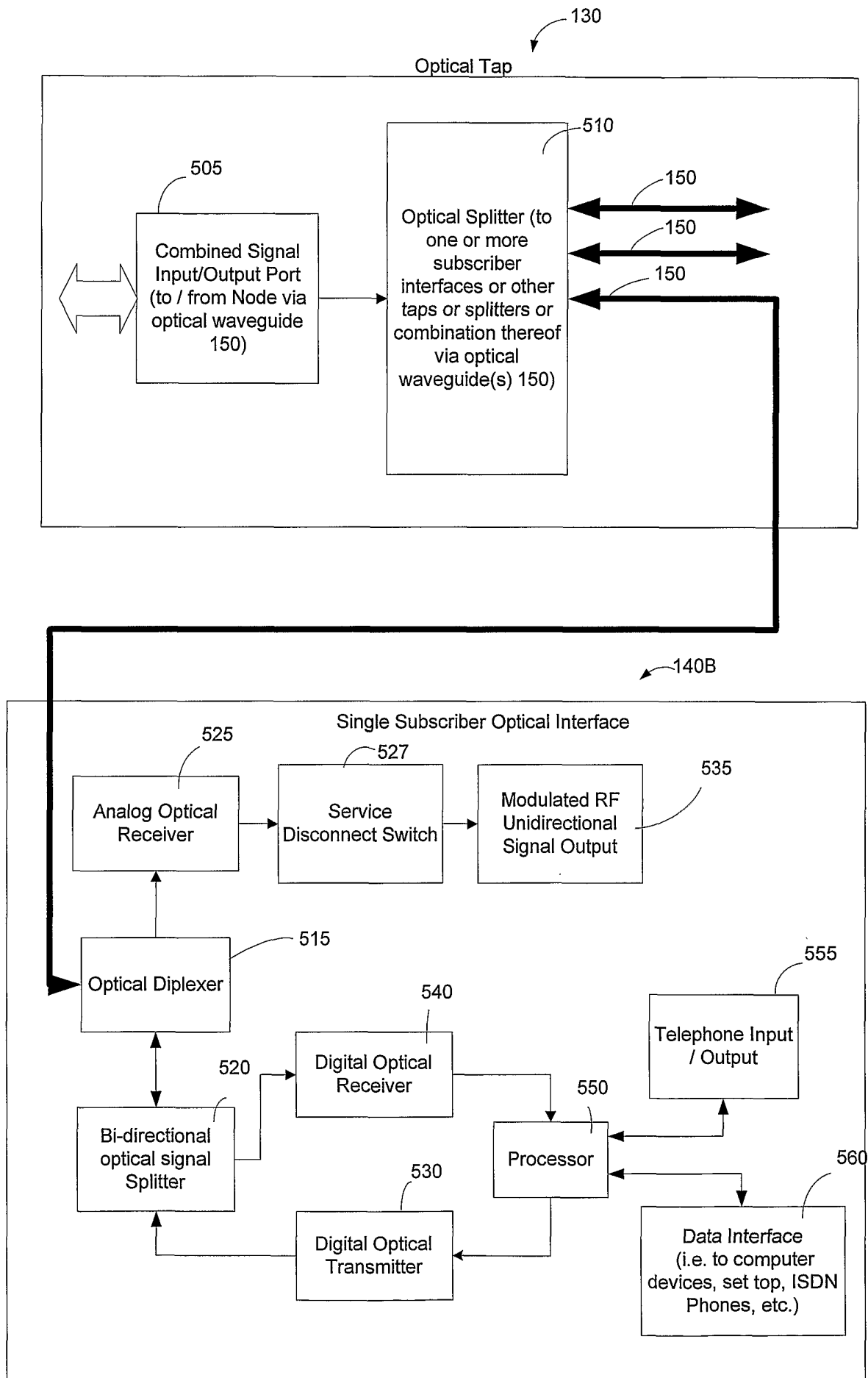


FIG. 5A

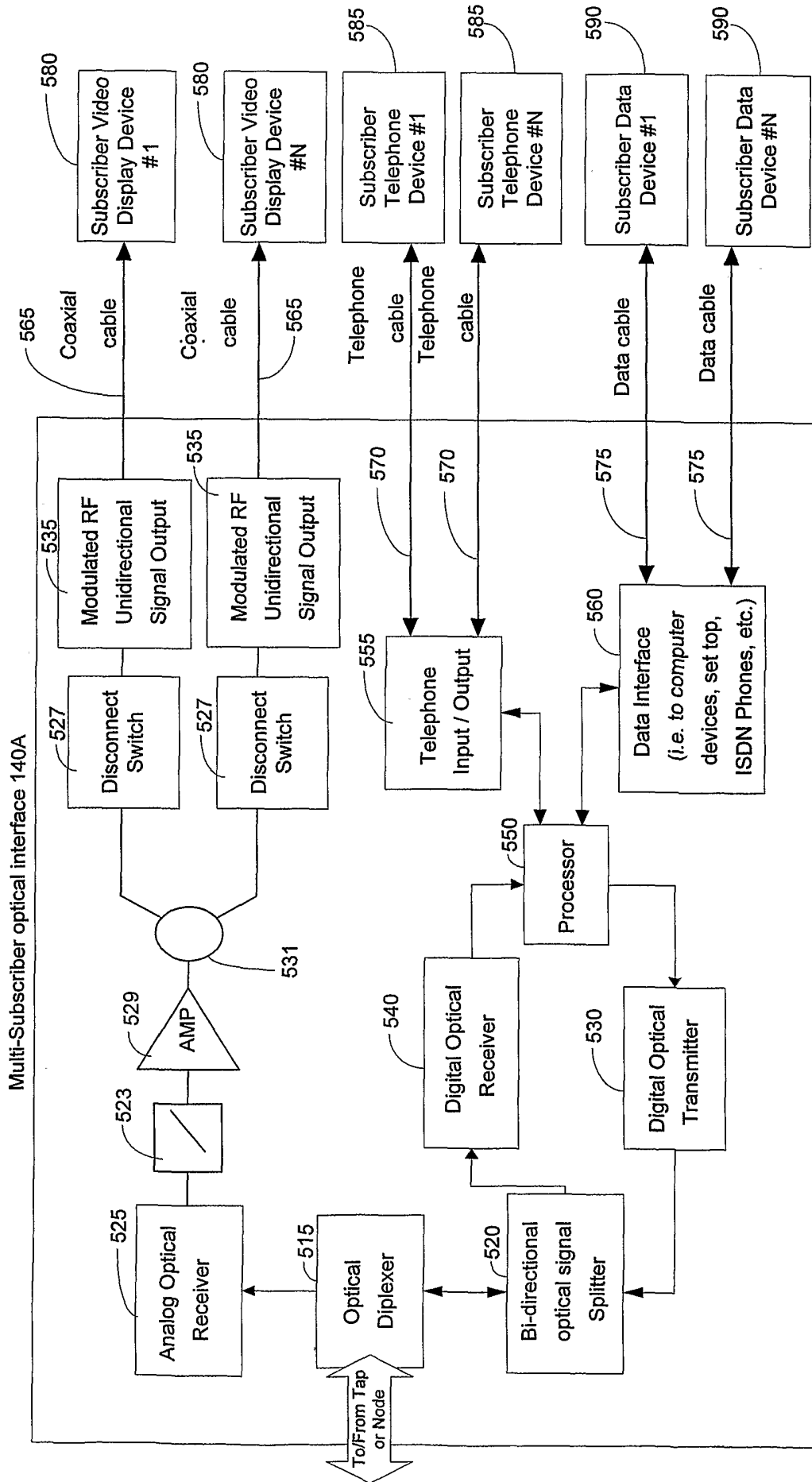


FIG. 5B

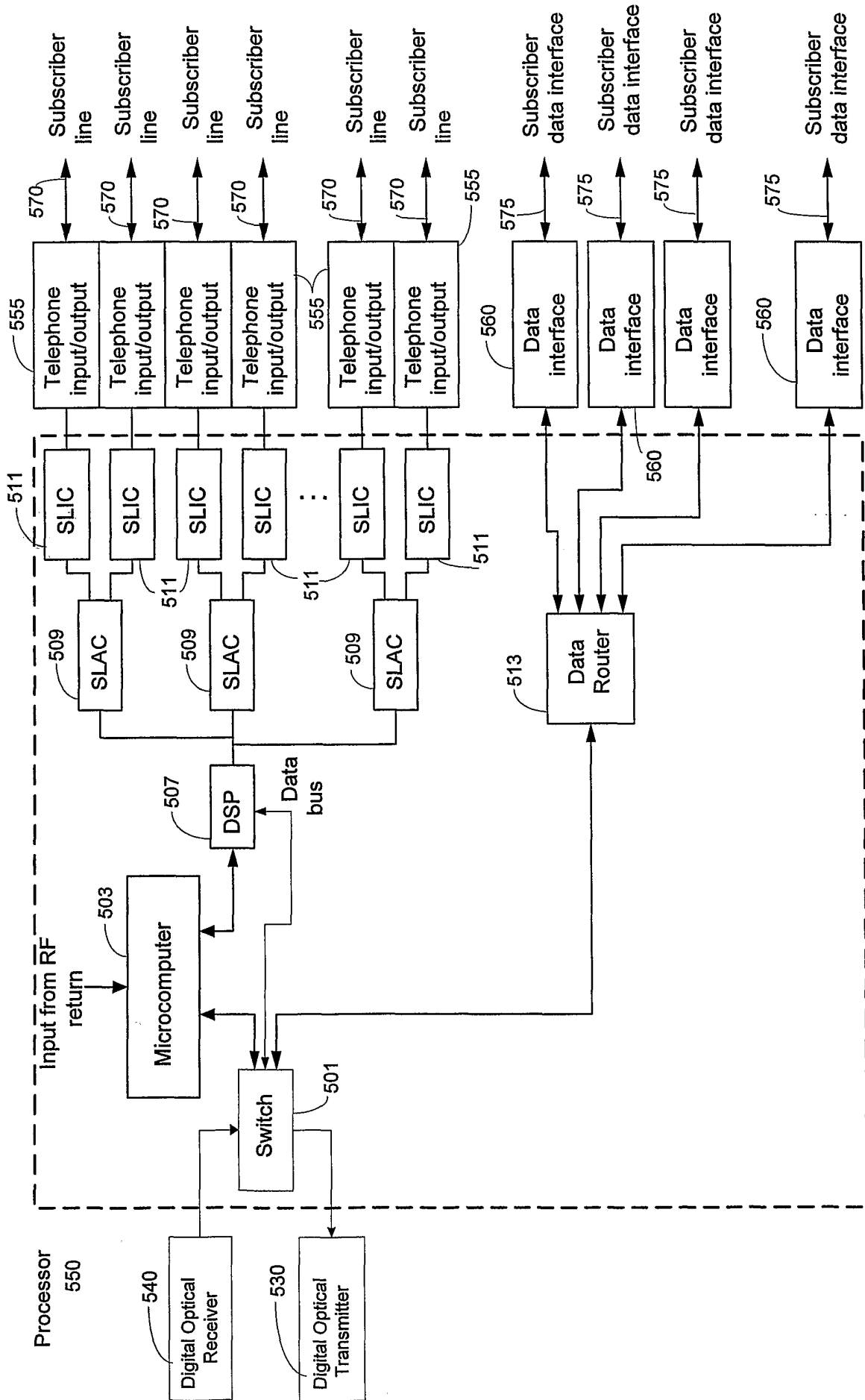


