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COMPENSATING FOR POOR ANGULAR SPREAD OF MILLIMETER WAVES

Abstract

Embodiments of the present disclosure are directed to systems and methods for enhancing connections between user equipment (UE) and a base station. Particularly in order to mitigate the poor angular spread of higher frequency signaling, a second set of signals may be transmitted to a UE using a different polarization than a first set of signals. Depending on one or UE-specific parameters, the second set of signals may comprise a different data stream than a first set of signals to facilitate spatial multiplexing, or the second set of signals may comprise the same data stream as the first set of signals to facilitate spatial diversity.

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Background/Summary

SUMMARY

[0001] The present disclosure is directed to improving the utilization of millimeter wave and higher frequency signaling in a wireless communication network, substantially as shown and/or described in connection with at least one of the Figures, and as set forth more completely in the claims.

[0002] According to various aspects of the technology, additional sets of signals are communicated to a UE using radio frequency (RF) waves in the extremely high frequency (EHF) range and higher (collectively referred to herein as “EHF+”) based on a determination that the UE has a threshold low data rank or that there exists certain threshold channel or cell conditions. Because smaller antennas are most often to transmit signals having higher frequencies, the utilization of EHF+ results in a smaller angular spread than the utilization of traditional frequencies in the Very High Frequency (VHF) and Ultra High Frequency (UHF) ranges. Reduced angular spread means that fewer multi-paths are available to a UE, which is expected to reduce the ability of the UE to used advanced signal processing techniques such as spatial diversity and spatial multiplexing. By communicating additional sets of signals using different polarizations, the number of layers available to the UE will increase, allowing for an improved wireless communication between the UE and a base station.

[0003] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used in isolation as an aid in determining the scope of the claimed subject matter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Aspects of the present disclosure are described in detail herein with reference to the attached Figures, which are intended to be exemplary and non-limiting, wherein:

[0005] FIG. **1** illustrates a computing device for use with the present disclosure;

[0006] FIG. **2**. illustrates a network environment in which implementations of the present disclosure may be employed;

[0007] FIG. **3**. Illustrates an environment with a plurality of waveforms in which implementations of the present disclosure may be employed; and

[0008] FIG. **4** depicts a flow diagram of a method in accordance with embodiments described herein.

DETAILED DESCRIPTION

[0009] The subject matter of embodiments of the invention is described with specificity herein to meet statutory requirements. However, the description itself is not intended to limit the scope of this patent. Rather, the inventors have contemplated that the claimed subject matter might be embodied in other ways, to include different steps or combinations of steps similar to the ones described in this document, in conjunction with other present or future technologies. Moreover, although the terms “step” and/or “block” may be used herein to connote different elements of methods employed, the terms should not be interpreted as implying any particular order among or between various steps herein disclosed unless and except when the order of individual steps is explicitly described.

[0010] Various technical terms, acronyms, and shorthand notations are employed to describe, refer to, and/or aid the understanding of certain concepts pertaining to the present disclosure. Unless otherwise noted, said terms should be understood in the manner they would be used by one with ordinary skill in the telecommunication arts. An illustrative resource that defines these terms can be found in Newton's Telecom Dictionary, (e.g., 32d Edition, 2022). As used herein, the term “base station” refers to a centralized component or system of components that is configured to wirelessly communicate (receive and/or transmit signals) with a plurality of stations (i.e., wireless communication devices, also referred to herein as user equipment (UE(s))) in a particular geographic area. As used herein, the term “network access technology (NAT)” is synonymous with wireless communication protocol and is an umbrella term used to refer to the particular technological standard/protocol that governs the communication between a UE and a base station; examples of network access technologies include 3G, 4G, 5G, 6G, 802.11x, and the like. The term “mmWave” means RF waves having a wavelength measured in millimeters or fractions of millimeters (i.e., less than one cm), generally in the range of 30 GHz-3 THz, though frequencies above and below that range may still be used by aspects of the present disclosure.

[0011] Embodiments of the technology described herein may be embodied as, among other things, a method, system, or computer-program product. Accordingly, the embodiments may take the form of a hardware embodiment, or an embodiment combining software and hardware. An embodiment takes the form of a computer-program product that includes computer-useable instructions embodied on one or more computer-readable media that may cause one or more computer processing components to perform particular operations or functions.

