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(54) **SYSTEM AND METHOD FOR MOBILE DATA EXPANSION AND PEDESTRIAN OBSTACLE DETECTION**

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(Continued)

(51) **Int. Cl.**

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H04W 16/26	(2009.01)
H02J 7/14	(2006.01)
H04W 88/08	(2009.01)
H04W 76/02	(2009.01)
G01S 13/92	(2006.01)

(Continued)

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CPC ***H04W 16/26*** (2013.01); ***G01S 1/68*** (2013.01); ***G01S 7/003*** (2013.01); ***G01S 13/92*** (2013.01); ***G01S 19/48*** (2013.01); ***G06K 9/18*** (2013.01); ***G06K 9/2063*** (2013.01); ***G06K 9/78*** (2013.01); ***H02J 7/14*** (2013.01); ***H02J 7/35*** (2013.01); ***H04B 1/3888*** (2013.01); ***H04B 1/40*** (2013.01); ***H04L 67/12*** (2013.01); ***H04W 4/025*** (2013.01); ***H04W 4/027*** (2013.01); ***H04W 4/028*** (2013.01); ***H04W 4/046*** (2013.01); ***H04W 36/14*** (2013.01); ***H04W 36/32*** (2013.01); ***H04W 40/02*** (2013.01); ***H04W 48/08*** (2013.01); ***H04W 76/02*** (2013.01); ***H04W 88/08*** (2013.01); *G01S 19/10* (2013.01); *G06K 2209/15* (2013.01); *H04W 84/12* (2013.01)

(58) **Field of Classification Search**

CPC H04B 7/15507; H04B 7/2606
USPC 455/73
See application file for complete search history.

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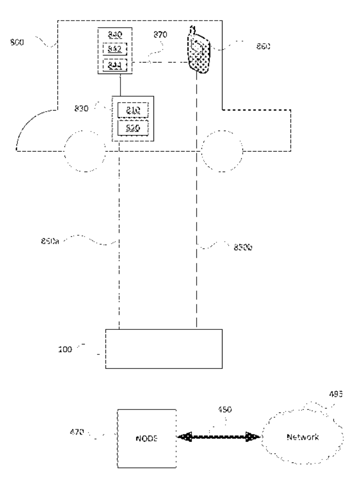
Primary Examiner — Ayodeji Ayotunde

(57) **ABSTRACT**

A data expansion system that provides continuum of discrete wireless small cell coverage areas for electronic devices in vehicles includes a set of traffic control devices configured to provide communicate information regarding the presence of an obstruction in a vehicle or pedestrian path. The system includes a first traffic control device configured to communicate with an electronic device in a first vehicle. The system also includes a second traffic control device communicatively coupled to the first traffic control device. The second traffic control device is configured to detect a presence of an object. The second traffic control device also is configured to communicate the presence of the object to at least one of: a network controller, the first traffic control device, or another traffic control device.

23 Claims, 17 Drawing Sheets



Related U.S. Application Data

of application No. 14/876,673, filed on Oct. 6, 2015, now Pat. No. 9,596,611, which is a continuation of application No. 13/840,578, filed on Mar. 15, 2013, now Pat. No. 9,219,991, which is a continuation-in-part of application No. 13/646,537, filed on Oct. 5, 2012, now Pat. No. 8,447,239.

(60) Provisional application No. 61/668,867, filed on Jul. 6, 2012.

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G06K 9/18	(2006.01)
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G01S 19/48	(2010.01)
H04W 36/32	(2009.01)
H04B 1/40	(2015.01)
H04B 1/3888	(2015.01)
G01S 19/10	(2010.01)
H04W 84/12	(2009.01)

