Figure 4

(57) Abstract: The present subject matter relates to one or more devices, systems and/or methods for providing wireless telecommunication services. A Small Form Factor Pluggable Unit (SFF) incorporates wireless capabilities, and includes all integrated or an external antenna. The SFP comprises wireless circuitry for transmitting and receive multiple and distinct wireless signals, including Wi-Fi and Bluetooth for communicating with various equipment and/or devices.
Small Form Factor Pluggable Unit With Wireless Capabilities

Technical Field

[0001] The exemplary teachings herein pertain to telecommunications equipment, methods and systems. Specifically, the present disclosure relates to methods and systems incorporating Small Form-factor Pluggable (SFP) devices used to provide communication services for the communication market.

Background

[0002] Small form factor pluggable units such as disclosed in U.S. Patent No. 8,761,604 issued to Lavoie et al. on June 24, 2014, herein fully incorporated by reference, are known in the art. As described in Column 1, lines 10-48 in the '604 patent:

[0003] Small Form-factor Pluggable (SFP) devices are standardized, hot-pluggable devices used to provide communication services for the communication market. The SFF (Small Form Factor) Committee defines the mechanical, electrical, and software specifications of the SFP device to ensure interoperability among SFP devices and chassis. SFF Committee document INF-8074i Rev 1.0 provides specifications for SFF (Small Formfactor Pluggable) Transceiver. SFF Committee documents SFF-8431 Rev 4.1 SFP-10Gb/s and Low Speed Electrical interface provides specifications for SFP+ devices. SFF Committee document INF-8438i Rev 1.0 provides specifications for QSFP (Quad Small Formfactor Pluggable) Transceiver. SFF Committee document INF-8077i Rev 4.5 (10 Gigabit Small Form Factor Pluggable Module) provides specifications for XFP devices. These documents represent the various families of SFP
devices available.

[0004] SFP devices are designed to be inserted within a cage, which the cage is attached to the equipment circuit assembly. SFF Committee document SFF-8432 Rev 5.1 SFP+ provides specifications for the SFP* module and cage. Ethernet switches, Ethernet routers, servers are examples of equipment using SFP type devices. SFP devices are available with different exterior connectors for various applications. SFP devices are available with coaxial connectors, SC/LC optical connectors, and RJ modular jack types connectors.

[0005] SFF Committee document SFF-8472 Diagnostic Monitoring Interface for Optical Transceivers provides specifications on the SFP device's identity, status, and real-time operating conditions. SFF-8472 describes a register and memory map which provides alarms, warnings, vendor identity, SFP description and type, SFP real time diagnostic, and vendor specific registers. This information is to be used by the SFP host equipment.

[0006] Other references relating to and/or discuss technology related to small form factor units or devices include U.S. Patent No. 8,036,539 issued to Kiely et al. on October 11, 2011 and U.S. Patent Application Publication No. 2006/0209886 issued to SiSherman et al. on September 21, 2006. Each of these references is herein fully incorporated by reference.

[0007] By way of further background, small form factor pluggable (SFP) devices are used to provide a flexible means of providing communication services for the telecommunication network. The SFP devices are typically deployed on communication network equipment such as an Ethernet access switch, Ethernet router, a broadband fiber multiplexer, or media converters. SFP devices are designed to support optical and wired Ethernet, TDM SONET, Fiber Channel, and other communications standards. Due to its small and portable physical size, SFP devices have expanded in specifications to address other applications. SFP devices presently are defined
for XPP, SFP, SFP+, QSFP, QSFP*, and CXP technologies. SFP devices are standardized among equipment vendors and network operators to support interoperability. Due to the low cost, size, and interoperability, SFP devices are used extensively in all communication service applications.

[0008] 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6, 5, and 60 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802). The base version of the standard was released in 1997, and has had subsequent amendments. The standard and amendments provide the basis for wireless network products using the Wi-Fi brand. While each amendment is officially revoked when it is incorporated in the latest version of the standard, the corporate world tends to market to the revisions because they concisely denote capabilities of their products. As a result, in the market place, each revision tends to become its own standard.

[0009] The 802.11 family consists of a series of half-duplex over-the-air modulation techniques that use the same basic protocol. 802.11-1997 was the first wireless networking standard in the family, but 802.11b was the first widely accepted one, followed by 802.11a, 802.11g, 802.11n, and 802.11ac. Other standards in the family (e-f, h, j) are service amendments and extensions or corrections to the previous specifications.

[0010] 802.11b and 802.11g use the 2.4 GHz ISM band, operating in the United States under Part 15 of the U.S. Federal Communications Commission Rules and Regulations. Because of this choice of frequency band, 802.11b and g equipment may occasionally suffer interference from microwave ovens, cordless telephones, and Bluetooth devices. 802.11b and 802.11g control their interference and susceptibility to interference by using direct sequence spread spectrum
(DSSS) and orthogonal frequency division multiplexing (OFDM) signaling methods, respectively. 802.11a uses the 5 GHz U-NII baud, which, for much of the world, offers at least 23 non-overlapping channels rather than the 2.4 GHz ISM frequency band, where adjacent channels overlap - e.g., WLAN channels. Better or worse performance with higher or lower frequencies (channels) may be realized, depending on the environment.