FIG. 5C

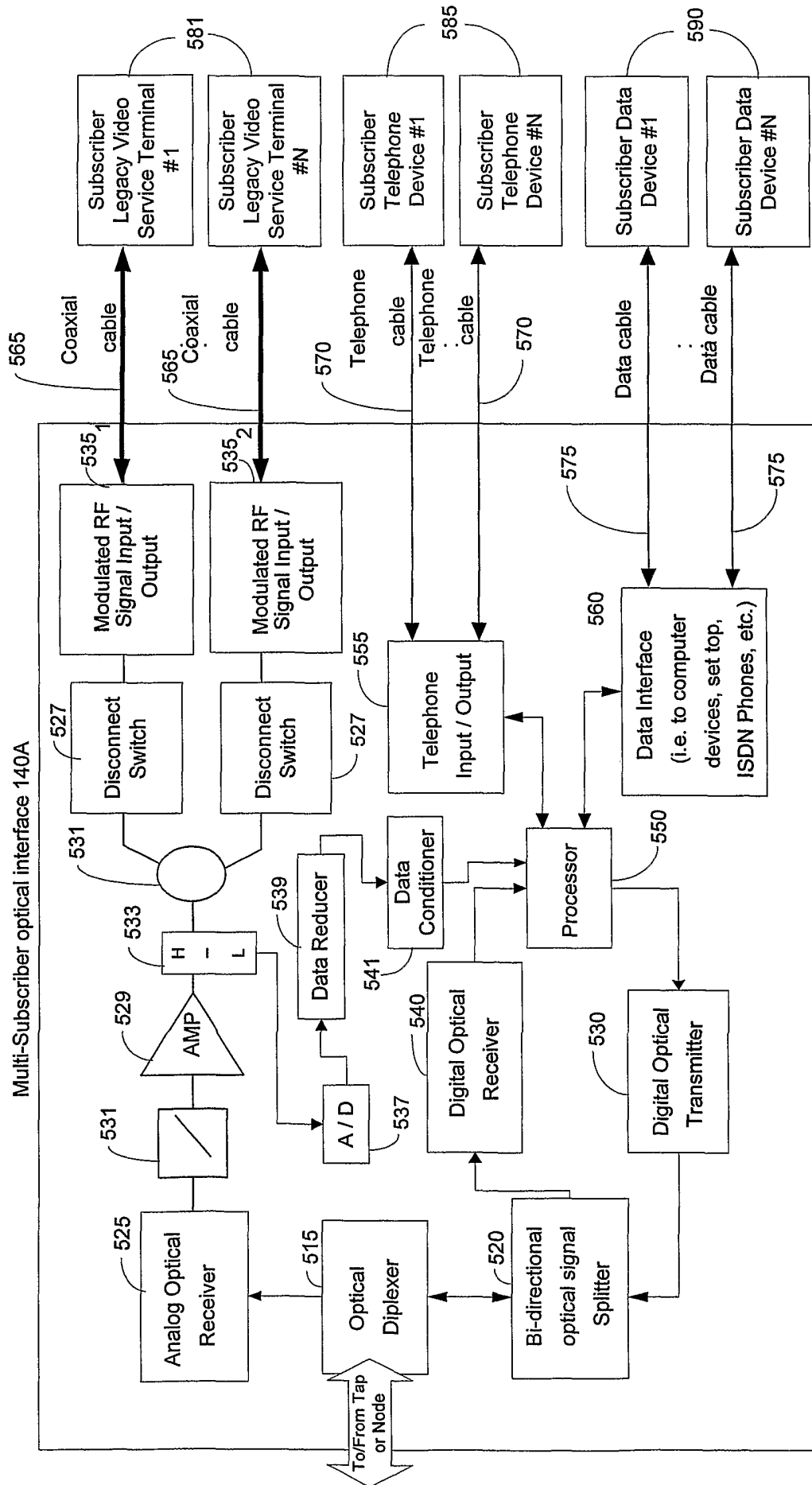


FIG. 5D

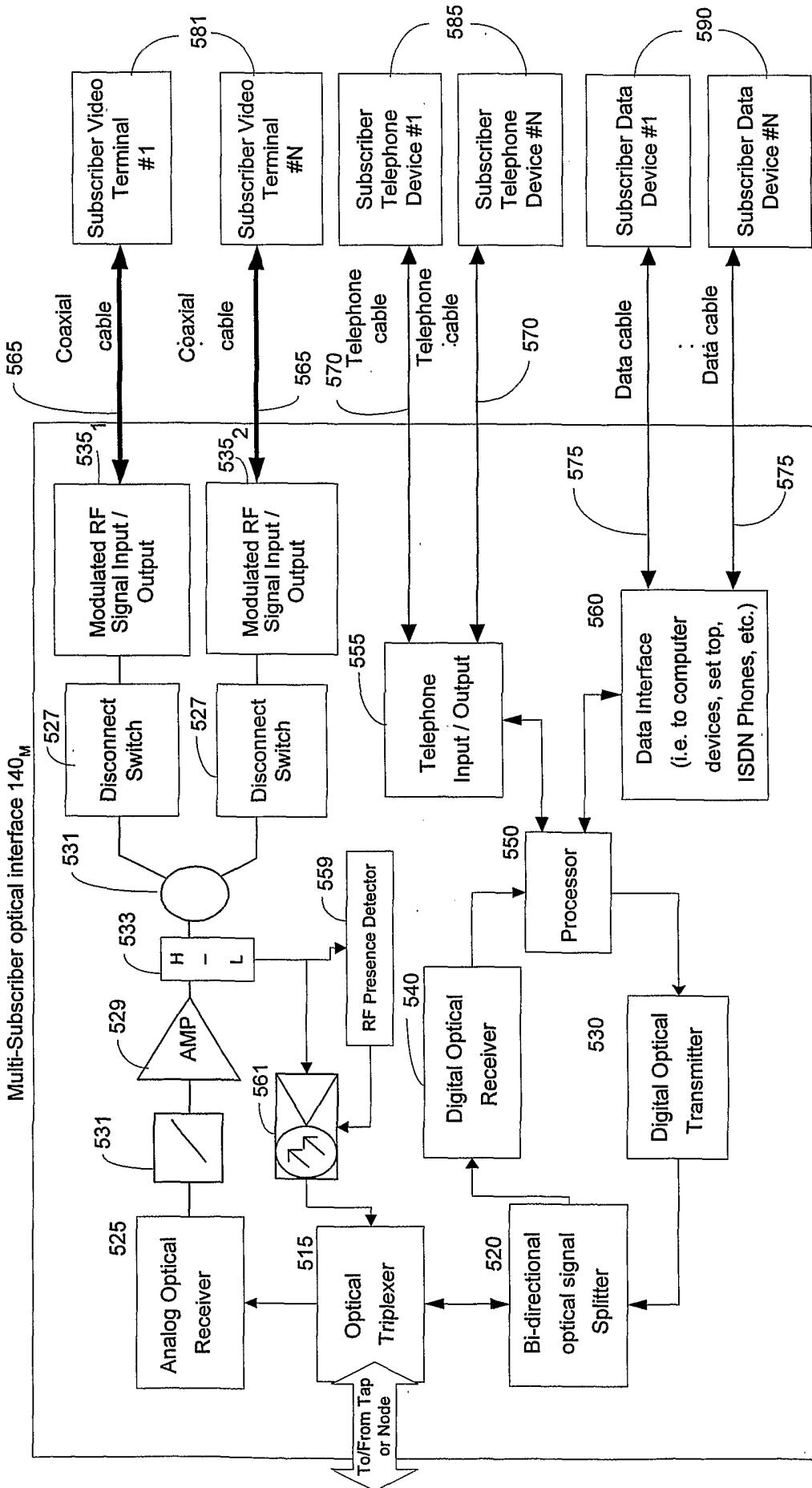