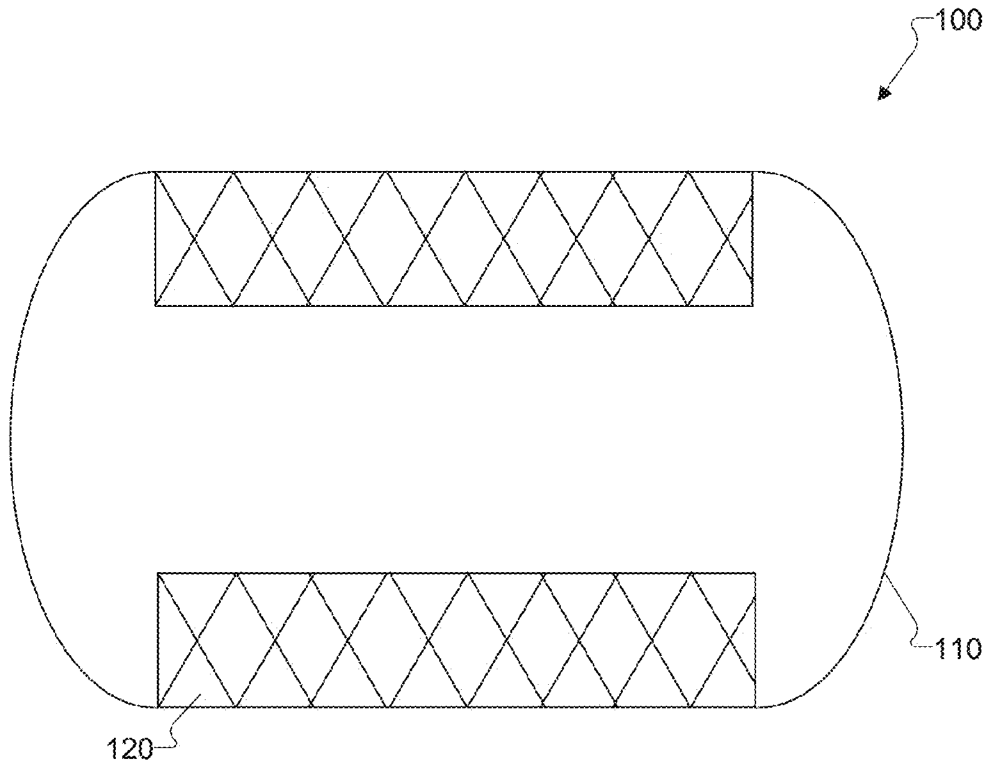


FIG. 1A

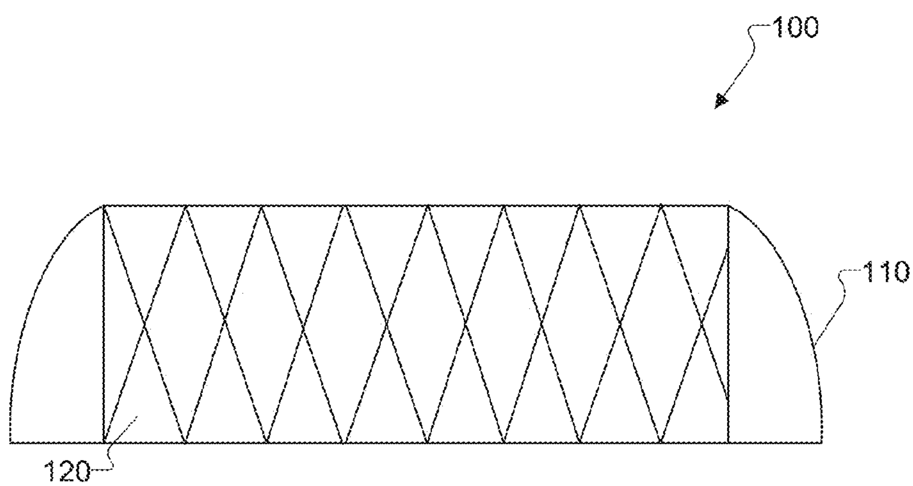


FIG. 1B

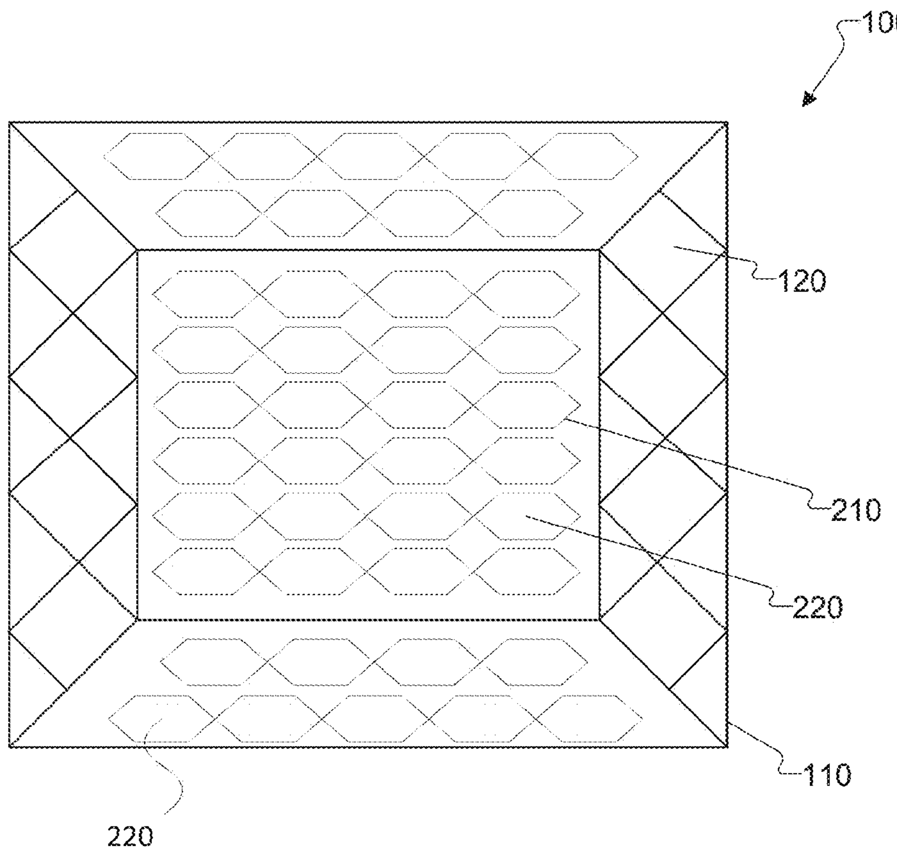


FIG. 2A

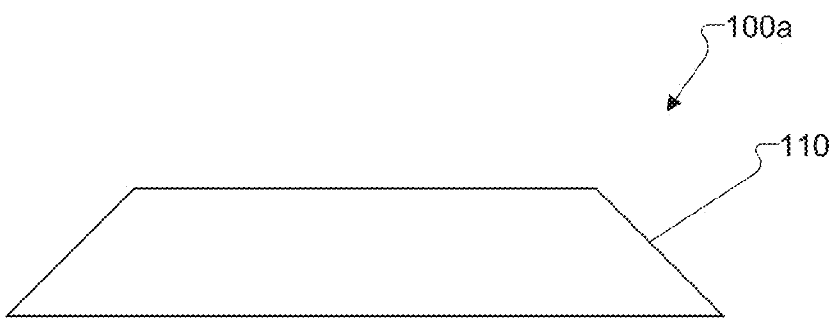


FIG. 2B

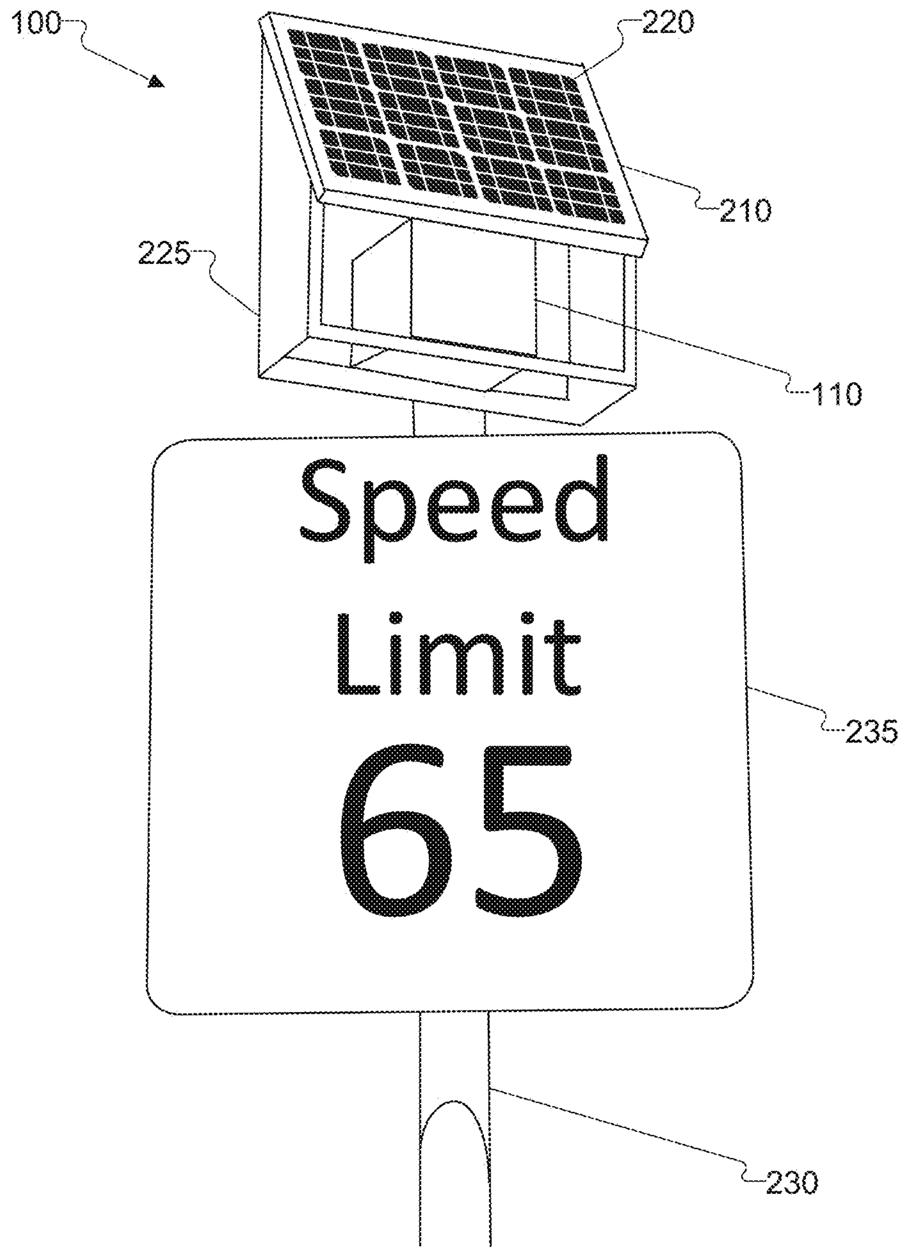