[0012] Computer-readable media include both volatile and nonvolatile media, removable and nonremovable media, and contemplate media readable by a database, a switch, and various other network devices. Network switches, routers, and related components are conventional in nature, as are means of communicating with the same. By way of example, and not limitation, computer-readable media comprise computer-storage media and communications media.

[0013] Computer-storage media, or machine-readable media, include media implemented in any method or technology for storing information. Examples of stored information include computer-useable instructions, data structures, program modules, and other data representations. Computer-storage media include, but are not limited to RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile discs (DVD), holographic media or other optical disc storage, magnetic cassettes, magnetic tape, magnetic disk storage, and other magnetic storage devices. These memory components can store data momentarily, temporarily, or permanently.

[0014] Communications media typically store computer-useable instructions—including data structures and program modules—in a modulated data signal. The term “modulated data signal” refers to a propagated signal that has one or more of its characteristics set or changed to encode information in the signal. Communications media include any information-delivery media. By way of example but not limitation, communications media include wired media, such as a wired network or direct-wired connection, and wireless media such as acoustic, infrared, radio, microwave, spread-spectrum, and other wireless media technologies. Combinations of the above are included within the scope of computer-readable media.

[0015] By way of background, modern and future wireless telecommunication systems utilize ever higher frequencies in order to achieve ever greater transmission capacity. The use of higher frequencies, such as mm frequencies, has a few key consequences. First, signals with higher frequencies are more susceptible to fading, meaning they lose power more quickly. Whether because of free space path loss on direct a direct path between a base station and a UE or the loss due to reflection/refraction on indirect paths between the base station and the UE, an effective connection between the base station and the UE may exist under a smaller set of conditions-typically closer ranges and less obstructions. Second, higher frequency signals are often communicated with antennas that are physically smaller than lower frequencies; using smaller antennas results in less angular spread of signals than signals communicated from larger antennas. A key feature of wireless communication networks is the ability to use spatial diversity and/or spatial multiplexing to improve the connection between the base station and the UE, but less angular spread means fewer multi-paths; fewer multi-paths inherently limits the opportunities to perform spatial diversity of spatial multiplexing.

[0016] The use of mmWave connections in wireless communications is presently limited; however, conventional measures to address a poor connection between the base station and the UE involve handing over to cells with preferable connections. Modern UEs are configured to regularly perform measurements of available signals, so if the UE was connected using a mmWave frequency and the UE determined that a lower frequency signal would provide a better connection (e.g., due to the mmWave signals experiencing fading), the base station may instruct the UE to handover to a cell utilizing that lower frequency.

[0017] Unlike conventional solutions, the present disclosure is directed to utilizing additional sets of mmWave signals to improve the wireless connection between the base station and the UE based on a determination that one or more trigger conditions are met. If the UE is connected to the base station on a first mmWave connection, the first mmWave connection is utilizing signaling having a first polarization, and a trigger condition is met (e.g., a threshold low rank, a threshold poor connection, and/or a threshold high load at the cell), then the base station may communicate a second set of mmWave signals using a second polarization to the UE in order to create a second channel. Depending on the circumstances, the second channel can be used to improve the quality of the connection between the base station and the UE (e.g., by the use of spatial diversity), or to improve the capacity of the connection (e.g., by the use of spatial multiplexing.

[0018] Accordingly, a first aspect of the present disclosure is directed to a system for enhancing a wireless connection between a base station and a user equipment (UE). The system comprises a plurality of antenna elements configured to transmit one or more downlink signals from the base station to the UE, the plurality of antenna elements comprising a first set of antenna elements and a second set of antenna elements. The system further comprises one or more computer processing components configured to determine that one or more UE-specific parameters of a first connection between the base station and the UE satisfies one or more UE-specific thresholds, the first connection comprising a first set of signals transmitted from the first set of antenna elements and having a first polarization. The one or more computer processing components are further configured to that one or more radio environment parameters of a coverage area comprising the UE satisfies one or more radio environment thresholds. The one or more computer processing components are further configured to, based on said determinations, transmit a second set of signals to the UE using the second set of antenna elements, wherein the second set of signals has a second polarization, the first polarization being different than the second polarization.