FIG. 5E

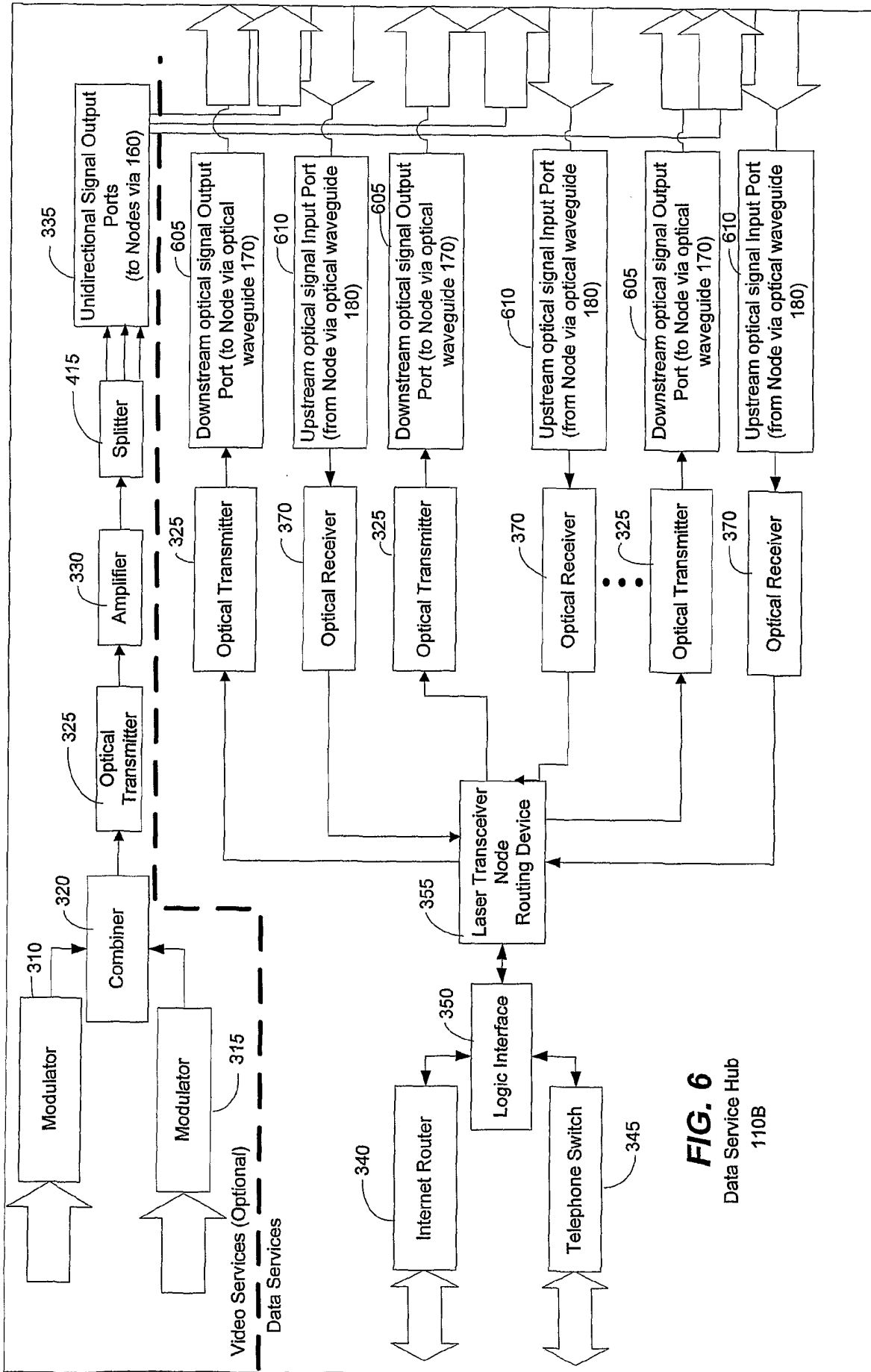


FIG. 6
Data Service Hub
110B

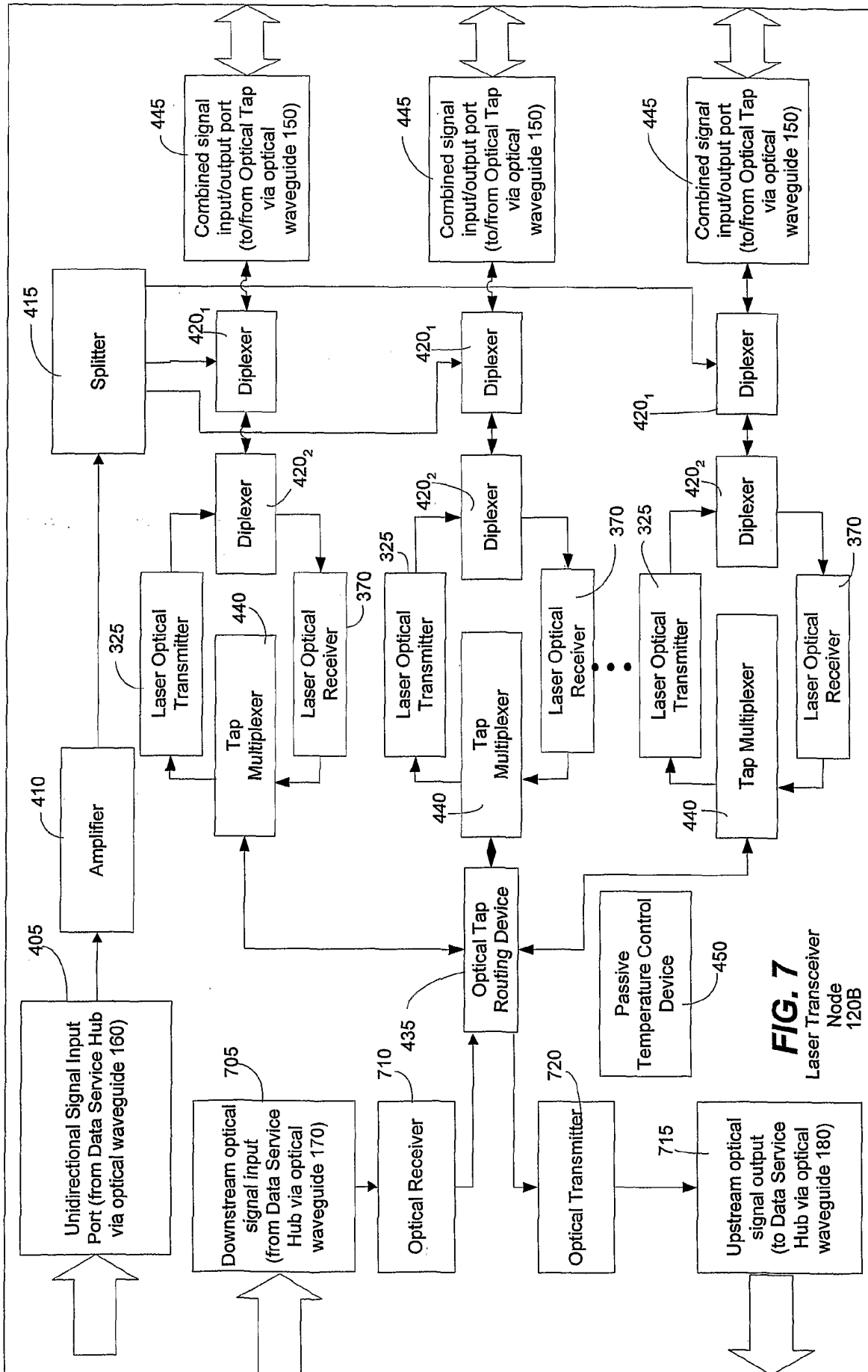


FIG. 7