FIG. 2C

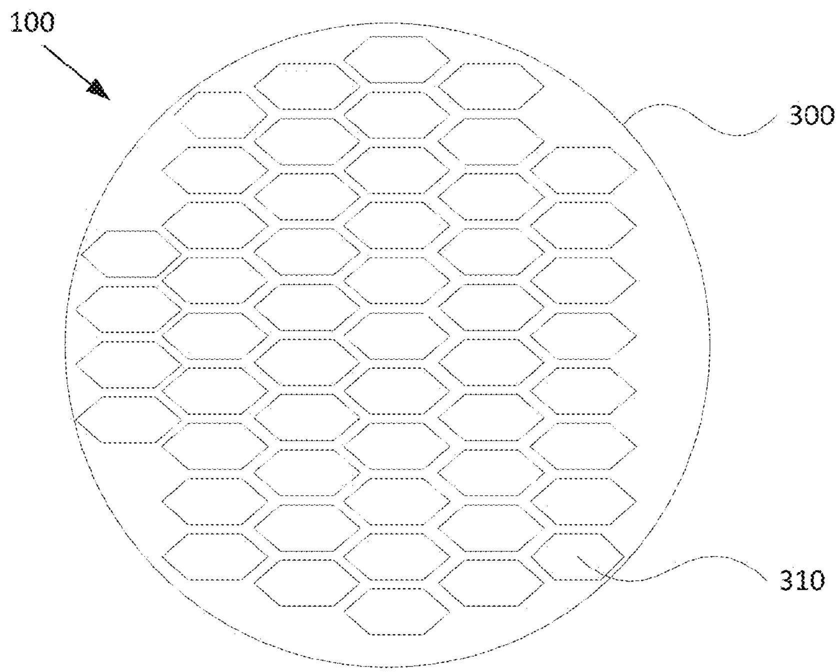


FIG. 3A

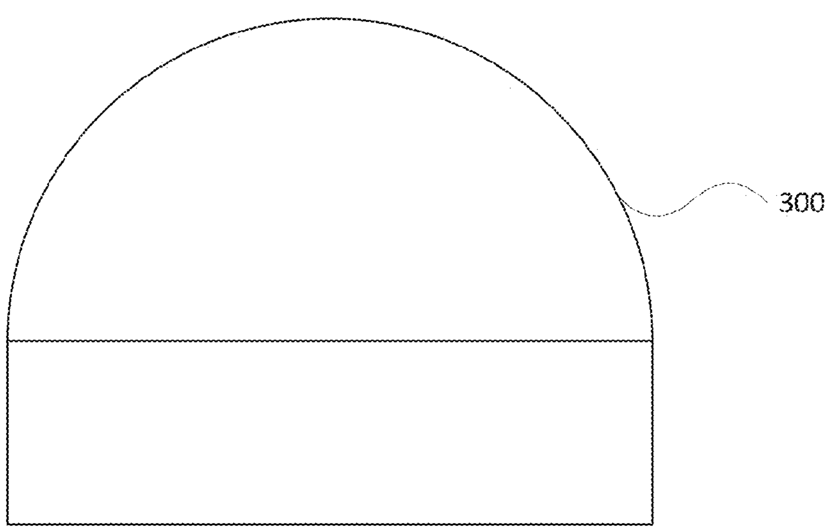


FIG. 3B

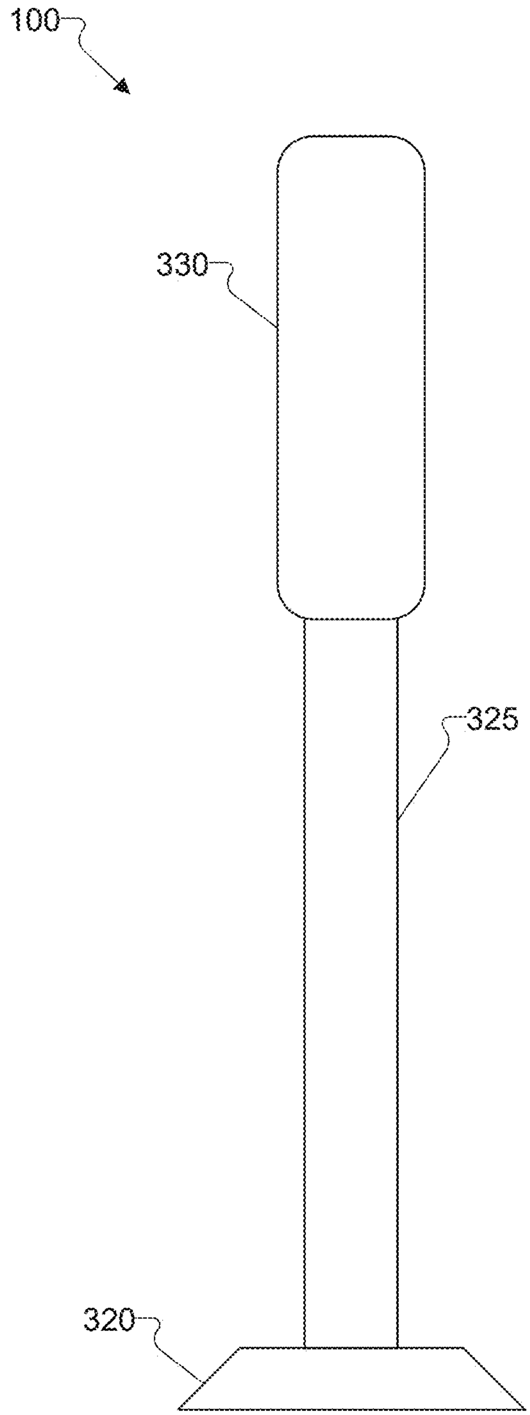


FIG. 3C

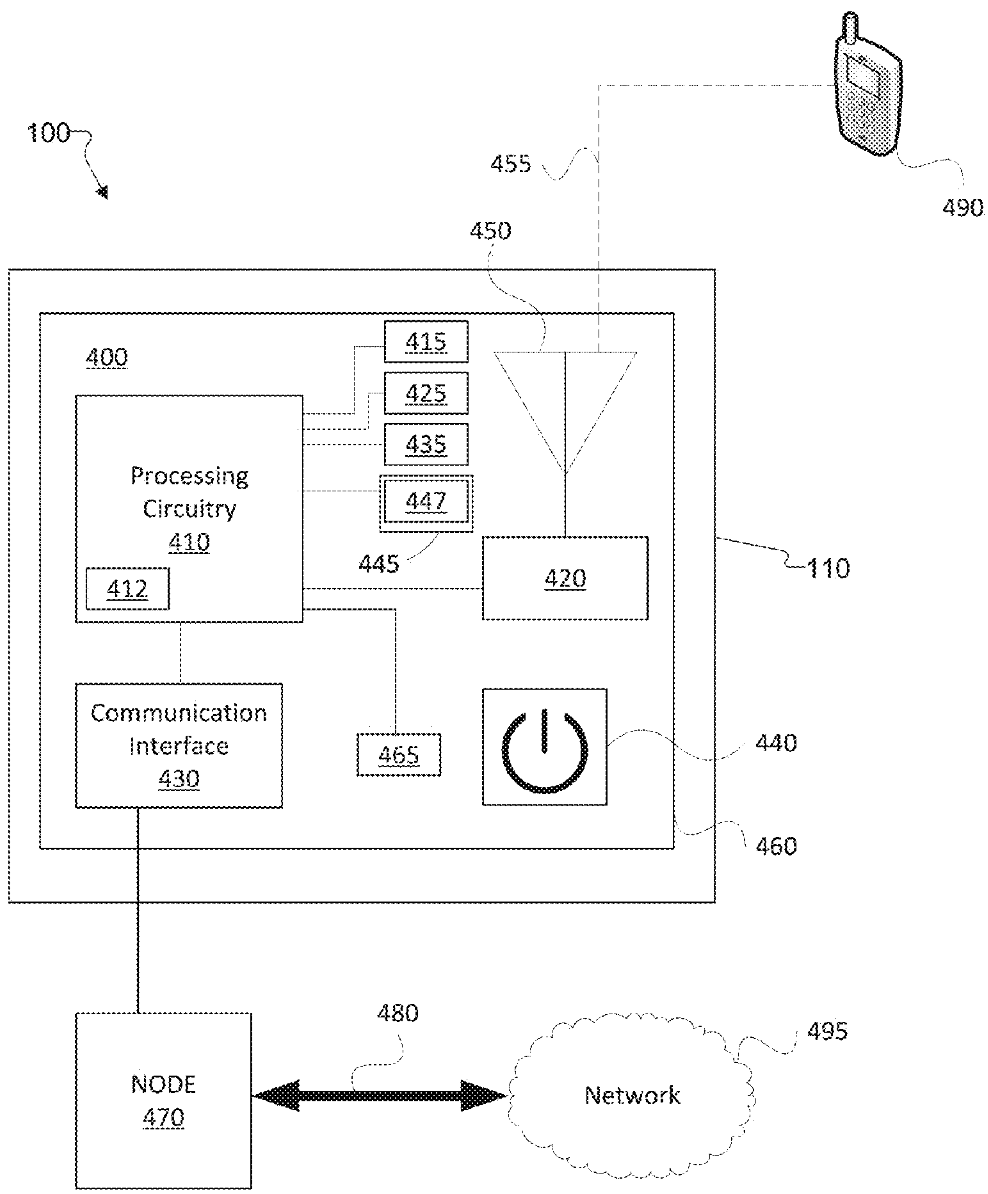
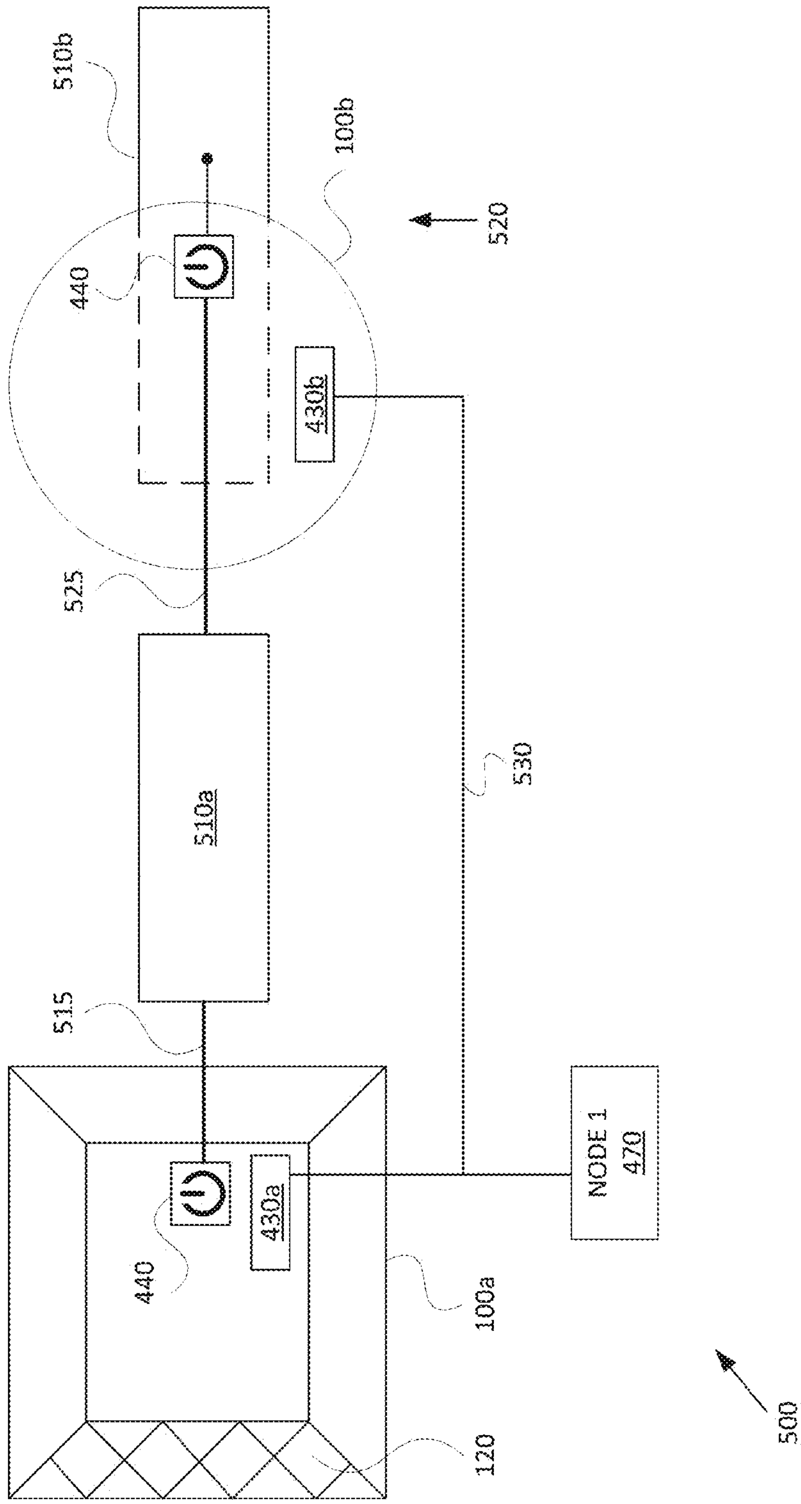