[0019] A second aspect of the present disclosure is directed to a method for enhancing a wireless connection between a base station and a user equipment (UE). The method comprises determining that one or more UE-specific parameters of a first connection between a base station and the UE satisfies one or more UE-specific thresholds, the first connection comprising a first set of signals transmitted from a first set of antenna elements and having a first polarization. The method further comprises determining that one or more radio environment parameters of a coverage area comprising the UE satisfies one or more radio environment thresholds. The method further comprises, based on said determinations, transmitting a second set of signals from the base station to the UE using a second set of antenna elements, wherein the second set of signals has a second polarization, the first polarization being different than the second polarization.

[0020] Another aspect of the present disclosure is directed to a non-transitory computer readable media having instructions stored thereon that, when executed by one or more computer processing components, cause the one or more computer processing components to perform a method for enhancing a wireless connection between a base station and a user equipment (UE). The method comprises determining that one or more UE-specific parameters of a first connection between a base station and the UE satisfies one or more UE-specific thresholds, the first connection comprising a first set of signals transmitted from a first set of antenna elements and having a first polarization. The method further comprises determining that one or more radio environment parameters of a coverage area comprising the UE satisfies one or more radio environment thresholds. The method further comprises, based on said determinations, transmitting a second set of signals from the base station to the UE using a second set of antenna elements, wherein the second set of signals has a second polarization, the first polarization being different than the second polarization.

[0021] Referring to FIG. **1**, an exemplary computer environment is shown and designated generally as computing device **100** that is suitable for use in implementations of the present disclosure. Computing device **100** is but one example of a suitable computing environment and is not intended to suggest any limitation as to the scope of use or functionality of the invention. Neither should computing device **100** be interpreted as having any dependency or requirement relating to any one or combination of components illustrated. In aspects, the computing device **100** is generally defined by its capability to transmit one or more signals to an access point and receive one or more signals from the access point (or some other access point); the computing device **100** may be referred to herein as a user equipment, wireless communication device, or user device. The computing device **100** may take many forms; non-limiting examples of the computing device **100** include a fixed wireless access device, cell phone, tablet, internet of things (IoT) device, smart appliance, automotive or aircraft component, pager, personal electronic device, wearable electronic device, activity tracker, desktop computer, laptop, PC, and the like.

[0022] The implementations of the present disclosure may be described in the general context of computer code or machine-useable instructions, including computer-executable instructions such as program components, being executed by a computer or other machine, such as a personal data assistant or other handheld device. Generally, program components, including routines, programs, objects, components, data structures, and the like, refer to code that performs particular tasks or implements particular abstract data types. Implementations of the present disclosure may be practiced in a variety of system configurations, including handheld devices, consumer electronics, general-purpose computers, specialty computing devices, etc. Implementations of the present disclosure may also be practiced in distributed computing environments where tasks are performed by remote-processing devices that are linked through a communications network.

[0023] With continued reference to FIG. **1**, computing device **100** includes bus **102** that directly or indirectly couples the following devices: memory **104**, one or more processors **106**, one or more presentation components **108**, input/output (I/O) ports **110**, I/O components **112**, and power supply **114**. Bus **102** represents what may be one or more busses (such as an address bus, data bus, or combination thereof). Although the devices of FIG. **1** are shown with lines for the sake of clarity, in reality, delineating various components is not so clear, and metaphorically, the lines would more accurately be grey and fuzzy. For example, one may consider a presentation component such as a display device to be one of I/O components **112**. Also, processors, such as one or more processors **106**, have memory. The present disclosure hereof recognizes that such is the nature of the art, and reiterates that FIG. **1** is merely illustrative of an exemplary computing environment that can be used in connection with one or more implementations of the present disclosure. Distinction is not made between such categories as “workstation,” “server,” “laptop,” “handheld device,” etc., as all are contemplated within the scope of FIG. **1** and refer to “computer” or “computing device.”