[0011] The segment of the radio frequency spectrum used by 802.11 varies between countries. In the US, 802.11a and 802.11g devices may be operated without a license, as allowed in Part 15 of the FCC Rules and Regulations. Frequencies used by channels one through six of 802.11b and 802.11g fall within the 2.4 GHz amateur radio band. Licensed amateur radio operators may operate 802.1 ih/g devices under Part 97 of the FCC Rules and Regulations, allowing increased power output but not commercial content or encryption.

[0012] Bluetooth is a wireless technology using short-wavelength IMF radio waves in the ISM band from 2.4 to 2.485 GHz from fixed and mobile devices, and in-building networks, invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization. Bluetooth is managed and oversees the development of the specification and manages the qualification program. Bluetooth technology is a global wireless communication standard that is present on a majority of mobile devices.

[0013] ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios. Its low power consumption limits transmission distances to 10-100 meters line-of-sight, depending on power output and environmental characteristics. ZigBee is typically used in low data rate applications that require long battery life and secure networking. ZigBee has a defined rate of
250 kbit/s, best suited for intermittent data transmissions from a sensor or input device,

Wi-Fi has become a very ubiquitous, cost effective, and popular wireless network technology. Service and Network Providers are increasing their Wi-Fi services as a cost effective technology to provide wireless services. These Providers typically deploy Wi-Fi services using a wireless router and an Ethernet Access Switch or Network Interface Device (NID). The Ethernet Access Switch or NID provides data transport to and from the telecommunication network. The wireless router provides the media conversion and protocol processing of the data received from the Ethernet Access Switch or NID. The Ethernet Access Switch or Network Interface Device will typically have one or more SFP ports. The SFP port will be populated with an SFP device, which the SFP device will connect to the wireless router with a cable, as illustrated in prior art Figure 1.

Communication equipment will typically use a secondary technology to provide information on device status, identity, and configuration to other devices. This secondary technology can also be used to provision or configure the device or communicate information to other remote devices or systems. This secondary technology is typically a wired technology and requires the use of a cable. The device will have a DB9 connector or RMS modular jack if RS232 is the communication protocol, as shown in prior art Figure 3A. The device can also use an RJ45 modular jack if Ethernet is the communication protocol, as shown in Figure 3B. The disadvantage of using wired technology for secondary communication is the added cost of the cable and the requirement to have a cable of proper length, wiring, and matching physical connectors. The cable also restricts the mobility of both the devices, where both devices must remain stationary to facilitate efficient communications.

Mobile devices such as smart phones, tablets, or wearable devices and Internet of Things
(IoT) devices cannot support large physical connectors such as a DB9 connector or an RJ45 modular jack. In addition, communications with mobile and wearable devices should not restrict the mobility of these devices.

[0017] SFP devices are very popular due to the low cost, standardization, and interoperability, SFP devices have endured many functional and mechanical changes. Since the initial development of the SFP in 2000, there have been many SFP improvements in functionality and mechanical form factor, such as XFP, X2, SFP, SFP+, QSFP, QSFP⁺, and CXP technologies. Presently, SFP support optical, wire, or coax services, such as Ethernet, SONET, Fiber Channel, 0S3, DSi, video, etc. SFPs supporting optical fiber service use an LC or SC connector. SFPs supporting wired Ethernet or DS1 services use an RJ45 modular connector, SFPs supporting wired DS3 or video services use a coax connector.

**Summary**

[0018] Generally, the SFP of the present disclosure comprises a small pluggable housing, a printed circuit board (PCB) located in the housing, and wireless circuitry. The small form factor pluggable unit, device or module of the present disclosure is provided with wireless capabilities, allowing for the provision of a versatile, cost-effective and improved reliability of wireless communication services in a standard SFP. The small size and industry standard small pluggable form factor provides the framework for device interoperability, lower part costs, manufacturing, and supply chain optimization. Other wireless products are larger, have propriety or less popular form factor.

[0019] The wireless SFP of the present invention functions as a wireless Access Point (AP). As a wireless AP (WAP), the present invention can be deployed as a cost-effective method to offload data traffic from cellular networks. The recent advances in Wi-Fi technology augment
fee deployment of the cellular networks using cost-efficient wireless access points in unlicensed Spectrum,

[0020] The wireless SFP of the present invention also functions as a wireless Repeater. As a wireless Repeater, the present invention can be deployed as a cost-effective method to establish or extend wireless services from a weak wireless signal.