100
455
490
450
400
415
425
435
447
Processing
Circuitry
410
412
445
420
110
Communication
Interface
430
465
440
460
480
495
NODE
470
Network

FIG. 4



510b
100b
440
520
430b
525
510a
530
515
NODE 1
470
430a
440
100a
120
500

FIG. 5

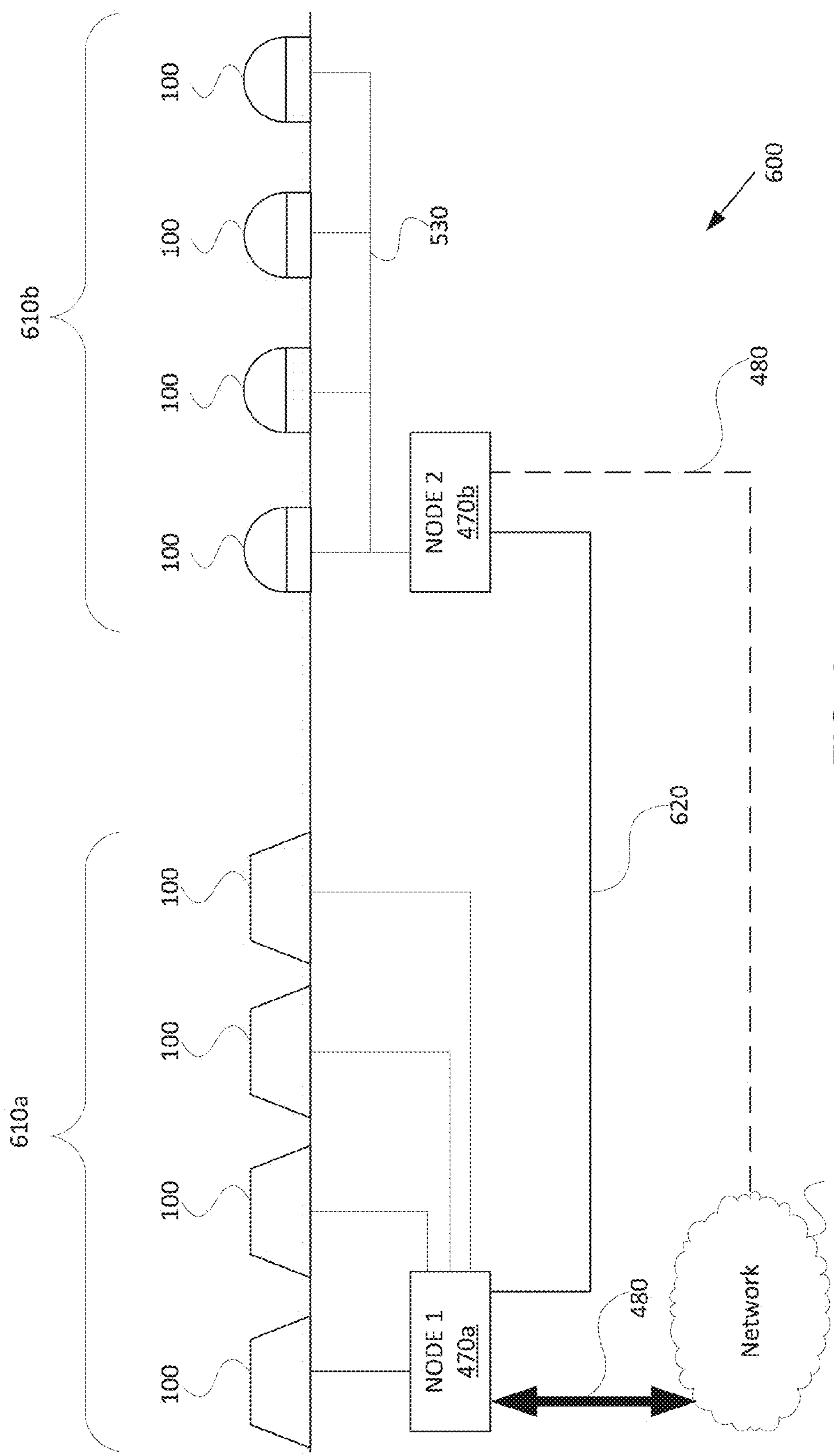

610b
100
100
100
100
530
600
480
NODE 2
470b
620
610a
100
100
100
100
NODE 1
470a
480
Network
495

FIG. 6

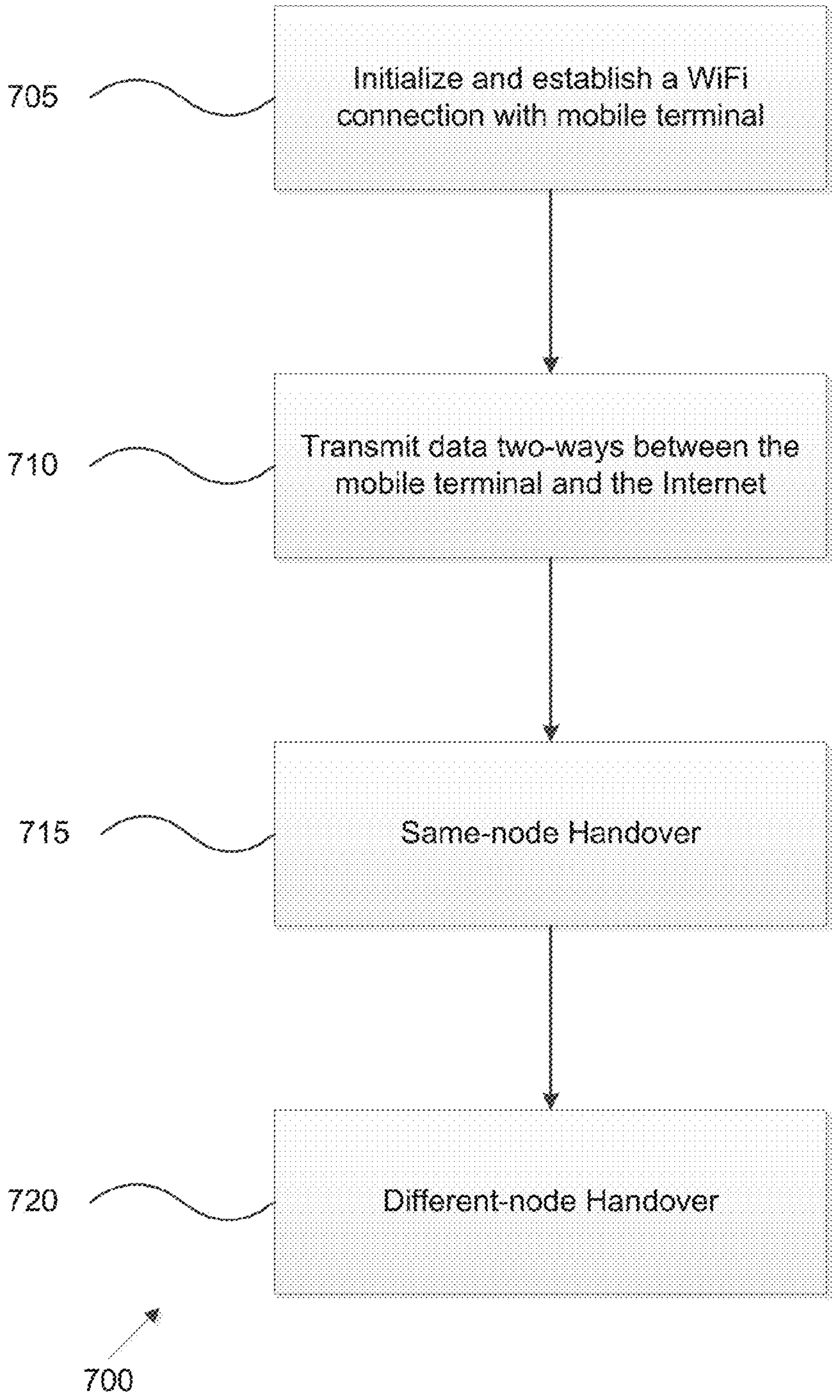

705
Initialize and establish a WiFi connection with mobile terminal
710
Transmit data two-ways between the mobile terminal and the Internet
715
Same-node Handover
720
Different-node Handover
700