[0024] Computing device **100** typically includes a variety of computer-readable media. Computer-readable media can be any available media that can be accessed by computing device **100** and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer-readable media may comprise computer storage media and communication media. Computer storage media includes both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. Computer storage media includes RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices. Computer storage media of the computing device **100** may be in the form of a dedicated solid state memory or flash memory, such as a subscriber information module (SIM). Computer storage media does not comprise a propagated data signal.

[0025] Communication media typically embodies computer-readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term “modulated data signal” means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of any of the above should also be included within the scope of computer-readable media.

[0026] Memory **104** includes computer-storage media in the form of volatile and/or nonvolatile memory. Memory **104** may be removable, nonremovable, or a combination thereof. Exemplary memory includes solid-state memory, hard drives, optical-disc drives, etc. Computing device **100** includes one or more processors **106** that read data from various entities such as bus **102**, memory **104** or I/O components **112**. One or more presentation components **108** presents data indications to a person or other device. Exemplary one or more presentation components **108** include a display device, speaker, printing component, vibrating component, etc. I/O ports **110** allow computing device **100** to be logically coupled to other devices including I/O components **112**, some of which may be built in computing device **100**. Illustrative I/O components **112** include a microphone, joystick, game pad, satellite dish, scanner, printer, wireless device, etc.

[0027] A first radio **120** and second radio **130** represent radios that facilitate communication with one or more wireless networks using one or more wireless links. In aspects, the first radio **120** utilizes a first transmitter **122** to communicate with a wireless network on a first wireless link and the second radio **130** utilizes the second transmitter **132** to communicate on a second wireless link. Though two radios are shown, it is expressly conceived that a computing device with a single radio (i.e., the first radio **120** or the second radio **130**) could facilitate communication over one or more wireless links with one or more wireless networks via both the first transmitter **122** and the second transmitter **132**. Illustrative wireless telecommunications technologies include CDMA, GPRS, TDMA, GSM, and the like. One or both of the first radio **120** and the second radio **130** may carry wireless communication functions or operations using any number of desirable wireless communication protocols, including 802.11 (Wi-Fi), WiMAX, LTE, 3G, 4G, LTE, 5G, NR, VOLTE, or other VoIP communications. In aspects, the first radio **120** and the second radio **130** may be configured to communicate using the same protocol but in other aspects they may be configured to communicate using different protocols. In some embodiments, including those that both radios or both wireless links are configured for communicating using the same protocol, the first radio **120** and the second radio **130** may be configured to communicate on distinct frequencies or frequency bands (e.g., as part of a carrier aggregation scheme). As can be appreciated, in various embodiments, each of the first radio **120** and the second radio **130** can be configured to support multiple technologies and/or multiple frequencies; for example, the first radio **120** may be configured to communicate with a base station according to a cellular communication protocol (e.g., 4G, 5G, 6G, or the like), and the second radio **130** may configured to communicate with one or more other computing devices according to a local area communication protocol (e.g., IEEE 802.11 series, Bluetooth, NFC, z-wave, or the like).

[0028] Turning now to FIG. **2**, an exemplary network environment is illustrated in which implementations of the present disclosure may be employed. Such a network environment is illustrated and designated generally as network environment **200**. At a high level the network environment **200** comprises one or more UEs, one or more base stations, and one or more networks. Though each of a first UE **204** and a second UE **206** are illustrated as cellular phones, a UE suitable for implementations with the present disclosure may be any computing device having any one or more aspects described with respect to FIG. **1**. Similarly, though a base station **202** is illustrated as a macro cell on a cell tower, any scale or form of access point acting as a transceiver station for wirelessly communicating with a UE, including small cells, pico cells, and the like, are suitable for use with the present disclosure.

[0029] The network environment **200** comprises one or more base station with which a UE may wirelessly communicate. The base station **202** comprises hardware and software components that allow it to wirelessly communicate with one or more UEs in one or more coverage areas. Each coverage area may be logically defined in space and frequency as one or more cells, which may or may not overlap. An example of such a cell is cell **210**, in which the base station **202** is configured to wirelessly communicate with the first UE **204** using a first wireless connection **212** and the second UE **206** using a second wireless connection **214**. Using any radio access technology selected by a mobile network operator (e.g., 4G, 5G, 6G, and the like), the base station may transmit and receive wireless signals using one or more antenna elements. In aspects for use with the present disclosure, the base station **202** may be configured to use each of a first set of antenna elements and a second set of antenna elements to carry out said wireless communication, wherein signals emitted from the first set of antenna elements have a first polarization and signals emitted from the second set of antenna elements have a second, different, polarization.