[0021] The wireless SFP of the present invention provides performance monitoring and testing using applicable sections of IEEE 802.1ag, ITU Y.1731, ITU Y.1564, MEF30, MEB 6, ITU Y.J564 and other similar standards or specifications. The wireless SEP of the present disclosure is also provided with remote testing capabilities, allowing for the provision of testing of wireless services through remote testing. Existing wireless products are not designed to have remote loopback testing capabilities and provide remote performance monitoring capabilities. Typical wireless routers or wireless access points are designed to be tested locally, requiring a person to be at the wireless router. Testing typically involves the measuring the wireless signal strength or fee ability to poll or communicate to the wireless device. The wireless SEP of the present invention includes the ability to also perform intrusive loopback testing to verify the wireless service. These Remote testing and performance monitoring capabilities will allow the Service Providers to address the maintenance and troubleshooting of wireless services remotely, i.e., without local presence. The ability to provide performance monitoring and testing will increase fee reliability and quality of the service of the wireless SEP.

[0022] The wireless SFP of the present invention is also provided with additional wireless communication channels. The additional wireless communication channels are used to communicate data to other devices, such as mobile devices, internet of Things (IoT) devices, wearable devices, and other wireless SFP devices. Devices will communicate any of the
following data: identity, position, status, events, and control. The additional wireless communication channels can be Bluetooth, Zigbee, or any other wireless technology. Bluetooth is a wireless technology standard for exchanging data over short distances using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz. Bluetooth is typically used as a secondary wireless communication method of mobile devices. The use of a secondary wireless technology allows time and location of the wireless SFP of the present invention. The mobile or IoT device will communicate information using Bluetooth or Zigbee to the wireless SFP. The wireless SFP will be installed at the customer's building or premises at unpredictable locations. Wi-Fi and Bluetooth triangulation using the wireless technology incorporated into the wireless SFP of the present invention allows for the provision of location and tracking of the SFP, such that it is readily available or accessible during wireless service outage or maintenance.

[0023] The wireless SFP of the present disclosure is also provided with an internal antenna or with a port or connector for connecting an external antenna, to improve wireless service performance or SFP installation. The improvement in wireless service with an internal antenna is accomplished with positioning the SFP among the many communication equipment small pluggable receptacles. The improvement in wireless service with an external antenna is accomplished with the positioning of the external antenna for optimal wireless signal transmission and reception.

[0024] Accordingly, the SFP of the present disclosure provides a cost effective method of providing wireless communications, by providing wireless communications capabilities in an industry standard small pluggable form factor. The SFP of the present disclosure will improve wireless service by optimizing wireless performance through communications with other wireless devices. The SFP of the present disclosure further improves wireless service by
providing an internal antenna or allowing for the attachment of an external antenna.

[0025] The wireless SFP of the present disclosure will also facilitate indoor or outdoor positioning systems (iOPS). IOPS is a system to locate wireless devices inside a structure using information collected by mobile or IoT devices and triangulation. The present disclosure uses a secondary wireless technology to communicate information to other wireless mobile devices. The communication with other wireless SFP and wireless mobile devices will allow time, location, and tracking information to be shared with the IOPS system or other similar Wi-Fi positioning systems. Wi-Fi and Bluetooth triangulation for IOPS data can be achieved using three wireless SFFs in a facility.

[0026] The SFF of the present disclosure also provides capabilities for the performance monitoring and testing of the wireless communication device for improved wireless serviceability and diagnostics of the wireless communication device. Further, the SFP of the present disclosure improves wireless service maintenance by providing a secondary wireless channel, allowing the SFF to be serviced quickly and easily.

[0027] Accordingly, it is an object of the present disclosure to provide a small, low cost, and simple method and device to provide and service wireless communications into an industry standard small pluggable factor.

[0028] It is another objective of the present disclosure to provide a SFF method and device which can be geographically located.

[0029] It is still another objective of the present disclosure to provide a SFP method and device which can communicate to other wireless devices.

[0030] It is still another objective of the present disclosure to provide a SFF method and device which can provide wireless performance for remote access.
[00003311] It is still ill an object of the present disclosure.

[00003322] It is still ill an object of the present disclosure.

[00003333] An additional object is to provide telecommunication service by way of example only, not by way of limitation. In the drawing figures, like reference numerals refer to the same or similar elements.

[00003344] Figures 1 is schematic diagram of a prior art telecommunication system for providing wireless service.

[00003355] Figures 2 is a schematic diagram of a telecommunication system for providing wireless service via the wireless SFP of the present disclosure.

[00003366] Figures 3A is a schematic diagram of a prior art telecommunication system using cables.

15 **Brief Description of the Drawings**
and connectors to communicate with equipment.

[0040] Figure 3B is a schematic diagram of a prior art telecommunication system using alternate cables and connectors to communicate with equipment.

[0041] Figure 4 is a schematic diagram of the telecommunication system of Figure 2, illustrating the use of a secondary wireless technology to communicate with equipment.

[0042] Figure 5A is a top front perspective view of the wireless SFP of the present disclosure with an integrated antenna with the housing partially removed to illustrate internal components and internal PCB antenna.

[0043] Figure 5B is a top front perspective view of the wireless SFP of Figure 5 with its housing.

[0044] Figure 5C is a bottom back perspective view of the wireless SFP of Figure 5 with its housing.

[0045] Figure 6 is a perspective view of the wireless SFP of the present disclosure with a coaxial connector to attach an external antenna with a coaxial connector.