FIG. 7

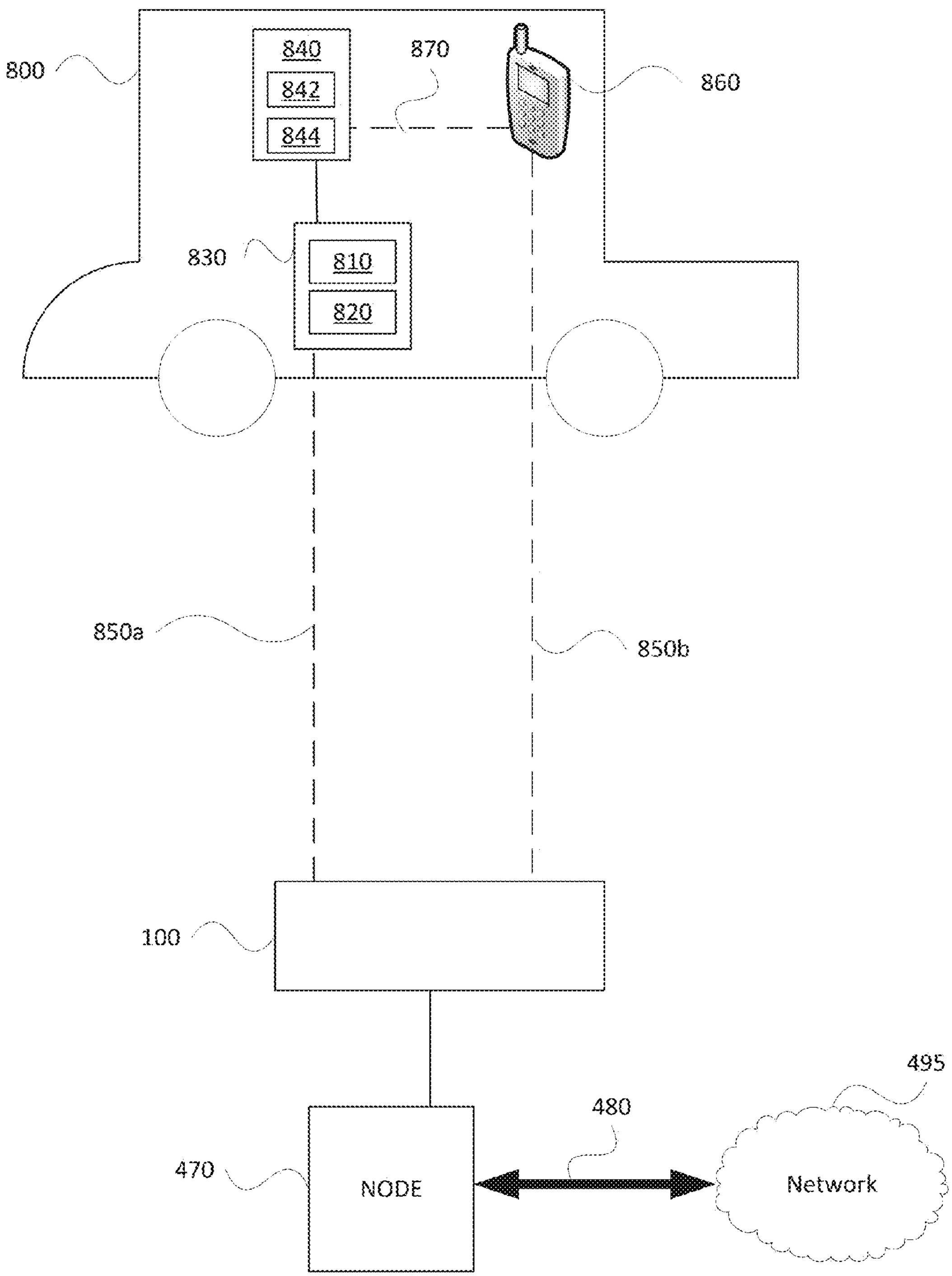

800
840
842
844
870
860
830
810
820
850a
850b
100
495
480
470
NODE
Network

FIG. 8

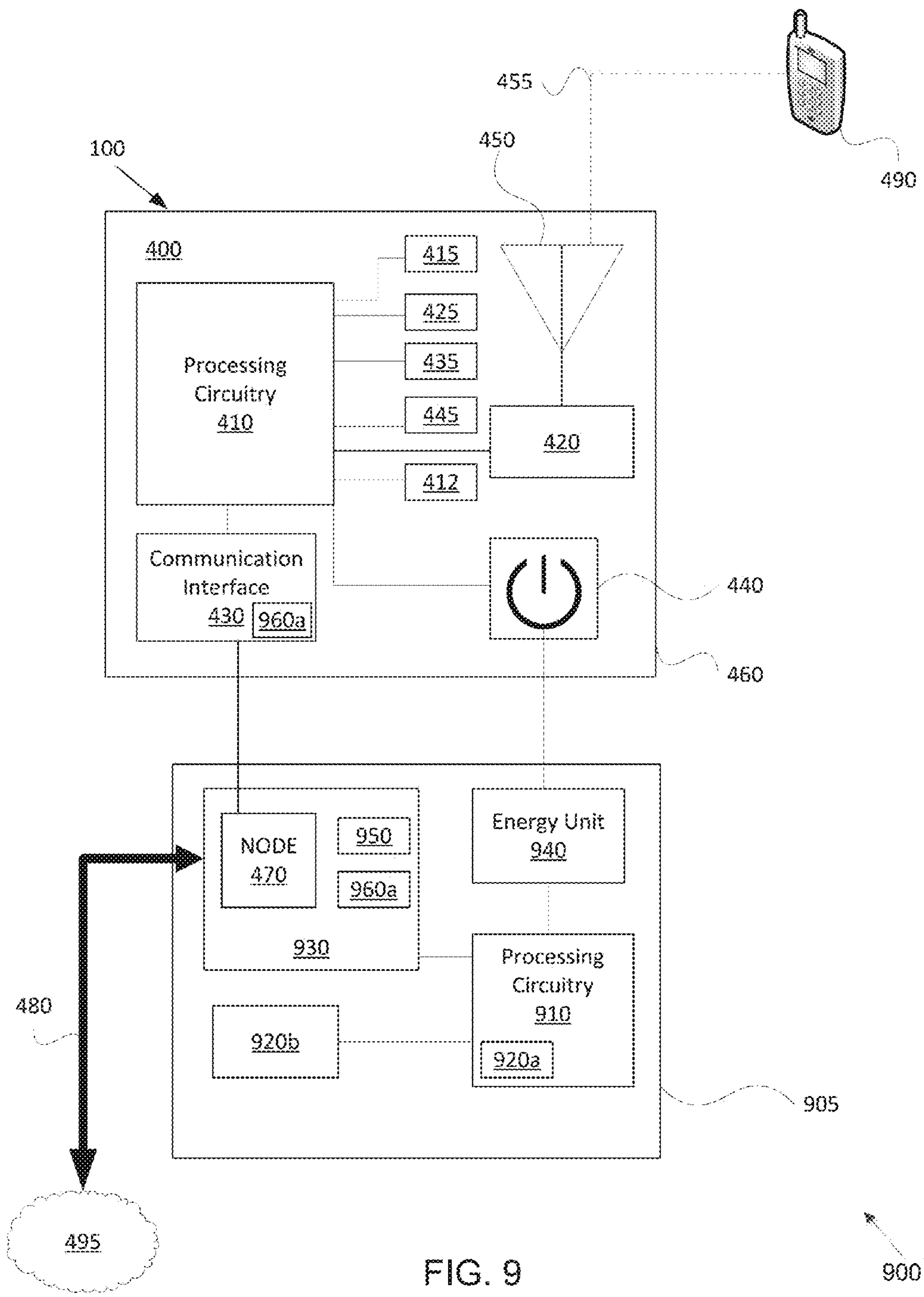

455
490
100
450
400
415
425
435
445
412
Processing
Circuitry
410
420
Communication
Interface
430
960a
440
460
NODE
470
950
960a
930
Energy Unit
940
Processing
Circuitry
910
920a
920b
480
905
495
900