Laser Transceiver
Node
120B

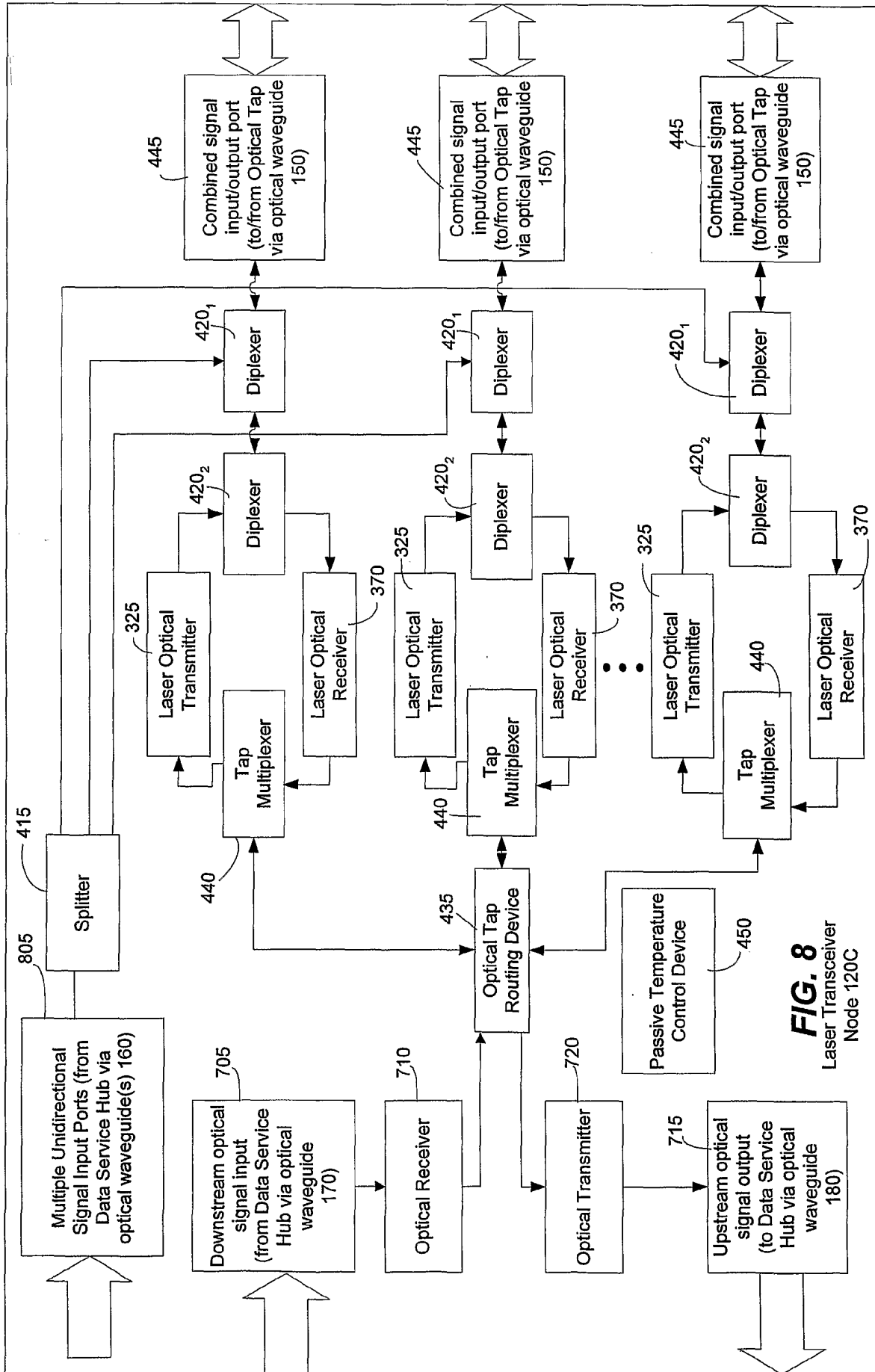


FIG. 8
Laser Transceiver
Node 120C