[0046] Figure 7 is a perspective view of an external antenna with a coaxial connector and a coax cable attachment for use with the wireless SFP of Figure 6.

[0047] Figure 8 is a perspective view of the wireless SFP of the present disclosure with a USB connector to attach an external antenna with a USB connector.

[0048] Figure 9 is a perspective view of an external antenna with a USB connector for use with the wireless SFP of Figure 8.

[0049] Figure 10 is a schematic diagram of the printed circuit board of the wireless SFP of Figure 5A, and illustrating the wireless SFP circuitry of the present disclosure.

[0050] Figure 11 is a schematic diagram of the printed circuit board of the wireless SFP of Figure 6, and illustrating the wireless SFP circuitry.
Detailed Description

[0056] The following description refers to numerous specific details which are set forth by way of examples to provide a thorough understanding of the relevant method(s), system(s) and device(s) disclosed herein. It should be apparent to those skilled in the art that the present disclosure may be practiced without such details. In other instances, well known methods, procedures, components, hardware and/or circuitry have been described at a relatively high-level, without detail, in order to avoid unnecessarily obscuring aspects of the present disclosure. While the description refers by way of example to wireless SFF devices and methods and systems, it should be understood that the method(s), system(s) and device(s) described herein may be used in any situation where wireless-technology services are needed or desired.

[0057] As illustrated in Figure 2, the wireless SFP device of the present disclosure replaces the Wi-Fi router, the SFP device in the N10, and the associated cabling and mounting hardware depicted in prior art Figure 1. Due to the wireless SFP device conformance to applicable SFF specifications, the wireless SFP device can be installed and deployed by any equipment which
supports SFP devices. In doing so, this allows any SFP supported equipment the added ability to provide wireless service. Further, the wireless SFP device of the present disclosure also simplifies the deployment and installation of wireless service by simply inserting the wireless SFP device into any equipment which supports SFP devices.

[0058] Unlike the wired systems of prior art Figure 3, a method and system of the present disclosure employs the use of a secondary wireless technology to communicate with equipment, as illustrated in Figure 4. Accordingly, the wireless SFP of the present disclosure uses wireless as additional technologies to communicate with devices. This additional wireless technology will be different than the Wi-Fi wireless technology, which Wi-Fi used as the primary data transport for the network. There may be two or more wireless technologies used to communicate with other mobile and wearable devices,

[0059] Wi-Fi, Bluetooth, and Zigbee wireless technologies represent wireless technologies which one, two, or all these technologies will coexist. Bluetooth is a wireless technology standard for exchanging data over short distances using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz. Bluetooth is typically used as a secondary wireless communication method of mobile devices. The Wi-Fi and Bluetooth technologies incorporated into the wireless SFP of the present invention allows for the provision of location and tracking of the wireless SFP, such that it is readily available or accessible during wireless service outage or maintenance. The Wi-Fi and Bluetooth will also provide the infrastructure to manage and track mobile and wearable devices through indoor positioning systems.

[0060] The additional wireless technology may use a single antenna for coexistence of all wireless technologies, as shown in Figure 4. The method and systems of the present disclosure will support multiple antennas to enhance the performance of the wireless technologies.
Figures SA-9 illustrate a number of embodiments of the wireless SFP and associated antenna. The wireless SFP can support multiple wireless services, such as Wi-Fi, Bluetooth, Zigbee, and others. The associated antenna can be integrated in the wireless SFP device, or can be connected via a suitable connector.

For example, the antenna may be etched on a printed circuit board (PCB) internal of the SFP. Figures 5A-SC illustrate such an integrated, internal PCB antenna. In this embodiment, a connector for an external antenna is not needed and thus is eliminated.

In another embodiment, the wireless SFP includes a coax connector to support an external antenna. Figure 6 illustrates the wireless SFP with such a coax connector. Figure 7 illustrates an external antenna having a coaxial connector. The external antenna can be connected to the coax connector on the wireless SFP via a coax cable attachment as depleted therein.

In an alternate embodiment, the wireless SFP includes a USB connector to support an external antenna. Figure 8 illustrates the wireless SFP with such a USB connector. Figure 9 illustrates an external antenna having a USB connector. The external antenna can be connected to the USB connector on the wireless SFP by plugging the complementary USB connector on the external antenna into the USB connector on the wireless SFP.

Figure 10 is a schematic diagram of the printed circuit board of the wireless SFP with internal antenna, and illustrating the wireless SFP circuitry. As can be seen, the wireless SFP circuitry includes (1) a wireless system on chip (SoC), (2) power supply circuitry, (3) one or more LEDs, (4) a microprocessor, (5) memory, and (6) a field programmable gate array (FPGA). The PCB also includes clock and timing circuitry. Antenna circuitry and an etched antenna. A back interface connector of the wireless SFP unit is also schematically illustrated, for connection...
to internal components of the network system when plugged into the chassis.