FIG. 9

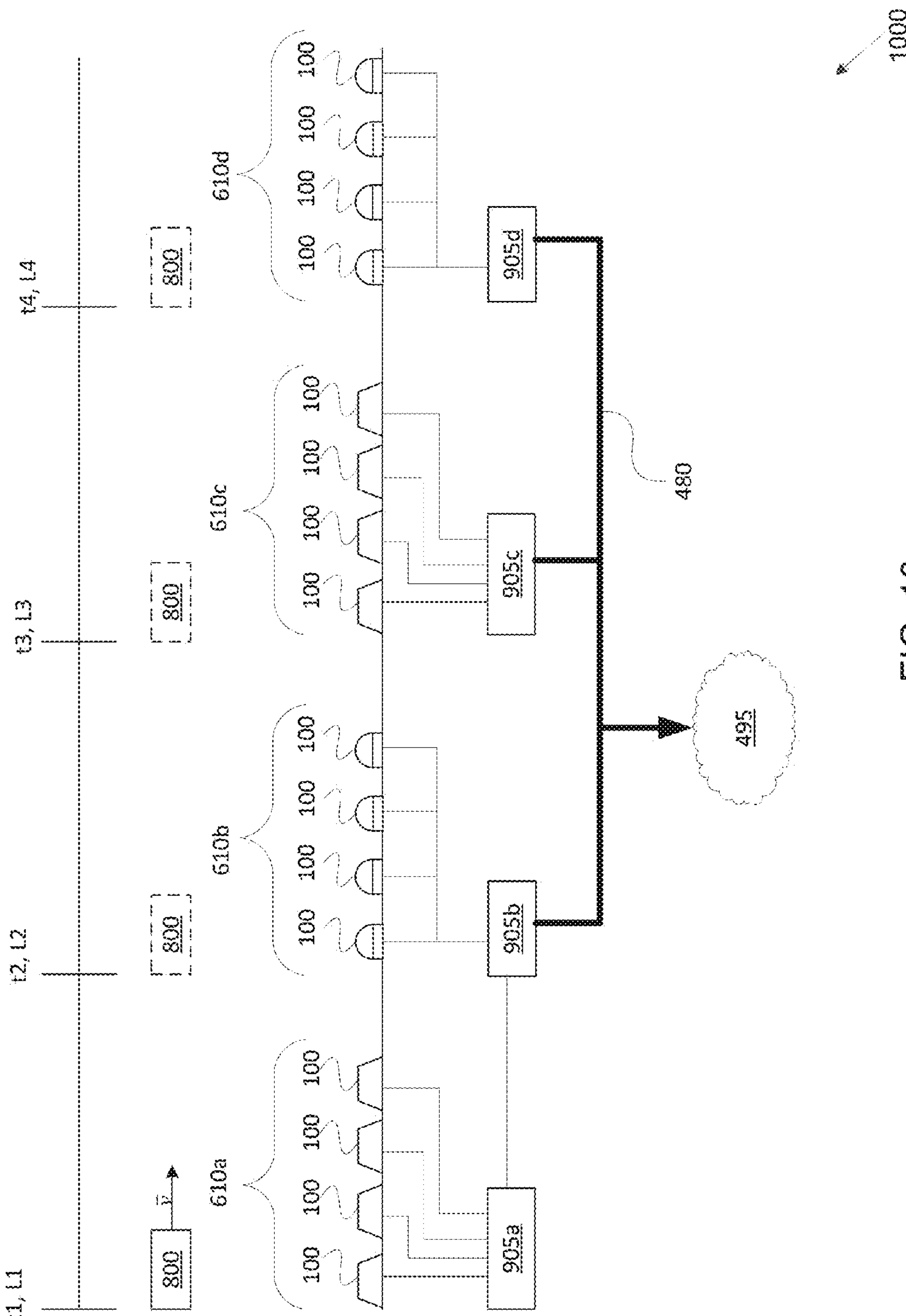

t1, L1
t2, L2
t3, L3
t4, L4
800
800
800
800
610a
610b
610c
610d
100
905a
905b
905c
905d
480
495
1000

FIG. 10

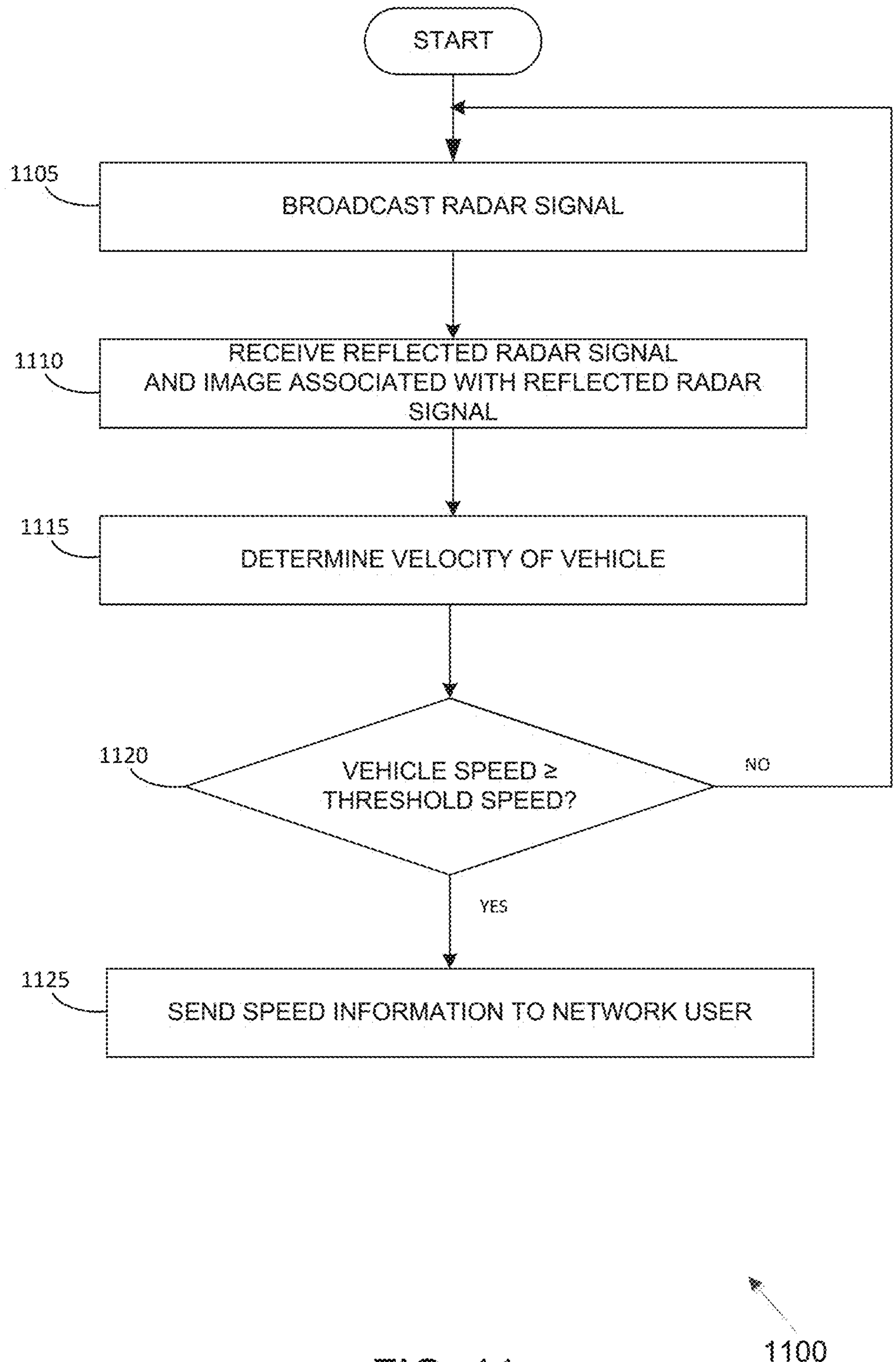

START
1105
BROADCAST RADAR SIGNAL
1110
RECEIVE REFLECTED RADAR SIGNAL
AND IMAGE ASSOCIATED WITH REFLECTED RADAR SIGNAL
1115
DETERMINE VELOCITY OF VEHICLE
1120
VEHICLE SPEED ≥ THRESHOLD SPEED?
NO
YES
1125
SEND SPEED INFORMATION TO NETWORK USER
1100