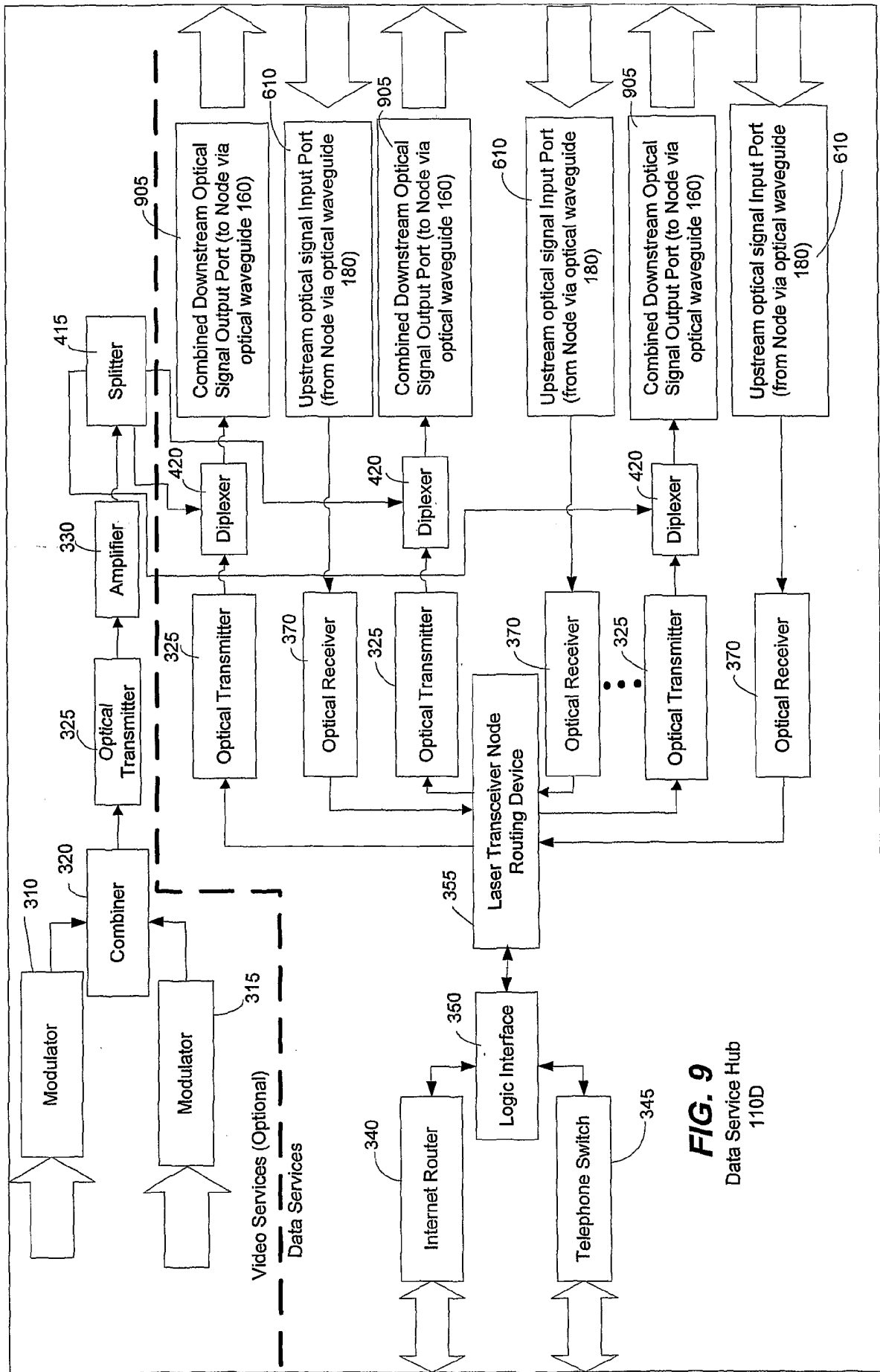


FIG. 9
Data Service Hub
110D

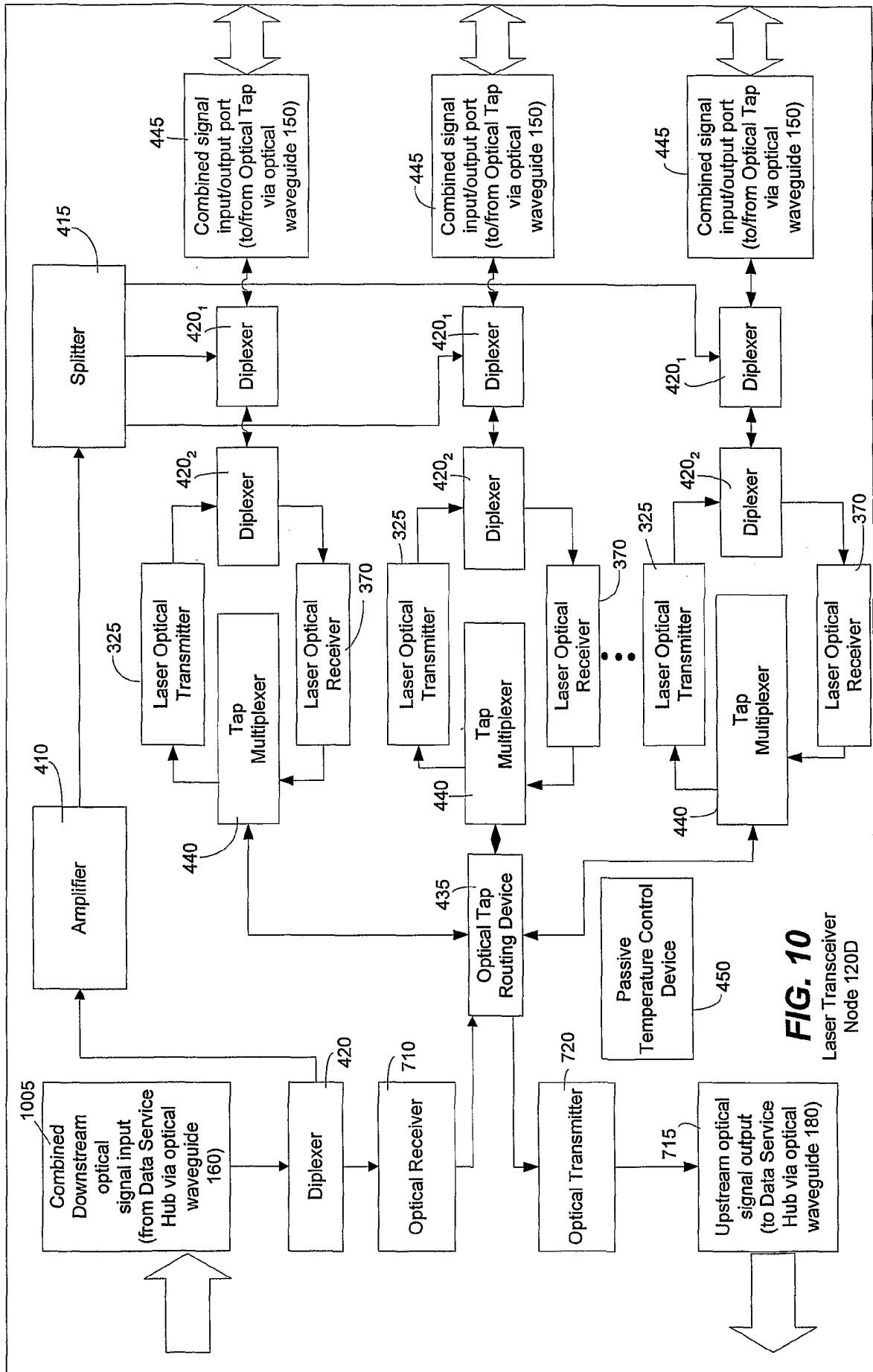


FIG. 10
Laser Transceiver Node 120D