[0066] Figure 11 is a schematic diagram of the printed circuit board of the wireless SFP with external coax antenna, and illustrating the wireless SFP circuitry. As can be seen, the wireless SFP circuitry includes (1) a wireless system on a chip (SoC), (2) power supply circuitry, (3) light emitting diode (LED), (4) microprocessor, (5) memory, and (6) a field programmable gate array (FPGA). The PCB also includes clock and timing circuitry. Antenna circuitry and external coaxial connector for connection with an external antenna. A back interface connector of the wireless SFP unit is also schematically illustrated, for connection to internal components of the network system when plugged into the chassis.

[0067] Figure 12 is a schematic diagram of the printed circuit board of the wireless SFP with external USB antenna, and illustrating the wireless SFP circuitry. As can be seen, the wireless SFP circuitry includes a (1) wireless system on a chip (SoC), (2) power supply circuitry, (3) light emitting diode (LED), (4) microprocessor, (5) memory, and (6) a field programmable gate array (FPGA). The PCB also includes clock and timing circuitry. Antenna circuitry and external USB type connector for connection with an external antenna. A back interface connector of the wireless SFP unit is also schematically illustrated, for connection to internal components of the network system when plugged into the chassis.

[0068] These components of the wireless SFP are described in more detail as follows:

[0069] (1) SoC Description

[0070] The wireless SFP utilizes a wireless SoC, which is a highly integrated circuit incorporating a (la) processor, (lb) wireless sub-system, (lc) Bluetooth sub-system, (ld) host interface, and (le) peripheral modules. The wireless SoC also includes a memory and a -switch. Figure 13 is a schematic diagram of the wireless system on a chip (SoC).
[0071] (la) SoC Processor

[0072] The wireless: SoC processor is a 32-bit ARM Cortex type processor which offers high CPU performance and is optimized for low interrupt latency, low power consumption, in a very small size. The processor provides protocol processing for the Wireless and Bluetooth subsystems. The processor also provides other general status and maintenance tasks.

[0073] (lb) SoC Wireless Sub-System

[0074] The SoC wireless sub-system includes an 802.11 a/b/g/n/ac radio, physical layer interface (PHY), and media access controller (MAC). The radio is a dual-band WLAN RF transceiver that has been optimized for use in 2.4 GHz and 5GHz. The radio provides communications for applications operating in the globally available 2.4 GHz unlicensed ISM or 5 GHz U-NII bands. The wireless PHY provides signal processing, modulation and decoding of the received signal from wireless medium. The wireless MAC controls the access to the wireless PHY and mediates data collisions. The wireless MAC are comprised with transmit and receive controllers, transmit and receive FIFOs to buffer sending and receiving data, and circuitry to manage the RF system and the wireless PHY. The SoC wireless sub-system will interface to the antenna either through an antenna connector or without the antenna connector by means of an antenna etched on an extended PCS. The etch PCB antenna can achieve performance of 2dB with minimal increase in the wireless SFP size. The use of an external antenna can achieve performance of 5dB and the flexibility to position the external antenna by mean of a coaxial cable, as discussed above.

[0075] (lc) SoC Bluetooth Sub-System

[0076] The SoC Bluetooth sub-system also includes an integrated Bluetooth radio and baseband core. The Bluetooth radio and baseband core is optimized for use in 2.4 GHz to provide low-power, low-cost, robust communications for applications operating in the globally available 2.4

16
GHz unlicensed ISM band. It is fully compliant with the Bluetooth Radio Specification and EDR specification and meets or exceeds the requirements to provide the highest communication link quality. Bluetooth Baseband Core (BBC) implements all of the time critical functions required for high-performance Bluetooth operation. The BBC manages the buffering, segmentation, and routing of data for all connections. It also buffers data that passes through it, handles data flow control, schedules transactions, monitors Bluetooth slot usage, optimally segments and packages data into baseband packets, manages connection status indicators, and composes and decodes packets and events. To manage wireless medium sharing for optimal performance, an external coexistence interface (switch) is provided that enables signaling between the one or two external collocated wireless devices such as Bluetooth.

[0077] (Id) SoC Host interface

[0078] The SoC host interface supports SDK) circuitry for high speed data transfer from the wireless sub-system to the wireless SFP FPGA circuitry. The invention supports SDIO version 3.0, 4-bit modes (2.00 Mbps). The SoC host interface may also support an Ethernet RMII/GMII/RGMII/SGMII circuitry for 10/100/1000BASE-T and XAUI 10GBASE-T high speed data transfer,

[0079] (1e) SoC Peripheral Modules

[0080] The SoC peripheral modules support general purpose input and output control pins and serial communications to external devices.