[0030] Each base station of the one or more base stations may be associated with one or more at least partially distinct networks, wherein each network is associated with one or more network identifiers. Each network may be a telecommunications network(s) (e.g., a packet data network or core network), data network, or portions thereof. A telecommunications network that at least partially comprises the network environment **200** may include additional devices or components (e.g., one or more base stations) not shown. Those devices or components may form network environments similar to what is shown in FIG. **2**, and may also perform methods in accordance with the present disclosure. Components such as terminals, links, and nodes (as well as other components) may provide connectivity in various implementations.

[0031] In order to make determinations regarding the use of additionally polarized signals, the network environment **200** may comprise a polarization optimization engine **220**. Though illustrated as a dedicated engine comprising three discrete modules, one skilled in the art will appreciate that different deployments of hardware and software may be utilized to effectuate the inventive concept of the present disclosure without departing therefrom. The polarization optimization engine **220** may be deployed at the base station **202**, a network edge (not illustrated), or within the network **208**. Accordingly, the polarization engine **220** may be said to comprise a monitor **222**, an analyzer **224**, and a controller **226**.

[0032] The monitor **222** is generally configured to make measure or obtain data points about a connection between a UE and the base station **202** and the radio environment in the cell **210** that may be used in order to determine if, and to what extent, additionally polarized signals should be communicated to the UE. The monitor **222** is also configured to communicate any one or more measurements or determinations to the analyzer **224**.

[0033] The monitor **222** is configured to monitor the connections between the base station **202** and UEs and UE-specific radio resource demand. In a first aspect, the base station **202** may determine that the second connection **214** with the second UE **206** is not optimized because one or more parameters of the signaling between the base station **202** and the second UE **206** are below a predetermined threshold; for example, because the UE **206** is relatively distant from the base station **202**, it may observe a threshold high amount of interference, a threshold low signal strength, and/or a threshold low signal quality. In another aspect, the base station **202** may determine a connection between the base station **202** and the first UE is not optimized because the first UE **204** is engaged in particularly heavy data usage; that is the monitor **222** may determine that the first UE **204** is requesting greater than a predetermined threshold amount of downlink radio resources. In such an aspect, the monitor **222** may be further configured to determine the one or more parameters of the first connection **212** with the first UE **204**. In yet other aspects, the monitor **222** may be configured to determine the number of data streams (i.e., channel matrix rank) between the cell **210** or the base station **202** is below a predetermined threshold (e.g., less than two data streams).

[0034] The monitor **222** is further configured to monitor one or more characteristics of the radio environment within the coverage area **210**. In addition to the monitor **222** being used to monitor UE-specific usage and UE-specific wireless connections, the monitor **222** may monitor the overall radio conditions in the cell **210**. The monitor **222** may determine a number of UEs connected to the base station **202** or the cell **210**. The monitor may, alternatively or additionally, determine a radio resource or spectrum utilization (e.g., a percentage of physical resource blocks that are cumulatively allocated to each UE connected to the cell **210** or the base station **202**). The monitor **222** may, alternatively or additionally, determine an interference level of the cell **210**, wherein the interference level may be the worst interference measurement (e.g., SINR) of any UE connected to the cell **210** or base station **202**, and/or wherein the interference level may be an average interference (e.g., SINR) of all UEs connected to the cell **210** or base station **202**. The monitor may, alternatively or additionally, determine an average or worst latency with one or more UEs connected to the cell **210** or base station **202**.