FIG. 11

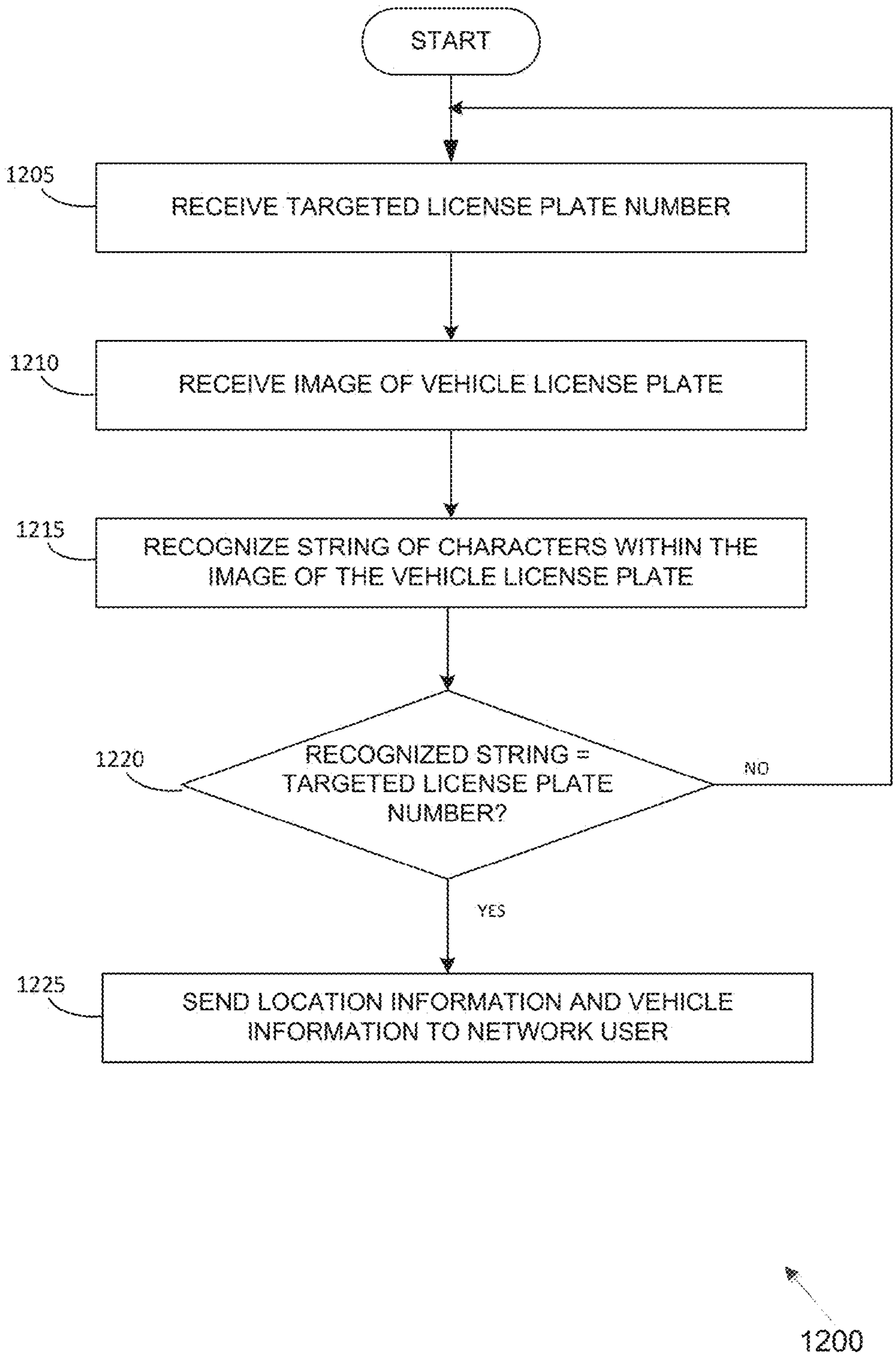

START
1205
RECEIVE TARGETED LICENSE PLATE NUMBER
1210
RECEIVE IMAGE OF VEHICLE LICENSE PLATE
1215
RECOGNIZE STRING OF CHARACTERS WITHIN THE IMAGE OF THE VEHICLE LICENSE PLATE
1220
RECOGNIZED STRING = TARGETED LICENSE PLATE NUMBER?
NO
YES
1225
SEND LOCATION INFORMATION AND VEHICLE INFORMATION TO NETWORK USER
1200

FIG. 12

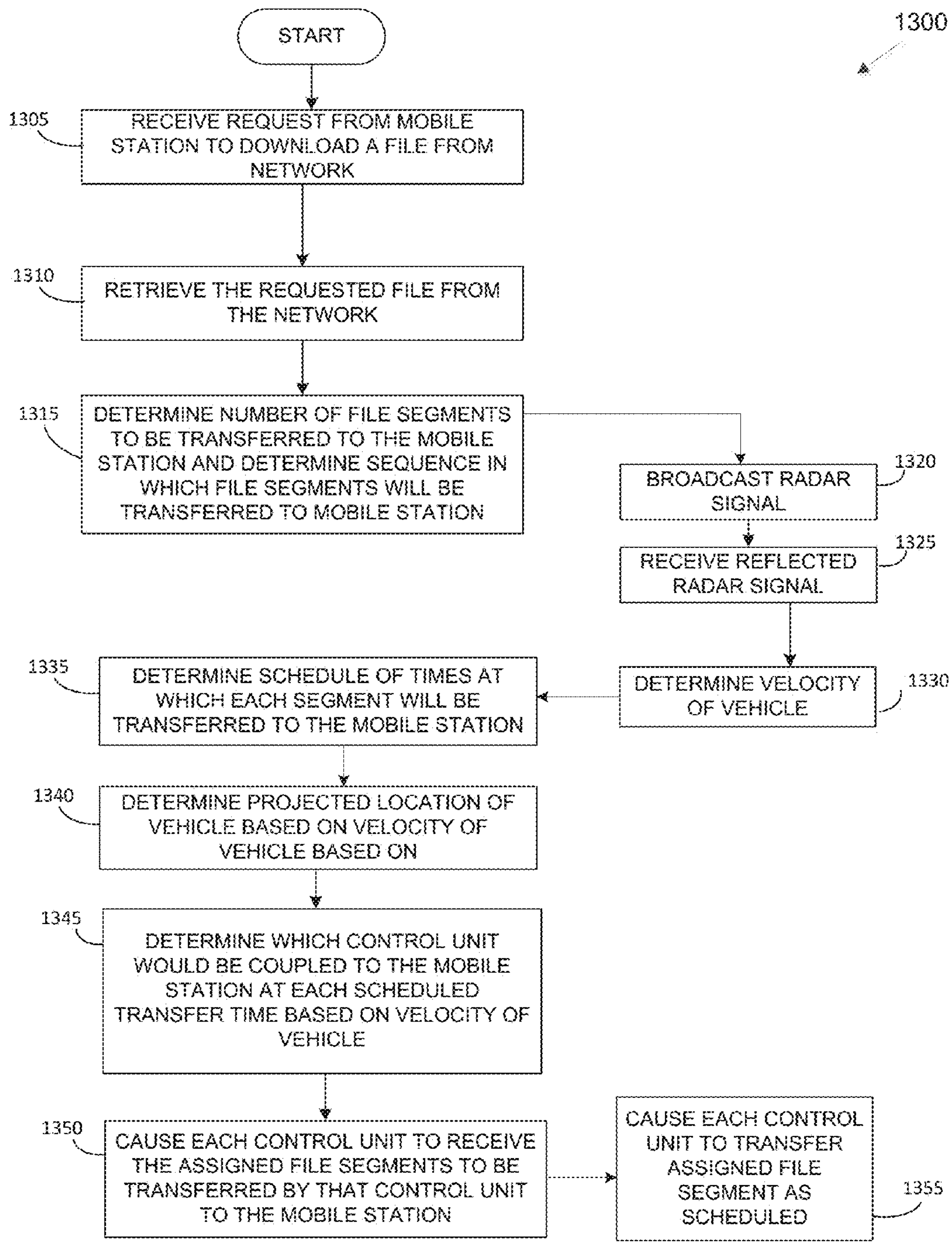

1300
START
1305
RECEIVE REQUEST FROM MOBILE STATION TO DOWNLOAD A FILE FROM NETWORK
1310
RETRIEVE THE REQUESTED FILE FROM THE NETWORK
1315
DETERMINE NUMBER OF FILE SEGMENTS TO BE TRANSFERRED TO THE MOBILE STATION AND DETERMINE SEQUENCE IN WHICH FILE SEGMENTS WILL BE TRANSFERRED TO MOBILE STATION
1320
BROADCAST RADAR SIGNAL
1325
RECEIVE REFLECTED RADAR SIGNAL
1330
DETERMINE VELOCITY OF VEHICLE
1335
DETERMINE SCHEDULE OF TIMES AT WHICH EACH SEGMENT WILL BE TRANSFERRED TO THE MOBILE STATION
1340
DETERMINE PROJECTED LOCATION OF VEHICLE BASED ON VELOCITY OF VEHICLE BASED ON
1345
DETERMINE WHICH CONTROL UNIT WOULD BE COUPLED TO THE MOBILE STATION AT EACH SCHEDULED TRANSFER TIME BASED ON VELOCITY OF VEHICLE
1350
CAUSE EACH CONTROL UNIT TO RECEIVE THE ASSIGNED FILE SEGMENTS TO BE TRANSFERRED BY THAT CONTROL UNIT TO THE MOBILE STATION
CAUSE EACH CONTROL UNIT TO TRANSFER ASSIGNED FILE SEGMENT AS SCHEDULED
1355