[0081] (2) Power Supply Circuitry Description

[0082] The wireless SFP power supply circuitry is comprised of linear dropout and switching regulators to provide power to the wireless SoC, FPGA, processor, memory, and clock timing blocks. A power supervisor circuitry ensure proper power-up sequencing for hot-insertions and
power brownout conditions,

[0083] (3) LED Description

Figure 14 is a table describing the functionality of the wireless SFP using a light emitting diode (LED). The wireless SFP LED can communicate information on the wireless SFP. In this present disclosure, the wireless SFP has a single tricolor LED to communicate status information on the wireless SFP system and both wireless communication technology. The present disclosure will use Wi-Fi and Bluetooth as the first and second wireless technology, respectively. When LED is emitting a steady green color, the wireless SFP is normal, Wi-Fi is linked and Bluetooth is idle. When the LED is only emitting a blinking green color, the Wi-Fi is communicating with other wireless devices while the Bluetooth communication is idle. When the LED is emitting only a steady blue color, the Bluetooth is linked while the Wi-Fi is idle. When the LED is emitting only a blinking blue color, the Bluetooth is communicating with other wireless devices while the Wi-Fi is idle. If the LED is blinking green and blue with a 1 second cadence, the Wi-Fi and Bluetooth are both linked and communicating with their respective wireless devices. When LED is emitting a steady amber color, the wireless SFP is in test or maintenance mode, with wireless disabled. When LED is emitting a blinking amber color, the wireless SFP is in provisioning or upgrade mode. When LED is not emitting any color, there is no power or the wireless SFP is not operational. It is foreseen that the LED(s) will be able to communicate data and information using very high frequency pulses such as Li-Fi technology.

[0085] (4) Microprocessor Description

The microprocessor is an ARM Cortex processor system with the responsibility of
managing and assisting the wireless SoC, the LED, and the FPGA. Additional responsibility of
the microprocessor is to communicate to the host interface the SFP digital diagnostics
monitoring per SFF-S472.

[0087] (5) Memory Description

[0088] The wireless SFP memory sub-system is comprised of ROM and RAM memory blocks.
The ROM and RAM memory blocks will provide data software program and data storage and
operation. The Flash ROM will also provide storage to mirror the software program. Mirroring
will allow the wireless SFP to have remote software upgrades and provisioning.

[0089] (6) FPGA Description

[0090] The wireless SFP FPGA provides the following sub-systems, an (6a) Ethernet MAC, an
(6b) Ethernet precision timing circuitry, an (6c) Ethernet QAM (operation, administration,
maintenance) circuitry, (6d) security circuitry, a (6e) host interface, and a (6f) processor. The
FPGA also includes a memory and serialize* and deserializer circuitry. Figure 15 is a schematic
diagram of the wireless SFP field programmable gate array (FPGA).

[0091] (6a) Ethernet MAC Description

[0092] The Ethernet MAC provides optional protocol processing of the data from the host
interface. The MAC sublayer provides addressing and channel access control mechanisms. The
Ethernet MAC functionality may be bypassed for customer applications, such as performing test,
maintenance, or network architecture applications. The Ethernet MAC controller can transmit
and receive data at 10/100/1000Mbps. It is foreseen that the Ethernet MAC could support 10G,
40G, and 100Gbps as well.

[0093] (6b) Ethernet Precision Timing Description

[0094] The Ethernet precision timing block provides IEEE 1588v2 and SyncE functions. IEEE
iS88v2 is a standard that defines a Precision Time Protocol (FTP) used in packet networking to precisely synchronize the real Time-of-Day (ToD) clocks and frequency sources in a distributed system to a master ToD clock, which is synchronized to a global clock source. The Ethernet precision time block provides IEEE1388 and SyneE functionality. IEEE1588 standard defines the Precision Time Protocol (PTP) that enables precise synchronization of clocks in a distributed network of devices. The PTP applies to systems communicating by local area networks supporting multicast messaging. This protocol enables heterogeneous systems that include clocks of varying inherent precision, resolution, and stability to synchronize. In both the transmit and receive directions 1588 packets are identified and timestamped with high precision.

Software makes use of these timestamps to determine the time offset between the system and its timing master. Software can then correct any time error by steering the device's 1588 clock subsystem appropriately. The device provides the necessary ToV to time-synchronize with a 1588 master elsewhere in the same system or to be the master to which slave components can synchronize.

[0095] (6c) Ethernet OAM Description

[0096] The Ethernet OAM provides link and sendee OAM functionality per MEF and ITU Y731. The Ethernet OAM supports the service activation test loopback of ITU Y7564 and RFC2544. Link OAM per IEEE 802.1ag. The Ethernet OAM support latching loopback per MEF46.

[0097] (6d) Ethernet Security Description

[0098] The Ethernet security impicraenis the DBS and Triple-DES (3DES) encryption standards, as described in NIST Federal Information Processing Standard (PIPS) publication 46-3, incorporated herein by reference. Each encryption type offers a compromise between service
application speed, FPGA logic area, and customer application. The Data Encryption Standard (DBS) is a 64-bit block cipher which uses a 56-bit key to encrypt or decrypt each block of data.

Given the short key length, DBS has been proven to be susceptible to brute force attacks and so is no longer considered secure for general use. Triple-DBS (3DES) strengthens the security by combining three BBS operations: an encrypt, a decrypt, and a final encrypt; each using a 56-bit key. This increases the effective key length, improving security. However, latterly 3DES has been superseded by the faster Advanced Encryption Standard (AES) algorithm, although it still finds use in security protocols such as IPsec and SSL/TLS for legacy purposes.

[0099] (6e) Host Interface Description

[00100] The host interface performs the data conversion from the wireless SoG sub-system to an SDK) or Ethernet media independent interface format.