[0035] The analyzer **224** is generally configured to use one or more data points from the monitor **222** in order to determine if, and to what extent, additionally polarized signals should be communicated to the UE. In one aspect, additionally polarized signals may be communicated if the analyzer **224** determines that one or more UE-specific conditions have been met for the first UE **204** and each of a plurality of radio environment conditions have been met. For example, if the one or more UE-specific conditions comprise a UE observing a threshold high downlink signal strength, a threshold high signal quality, a threshold high SINR, and a data rank of less than two (i.e., less than two active data streams), and the plurality of radio environment conditions comprise a threshold high average SINR, a threshold low latency, a threshold low number of connected UEs, and a threshold low radio resource utilization, then the analyzer **224** may communicate to the controller **226** that a second set of downlink signals can be communicated to the first UE **204**. In another aspect, additionally polarized signals may be communicated if the analyzer **224** determines that one or more UE-specific conditions have been met for the second UE **206** and at least one radio environment condition of a plurality of radio environment conditions have been met. With reference to the preceding example, the analyzer **224** may communicate to the controller **226** that a second set of downlink signals can be communicated if one or more of the average SINR, latency, connected UE, and utilization threshold are met. In yet another aspect, additionally polarized signals may be communicated if the analyzer **224** determines that each of a plurality of UE-specific conditions have been met for the first UE **204** and at least one of a plurality of radio environment conditions have been met. In another aspect, additionally polarized signals may be communicated if the analyzer **224** determines that one or more UE-specific conditions have been met for the second UE **206** and that a radio environment score is greater than a threshold value, wherein the radio environment score comprises a sum of values (weighted or unweighted) associated with one or more radio environment conditions. If the analyzer **224** determines that the UE-specific conditions for a particular UE or the radio environment conditions are not met, then the analyzer **224** will communicate an indication to the controller **226** that additionally polarized signals should not be communicated to the particular UE.

[0036] The controller **226** is generally configured to receive one or more indications from the analyzer **224**, determine how additionally polarized signals should be communicated, and communicate instructions to the base station **202**. Accordingly, the controller **226** may determine polarization and data stream configurations if an additionally polarized set of signals should be communicated. If the controller **226** receives an indication that additionally polarized signals should be communicated to the first UE **204**, then the controller **226** may determine a polarization used by a first set of antennas of the base station **202** to communicate a first set of downlink signals to the first UE **204**. The controller **226** may then select a second set of antennas of the base station

202 that can communicate a second set of signals to the first UE **204** using a second polarization, wherein the second polarization is different than the first polarization. For example, the controller **226** may determine that, prior to optimization, the base station was using the first set of antennas to communicate a vertically polarized set of first signals to the first UE **204**; accordingly, the controller **226** may select the select second set of antennas on the basis that the second set of antennas can communicate the second set of signals using a non-vertical polarization (e.g., slant polarization, horizontal polarization, circular polarization, elliptical polarization, and the like).
[0037] Turning now to FIG. **3**, a network environment **300** is provided that illustrates multiple, differently-polarized signals being communicated to a UE. The network environment comprises a base station **302** (such as the base station **202** of FIG. **2**), and a UE **306** (such as the first UE **204** or the second UE **206** of FIG. **2**). Based on the controller **226** of FIG. **2** determining that a first set of signals is transmitted from a first set of antenna elements of the base station **302** to the UE **306** using a vertically polarized signal **314**, and that a second set of signals should be transmitted to the UE **306**, then the controller **226** of FIG. **2** may instruct the base station **302** to transmit a second set of signals from a second set of antenna elements of the base station **302** to the UE **306** using a non-vertically polarized signal **312**. Though illustrated as being slant polarized, the non-vertically polarized signal **312** is characterized by its difference from the vertically polarized signal **314** and, therefore, may be horizontally polarized, circularly polarized, elliptically polarized, or the like.
[0038] Returning to FIG. **2**, the controller **226** is further configured to determine what type of data session should be created using the second set of signals discussed above, with respect to FIGS. **2-3**. The controller **226** may instruct the base station to communicate the same data using both the first set of signals (having a first polarization) and the second set of signals (having a second polarization), or the controller **226** may instruct the base station to communicate different data streams using the first and second set of signals. If, for example, the controller **226** receives an indication that the first UE **204** has satisfied one or more UE specific parameters indicating that the first connection **212** first UE **204** and the base station **202** is better than a predetermined threshold and that the first UE **204** is only being served by a single data stream, then the controller **226** may instruct the base station **202** to utilize the second set of downlink signals (with the second polarization) to communicate a second data stream-increasing the overall throughput by way of spatial multiplexing. Conversely, if the controller **226** receives an indication that the second UE **206** has satisfied a different set of UE-specific parameters, wherein the second connection **214** is worse than a predetermined threshold, then the controller **226** could instruct the base station **202** to communicate the same data in both the first set of signals (having the first polarization) and the second set of signals (having the second polarization)—increasing the overall quality of the second connection **214** by way of spatial diversity.
[0039] In addition to making polarization decisions, the controller **226** may also be configured to monitor the effect of polarization optimization actions. For example, the controller **226**, in concert with the monitor **222** and the analyzer **224**, may, a predetermined amount of time after implementation of the polarization optimization action (e.g., transmitting the second set of signals from the second set of antenna elements, wherein the second set of signals has a second, different polarization than a first set of signals transmitted by a first set of antenna elements), re-evaluate the one or more of the UE-specific parameters and the radio environment parameters in order to determine if the transmission of the additional signals has undesirably degraded the radio environment of the cell **210** (e.g., by worsening SINR to a below threshold value). Finally, the controller **226** may be configured to only implement one or more polarization optimization actions based on a determination that the base station **202** is configured to transmit signals using a mmWave frequency between 30 GHz and 300 GHz or in frequency range 2 (FR2) in the range of 24 GHz and 53 GHz.
[0040] Turning now to FIG. **4**, a flow chart representing a method **400** is provided. Generally the method **400** may be used by a base station, such as the base station **202** of FIG. **2**, to improve the