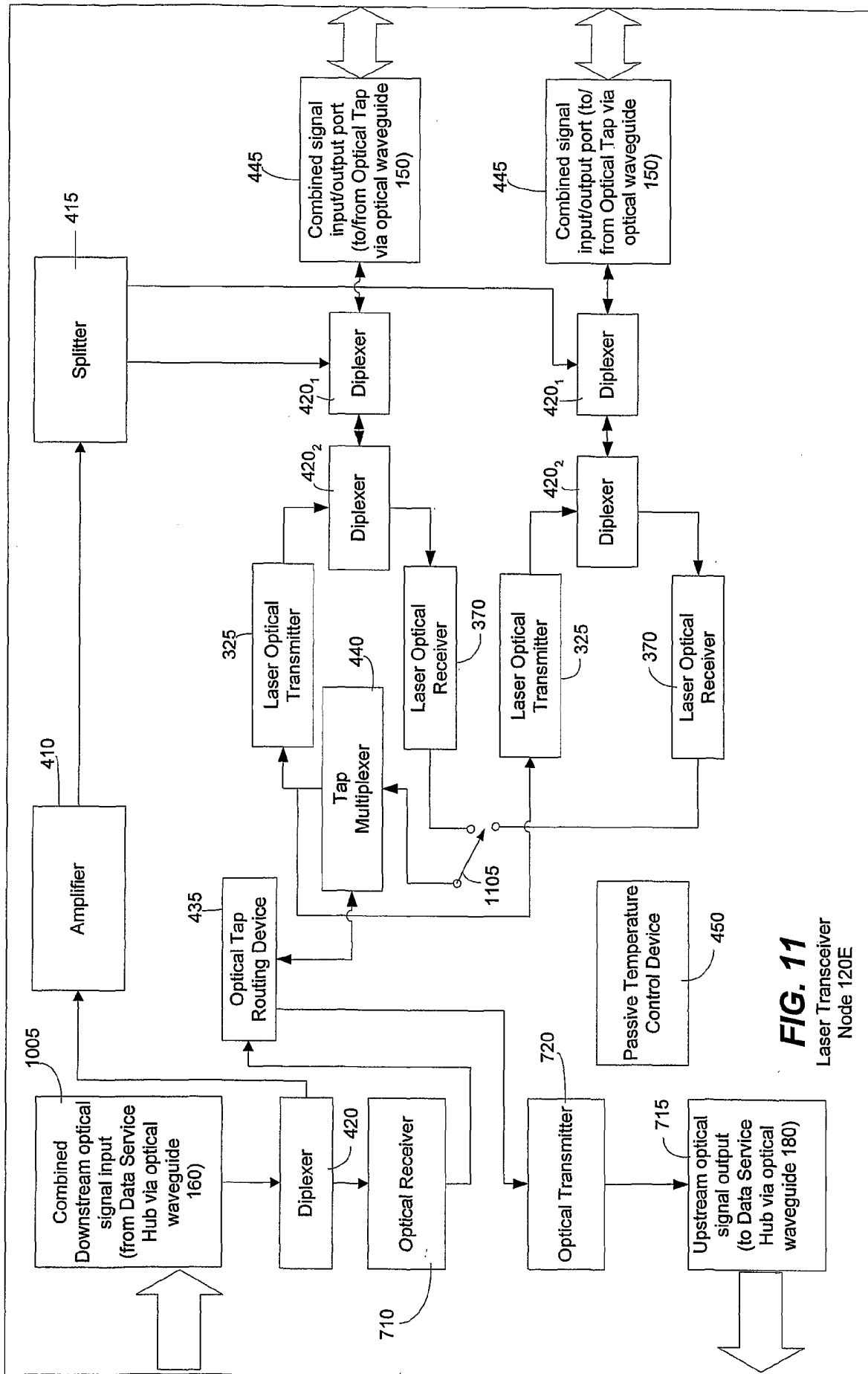


FIG. 11
Laser Transceiver Node 120E

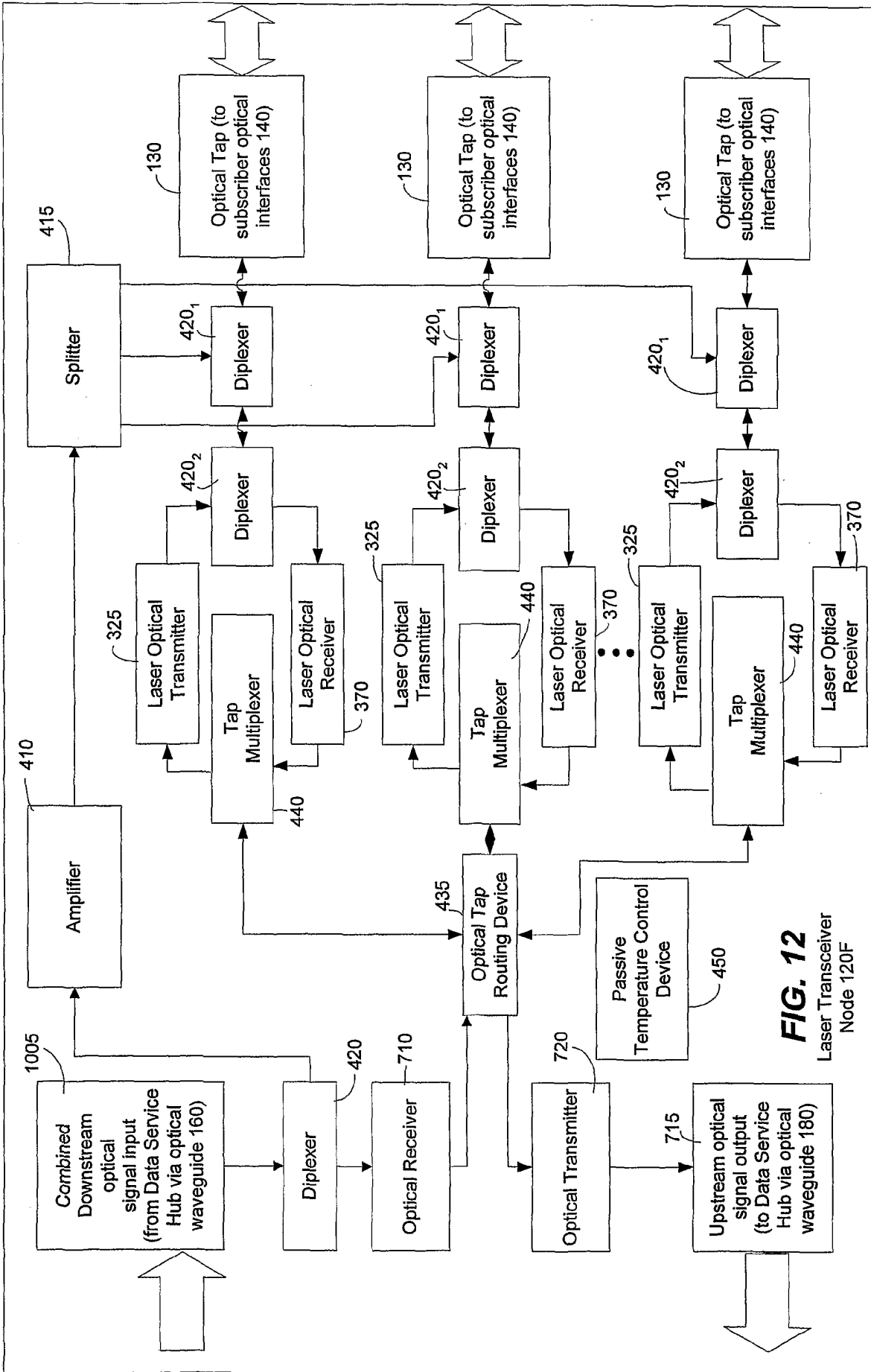