[00101] (6f) Processor

[00102] The processor is a dual-core ARM Cortex processor system. The processor will assist in protocol processing, data management, and system administration for all junctional blocks within the FPGA. The process will assist the Ethernet MAC, the IEEE 1588, the Ethernet OAM, and the security functional blocks,

[00103] The following is a description of the data flow received (Receive Data Flow) in the wireless SFPs of Figures 10, 11 and 12.

[00104] Wireless signals are received by the wireless-SEP wireless SoC's Radio through the antenna connector by means of an external antenna or without the connector by means of the etch PCB antenna. The antenna will filter and convert the wireless signal to an electrical signal, which the electrical signal will be received by the wireless SoC radio. The radio's transmit and receive sections include all on-chip filtering, mixing, and gain control junctions. The wireless
signals will then be processed by the wireless PHY. The wireless PHY is designed to comply
with IEEE 802.11ac and IEEE 802.11a/b/g/n single-stream specifications to provide wireless
LAN connectivity supporting data rates from 1 Mops to 4333 Mbps for low-power, high-
performance applications. The PHY has been designed to work in the presence of interference,
radio nonlinearity, and various other impairments. It incorporates optimized implementations of
the filters, FFT and Viterbi decoder algorithms. The PHY carrier sense has been toned to
provide high throughput for IEEE802.11g/11b hybrid networks with Bluetooth coexistence-
Wireless signals from the PHY circuitry are then connected to a media access controller (MAC).
The wireless MAC is designed to support high-throughput operation with low-power
consumption. It does so without compromising the Bluetooth coexistence policies, thereby
enabling optimal performance over both networks. In addition, several power saving modes have
been implemented that allow the MAC to consume very little power while maintaining network-
wide timing synchronization. The data from the MAC will then interface with the wireless SoC
host interface, which will convert the data into an SDIO or Ethernet media independent format.

[00105] The wireless SoC data will then interface with the FPGA. The PPGA will either
convert the SDIO data format or connect directly to the FPGA Ethernet MAC. The Ethernet
MAC will provide protocol processing and update the data with IEEE 1588 or SyncE
information. If required, the updated data from the Ethernet MAC will be encrypted by the
security functional block. The data will be serialized and transmitted differentially at compatible
voltage levels per the appropriate SFF specification document to the wireless SFP PCB edge
connector.

[00106] The wireless data received from the Bluetooth will flow from the Bluetooth sub-system
to the wireless SoC and SFP processor. The wireless SoC processor will inspect and process the
data accordingly. The Bluetooth data may provide wireless mobile location, identity, status, etc, for the wireless SoC and SFP processor.

[00107] The following is a description of the data flow transmitted (Transmit Data Flow) in the wireless SFPs of Figures 10, 11 and 12.

[00108] The transmit data from the SFP PCB edge connector will interface with the FPGA. The FPGA will convert the serialized data format to the Ethernet MII format of the FPGA Ethernet MAC. The Ethernet MAC will provide protocol processing and update the data with IEEE 1588 or SyncE information. If required, the updated data from the Ethernet MAC will be encrypted by the security functional block. The transmit data from the FPGA will interface to the wireless SoC's host interface. The wireless SoC host interface will convert the transmit data to the SoC MAC for protocol processing. The transmit data will then interface to the SoC PHY and Radio. The SoC PHY and Radio will convert the transmit data RF signal to wireless using an external antenna attachment or the internal etched PCB antenna,

[00109] The Bluetooth wireless data will transmit from the wireless SFP and SoC processor to the wireless-SoC Bluetooth sub-system. The transmit data from the Bluetooth sub-system will be interleaved by the Wi-Fi coexistence switch to either a connector for the external antenna or directly onto an etched PCB antenna. The Bluetooth data will be transmitted to other wireless SFP and wireless mobile devices. The data will consist of location, identity, status of all wireless SFP devices or wireless mobile devices, or IoT.

[00110] Figure 16 illustrates an exemplary embodiment of a method and system of the present disclosure used for Wi-Fi triangulation and Bluetooth communications involving three wireless SFPs and mobile devices. As illustrated, the three wireless SFP devices are placed into ports in three different-network interface devices, each of which is connected to a network edge switch.
These three wireless SFPs selectively communicate via both wireless 1 and wireless 2 signals with various devices. The signals can be triangulated such that the location of a device with a transmitter can be determined by measuring either the radial distance, or the direction, of the received signal from two or three different points, and the geographic position of the device can be pinpointed.

[00111] While the embodiments disclosed herein are illustrative of the structure, function and operation of the exemplary method(s), system(s) and device(s), it should be understood that various modifications may be made thereto with departing from the teachings herein. Further, the components of the method(s), system(s) and device(s) disclosed herein can take any suitable form, including any suitable hardware, circuitry or other components capable of adequately performing their respective intended functions, as may be known in the art.