quality of a connection with a user equipment (UE). At a first step **410**, it is determined that one or more UE-specific parameters satisfy a UE-specific threshold, according to any one or more aspects discussed with respect to FIGS. **2-3**. At a second step **420**, it is determined that one or more radio environment parameters satisfy a radio environment threshold, according to any one or more aspects discussed with respect to FIGS. **2-3**. At a third step **430**, a second set of downlink signals are communicated to a UE based on the UE-specific and radio environment thresholds being satisfied, wherein the second set of signals are communicated to the UE in addition to a first set of downlink signals, the first set of downlink signals transmitted from a first set of antenna elements and having a first polarization and the second set of downlink signals being transmitted from a second set of antenna elements and having a second polarization, according to any one or more aspects discussed with respect to FIGS. **2-3**.

[0041] Many different arrangements of the various components depicted, as well as components not shown, are possible without departing from the scope of the claims below. Embodiments in this disclosure are described with the intent to be illustrative rather than restrictive. Alternative embodiments will become apparent to readers of this disclosure after and because of reading it. Alternative means of implementing the aforementioned can be completed without departing from the scope of the claims below. Certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations and are contemplated within the scope of the claims.

[0042] In the preceding detailed description, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown, by way of illustration, embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. Therefore, the preceding detailed description is not to be taken in the limiting sense, and the scope of embodiments is defined by the appended claims and their equivalents.

Claims

1. A system for enhancing a wireless connection between a base station and a user equipment (UE), the system comprising: a plurality of antenna elements configured to transmit one or more downlink signals from the base station to the UE, the plurality of antenna elements comprising a first set of antenna elements and a second set of antenna elements; and one or more computer processing components configured to perform operations comprising: determining that one or more UE-specific parameters of a first connection between the base station and the UE satisfies one or more UE-specific thresholds, the first connection comprising a first set of signals transmitted from the first set of antenna elements and having a first polarization; determining that one or more radio environment parameters of a coverage area comprising the UE satisfies one or more radio environment thresholds; and based on said determinations, transmitting a second set of signals to the UE using the second set of antenna elements, wherein the second set of signals has a second polarization, the first polarization being different than the second polarization.

2. The system of claim 1, wherein each of the first set of signals and the second set of signals have a frequency greater than 24 GHz.

3. The system of claim 2, wherein the first polarization is vertical and the second polarization is selected from a group consisting of slant, horizontal, circular, and elliptical.

4. The system of claim 3, wherein the radio environment parameters comprise an interference level, a latency value, a number of connected UEs, and a utilization value.