FIG. 12
Laser Transceiver Node 120F

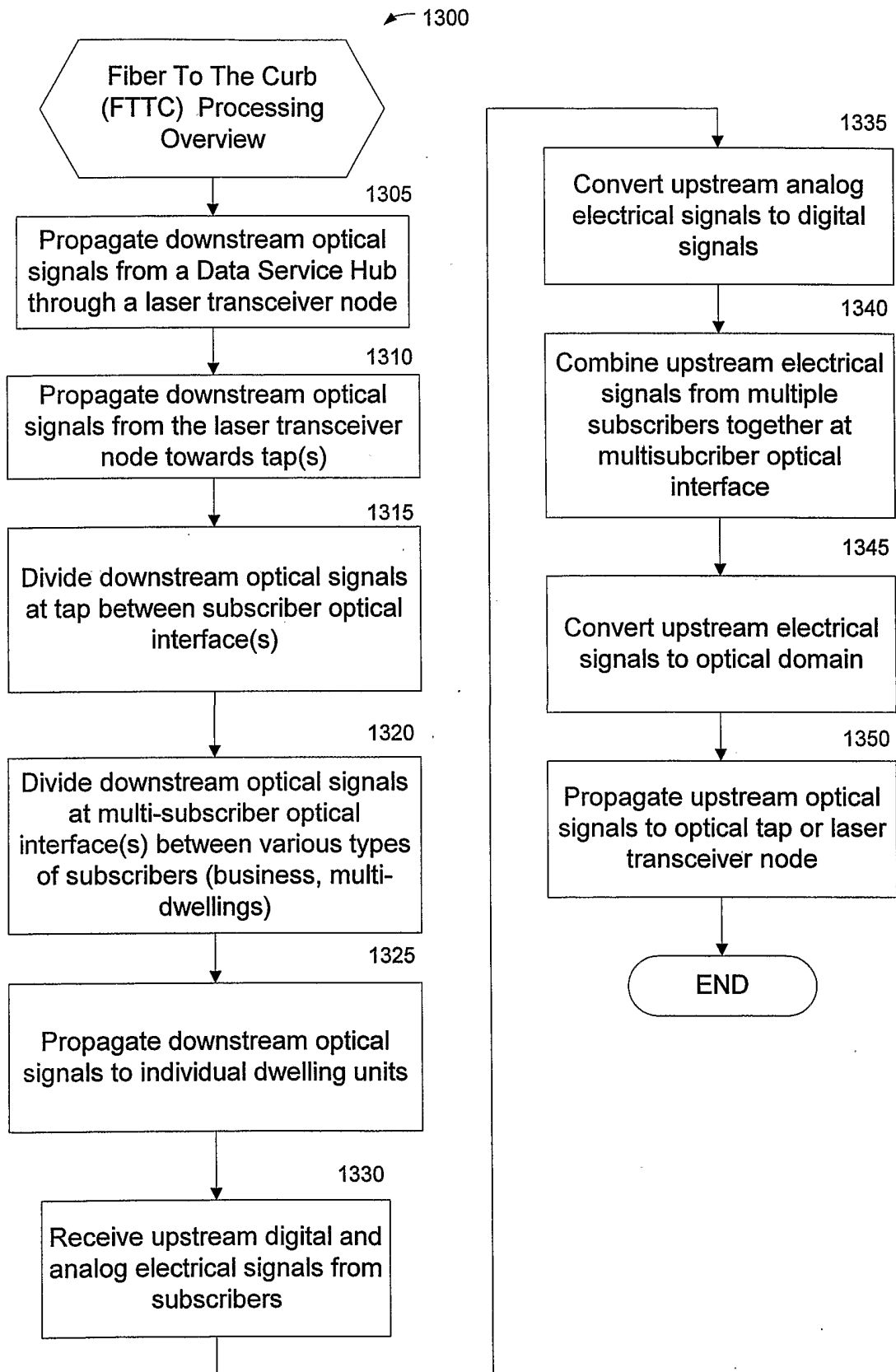


FIG. 13

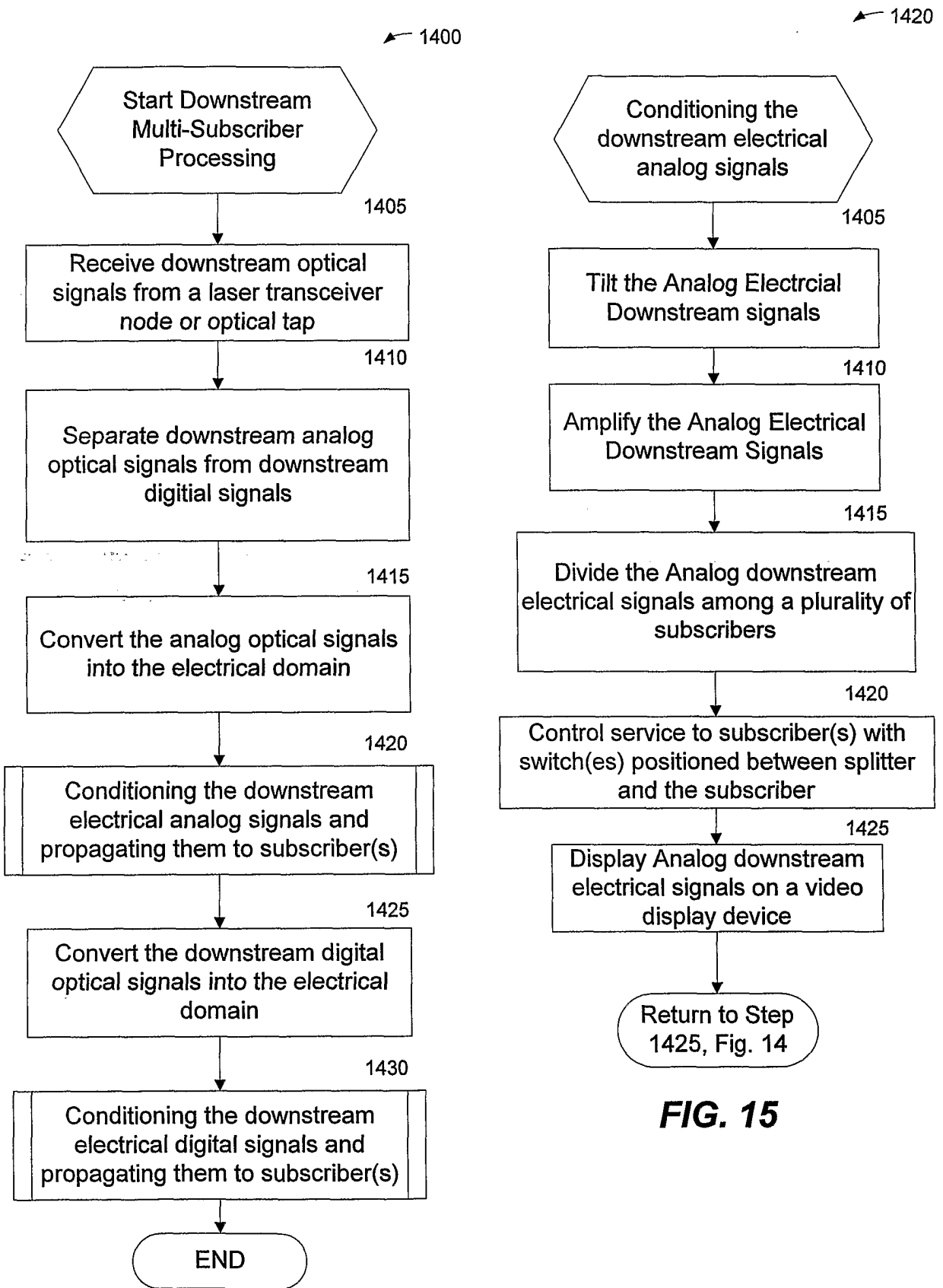