[00112] It should be understood that the individual components of the circuitry illustrated in Figures 10-13 and 15 could be any commercially available components, respectively. For example, the wireless SoC could be a Broadcom/Cypress BCM4339, a Marvell Avastar 88W8877, a Marvel! 88W8977, or any equivalent or similar SoC suitable to produce the device(s), system(s) and method(s) disclosed herein, and/or achieve the functionality of the device(s), system(s) and method(s) disclosed herein. The FPGA could be either a Microsemi SmartFusion2 SoC FPGA, an Intel/Altera Cyclone V FPGA, or any equivalent or similar FPGA suitable to produce the device(s), system(s) and method(s) disclosed herein, and/or achieve the functionality of the device(s), system(s) and method(s) disclosed herein.

[00113] While the foregoing discussion presents the teachings in an exemplary fashion - with respect to the disclosed method(s), system(s) and device(s) for providing wireless communication services, it will be apparent to those skilled in the art that the present disclosure
may apply to other method(s) and system(s) utilizing wireless technologies. Further, while the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that the method(s), system(s) and device(s) may be applied in numerous applications, only some of which have been described herein.
What is claimed is:

1. A small form-factor pluggable device comprising:
   
a printed circuit board having circuitry; and

   wherein the circuitry provides for the transmission and receipt of at least one type of
wireless signals via at least one wireless communication channel.

2. The device of Claim 1, wherein the circuitry includes antenna circuitry.

3. The device of Claim 2, further comprising an internal antenna.

4. The device of Claim 3, wherein the internal antenna is an etched antenna on the
  printed circuit board.

5. The device of Claim 2, further comprising an antenna connector.

6. The device of Claim 5, wherein the antenna connector is a Coax connector.

7. The device of Claim 5, wherein the antenna connector is a USB connector.

8. The device of Claim 1, wherein the circuitry includes a wireless system on chip
   iSoC).

9. The device of Claim 1, wherein the circuitry includes power supply circuitry.

10. The device of Claim 1, wherein the circuitry includes at least one status indicator.

11. The device of Claim 1, wherein the at least one status indicator is an LED.

12. The device of Claim 1, wherein the circuitry includes a microprocessor.

13. The device of Claim 1, wherein the circuitry includes a memory.

14. The device of Claim 1, wherein the circuitry includes a field programmable gate
array (FPGA).

15. The device of Claim 1, wherein the circuitry includes clock and timing circuitry.

16. The device of Claim 1, further comprising a back interface connector.
17. The device of Claim 8, wherein the wireless system on chip (SoC) comprises a processor, a wireless sub-system, a Bluetooth sub-system, a host interface, and peripheral modules.

18. The device of Claim 14, wherein the FPGA comprises an Ethernet MAC, an Ethernet precision timing circuitry, an Ethernet OAM circuitry* security circuitry, a host interface, and a processor.

19. A wireless telecommunication system comprising:

a network interlace device; and

a small form-factor pluggable having wireless circuitry and an associated antenna;

wherein the small form-factor pluggable device takes the place of and eliminates the need for a wireless router.

20. A method for wireless telecommunication, comprising the steps of:

providing wireless circuitry on a small form-factor pluggable device;

providing an antenna for the wireless circuitry; and.

plugging-the small form-factor pluggable device into a network interface -device.
FIGURE 1
(Prior Art)

FIGURE 2
FIGURE 3A
(Prior Art)

FIGURE 3B
(Prior Art)
Figure 4
Figure 6

Figure 7
FIGURE 13
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FIGURE 14
FIGURE 15
INTERNATIONAL SEARCH REPORT

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/57285

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04B 10/00, H01Q 9/04 (2016.01)


According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)


IPC(8) - H04B10/00, H01Q9/04 (2016.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched


IPC(8) - H04B10/00, H01Q9/04 (2016.01); USPC - 398/1 15

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Patbase; Google Web, Google Patent, Freepatentsonline

Search terms used: small form factor pluggable sfp router wireless antenna transceiver system chip tpga field programmable ethernet MAC timing clock processor back interface io oam status indicator led

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category* Citation of document, with indication, where appropriate, of the relevant passages Relevant to claim No.

X --- US 2010/0014868 A1 (MCGLYNN et al.) 21 January 2010 (21.01.2010), Fig 2C; para [0003], [0006]-[0069] 1, 12, 20


Y A US 2010/0225556 A1 (ROFOUGARAN et al.) 09 September 2010 (09.09.2010), Fig 1, para [0012], [0023], [0033], [0034], [0063] 8, 17


Y Y US 2008/0081614 A1 (LEE et al.) 03 April 2008 (03.04.2008), Fig 4; para [0011], [0032], [0033] 7

(*) Further documents are listed in the continuation of Box C.

| * | Special categories of cited documents: |
| "A" | document defining the general state of the art which is not considered to be of particular relevance |
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| "L" | document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) |
| "O" | document referring to an oral disclosure, use, exhibition or other means |
| "P" | document published prior to the international filing date but later than the priority date claimed |

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

X document member of the same patent family

Date of the actual completion of the international search 15 December 2016

Date of mailing of the international search report 17 JAN 2017

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Form PCT/ISA/210 (second sheet) (January 2015)