5. The system of claim 4, wherein the one or more radio environment parameters comprises the interference level, the number of connected UEs, and the utilization value, and wherein satisfying the one or more radio environment thresholds comprises the interference level being an average

interference level for all UEs in the coverage area and less than a first threshold, the number of connected UEs being less than a second threshold, and the utilization value being a physical resource block utilization value being less than a third threshold.
6. The system of claim 4, wherein the one or more UE-specific parameters are worse than a predetermined threshold, the one or more parameters comprising an interference value, a signal strength value, or a signal quality value.
7. The system of claim 6, wherein the one or more UE-specific parameters comprise an interference value, a signal strength value, and a signal quality value, and wherein the interference value is a signal to noise ratio (SINR) less than a first threshold, the signal strength value is a reference signal receive power (RSRP) less than a second threshold, and the signal quality is a reference signal receive quality (RSRQ) less than a third threshold.
8. The system of claim 6, wherein each of the first set of signals and the second set of signals communicate a same data stream to the UE.
9. The system of claim 4, wherein the one or more UE-specific parameters comprises a UE MIMO rank and wherein satisfying the one or more UE-specific thresholds comprises the UE MIMO rank being less than two.
10. The system of claim 9, wherein the one or more UE-specific parameters comprise a signal to interference noise ratio (SINR), a reference signal receive power (RSRP), or a reference signal receive quality (RSRQ), and wherein satisfying the one or more UE-specific thresholds comprises the one or more UE-specific parameters exceeding the one or more UE-specific thresholds.
11. The system of claim 9, wherein the one or more UE-specific parameters comprise the signal to interference noise ratio (SINR), the reference signal receive power (RSRP), and the reference signal receive quality (RSRQ), and wherein satisfying the one or more UE-specific thresholds comprises the SINR exceeding a first threshold, the RSRP exceeding a second threshold, and the RSRQ exceeding a third threshold.
12. The system of claim 10, wherein the first set of signals comprises a first data stream and the second set of signals comprises a second data stream, the first data stream being different than the second data stream.
13. A method for enhancing a wireless connection between a base station and a user equipment (UE), the method comprising: determining that one or more UE-specific parameters of a first connection between a base station and the UE satisfies one or more UE-specific thresholds, the first connection comprising a first set of signals transmitted from a first set of antenna elements and having a first polarization; determining that one or more radio environment parameters of a coverage area comprising the UE satisfies one or more radio environment thresholds; and based on said determinations, transmitting a second set of signals from the base station to the UE using a second set of antenna elements, wherein the second set of signals has a second polarization, the first polarization being different than the second polarization.
14. The method of claim 13, wherein each of the first set of signals and the second set of signals have a frequency greater than 24 GHz, and wherein the first polarization is vertical and the second polarization is selected from a group consisting of slant, horizontal, circular, and elliptical.
15. The method of claim 14, wherein each of the first set of signals and the second set of signals communicate a same data stream to the UE.
16. The method of claim 14, wherein the first set of signals comprises a first data stream and the second set of signals comprises a second data stream, the first data stream being different than the second data stream.
17. A non-transitory computer readable media having instructions stored thereon that, when executed by one or more computer processing components, cause the one or more computer processing components to perform a method for enhancing a wireless connection between a base station and a user equipment (UE), the method comprising: determining that one or more UE-specific parameters of a first connection between a base station and the UE satisfies one or more

UE-specific thresholds, the first connection comprising a first set of signals transmitted from a first set of antenna elements and having a first polarization; determining that one or more radio environment parameters of a coverage area comprising the UE satisfies one or more radio environment thresholds; and based on said determinations, transmitting a second set of signals from the base station to the UE using a second set of antenna elements, wherein the second set of signals has a second polarization, the first polarization being different than the second polarization.

18. The non-transitory computer readable media of claim 17, wherein each of the first set of signals and the second set of signals have a frequency greater than 24 GHz, and wherein the first polarization is vertical and the second polarization is selected from a group consisting of slant, horizontal, circular, and elliptical.

19. The non-transitory computer readable media of claim 18, wherein each of the first set of signals and the second set of signals communicate a same data stream to the UE.

20. The non-transitory computer readable media of claim 19, wherein the first set of signals comprises a first data stream and the second set of signals comprises a second data stream, the first data stream being different than the second data stream.