FIG. 14

FIG. 15

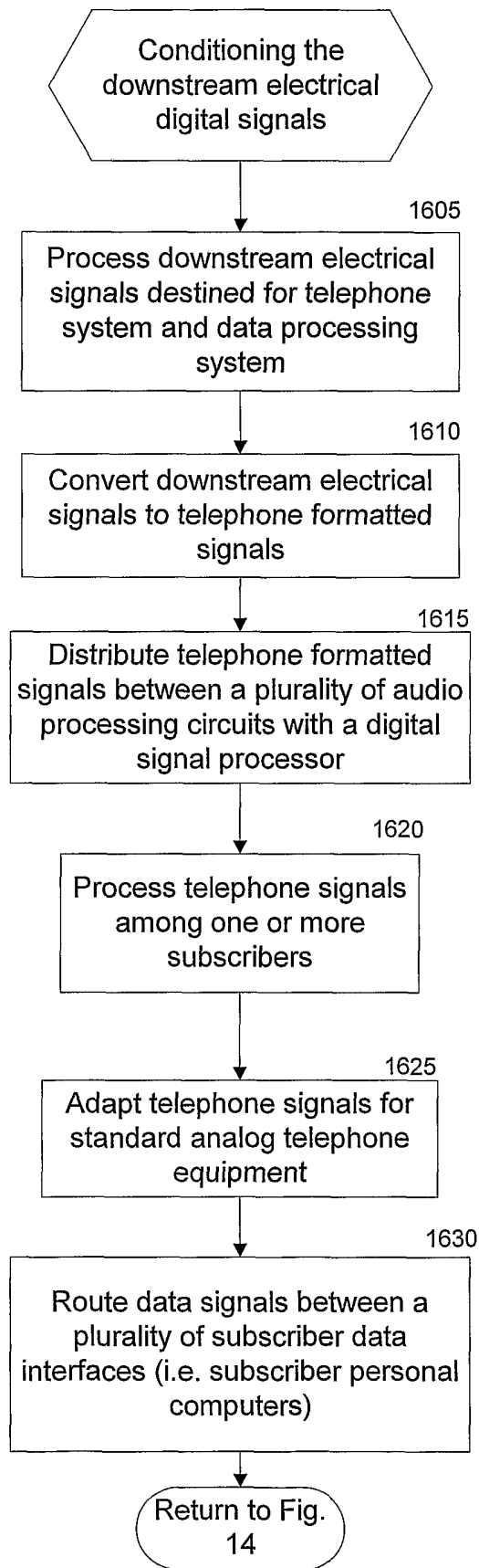


FIG. 16

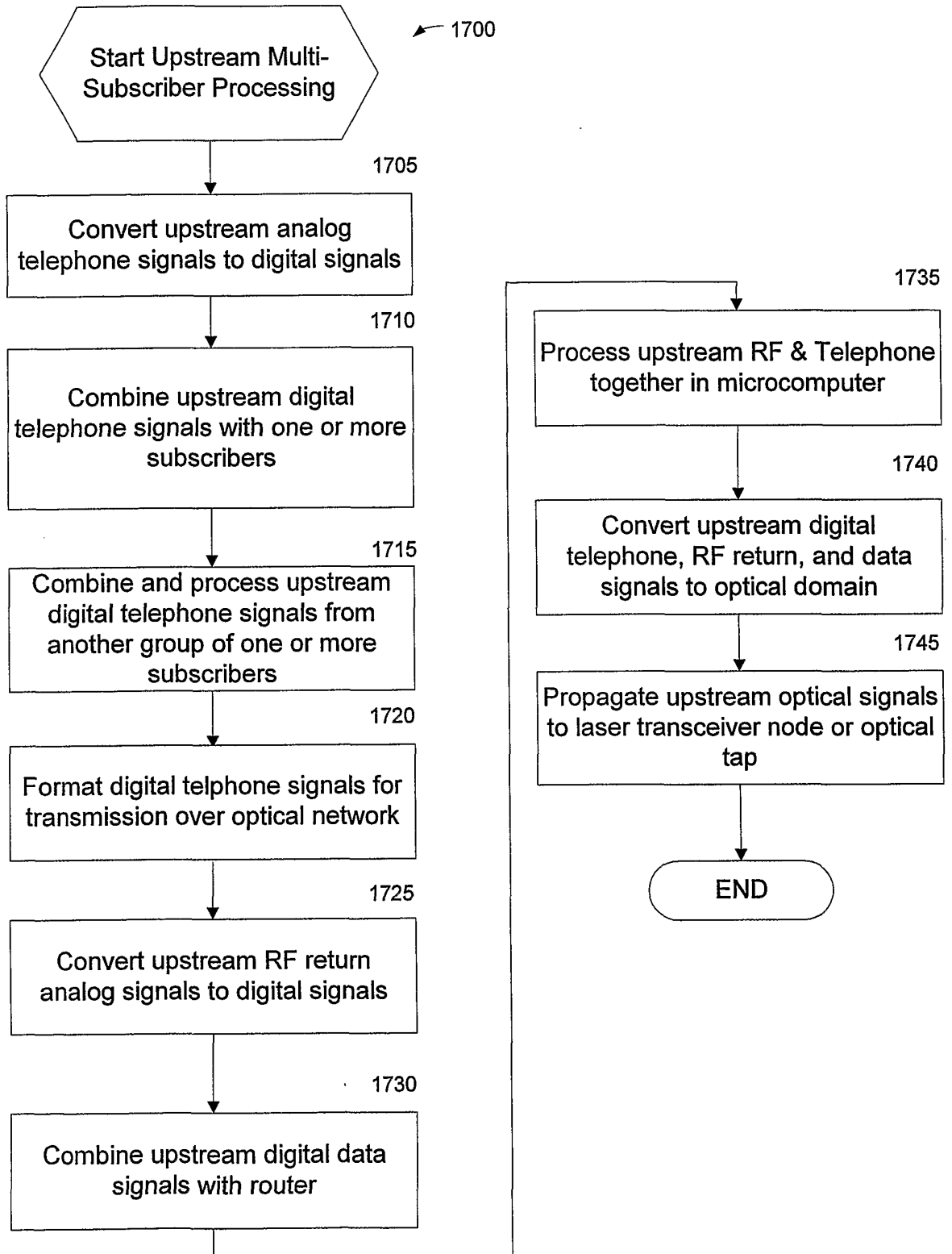


FIG. 17