FIG. 13

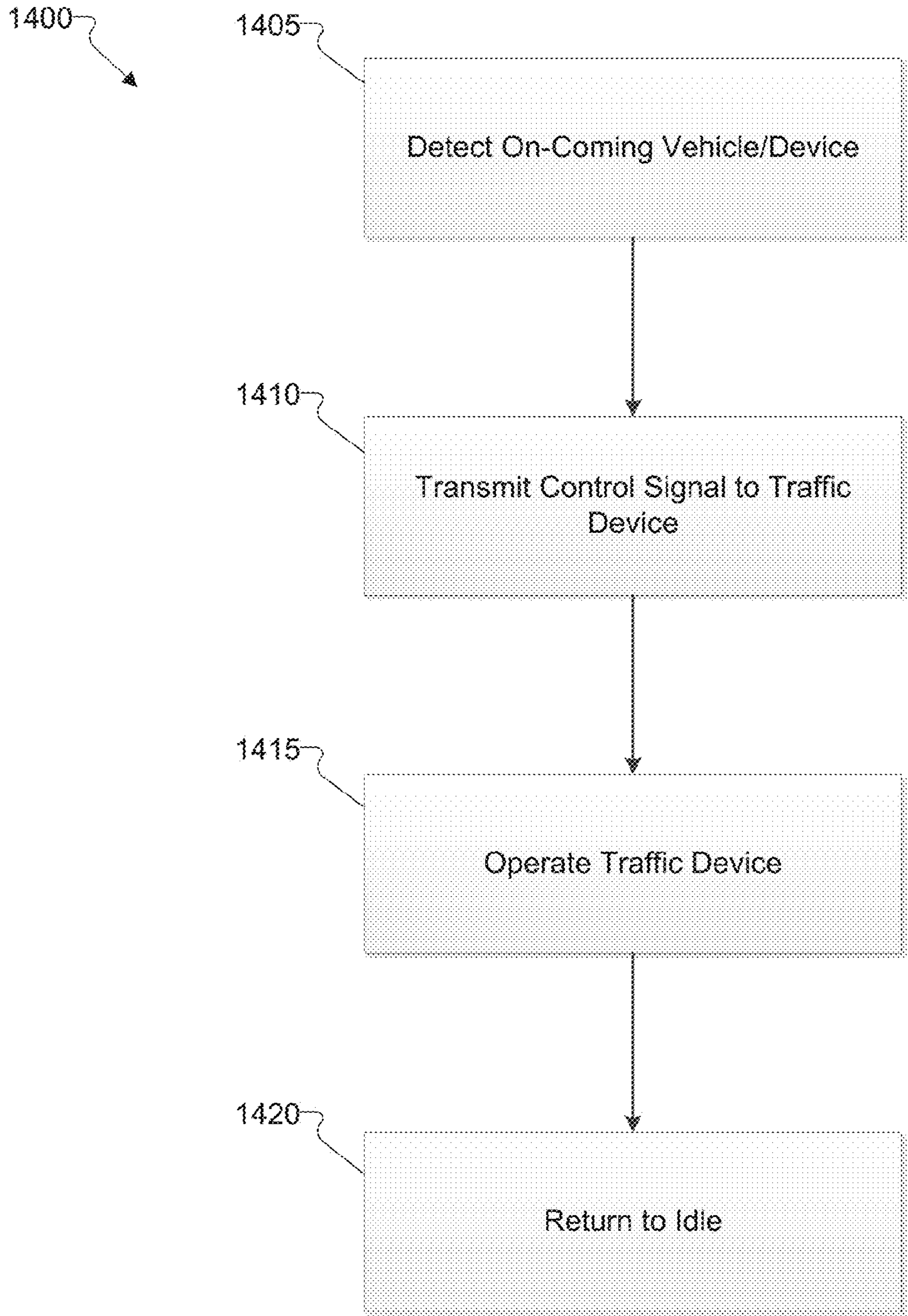

1400
1405
Detect On-Coming Vehicle/Device
1410
Transmit Control Signal to Traffic Device
1415
Operate Traffic Device
1420
Return to Idle

FIG. 14

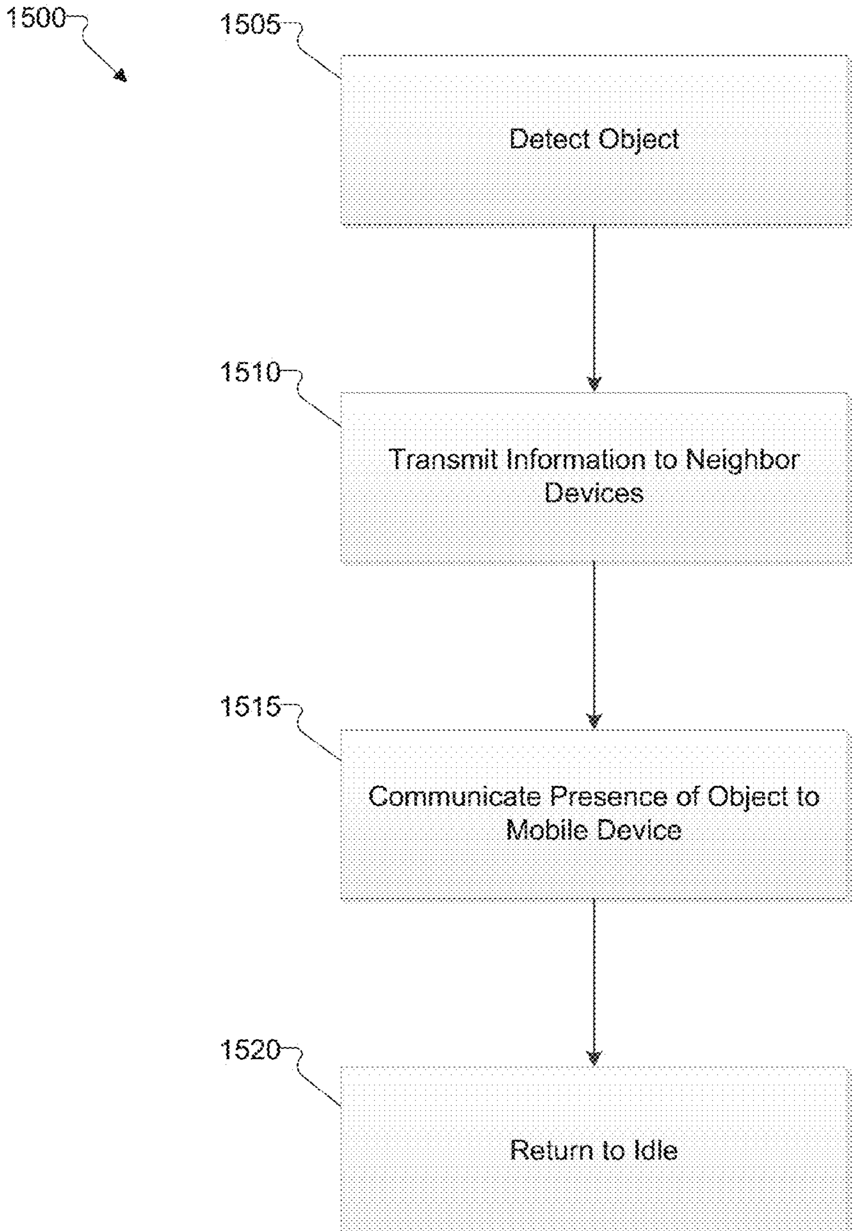

1500
1505
Detect Object
1510
Transmit Information to Neighbor Devices
1515
Communicate Presence of Object to Mobile Device
1520
Return to Idle

FIG. 15

SYSTEM AND METHOD FOR MOBILE DATA EXPANSION AND PEDESTRIAN OBSTACLE DETECTION

CROSS-REFERENCE TO RELATED APPLICATIONS AND CLAIMS OF PRIORITY

This application is a continuation-in-part of U.S. Non-Provisional patent application Ser. No. 15/267,013 entitled "SYSTEM AND METHOD FOR MOBILE DATA EXPANSION" and filed Sep. 15, 2016, which is a continuation-in-part of U.S. Non-Provisional patent application Ser. No. 14/876,673 entitled "SYSTEM AND METHOD FOR MOBILE DATA EXPANSION" and filed Oct. 6, 2015, now U.S. Pat. No. 9,596,611, which is a continuation of U.S. Non-Provisional patent application Ser. No. 13/840,578 entitled "SYSTEM AND METHOD FOR MOBILE DATA EXPANSION" and filed Mar. 15, 2013, now U.S. Pat. No. 9,219,991, which is a continuation-in-part of U.S. Non-Provisional patent application Ser. No. 13/646,537 entitled "SYSTEM AND METHOD FOR MOBILE DATA EXPANSION" and filed on Oct. 5, 2012, now U.S. Pat. No. 8,447,239, and claims priority through those applications to U.S. Provisional Patent Application No. 61/668,867 entitled "SYSTEM AND METHOD FOR MOBILE DATA EXPANSION" and filed on Jul. 6, 2012. The content of the above-identified patent documents is incorporated herein by reference.

TECHNICAL FIELD

The present application relates generally to mobile broadband data services, and more specifically to discrete WiFi hotspots for mobile devices.

BACKGROUND

Wireless data communications are increasing in demand and popularity. Mobile devices use cellular data networks or small wireless fidelity (WiFi) networks (WiFi hotspots) to access broadband data services for mobile devices. While cellular data networks provide a wider coverage, WiFi hotspots are capable of higher data transfer rates and lower power usage at a lower cost. However, WiFi hotspots provide a limited coverage area inhibiting use when the user is moving between locations.

SUMMARY

A system is provided. The system includes a first traffic control device configured to communicate with an electronic device in a first vehicle. The system also includes a second traffic control device communicatively coupled to the first traffic control device. The second traffic control device is configured to detect a presence of an object. The second traffic control device also is configured to communicate the presence of the object to at least one of: a network controller, the first traffic control device, or another traffic control device.

A method is provided. The method includes communicating, by a first traffic control device, with an electronic device in a first vehicle. The method also includes detecting, by a second traffic control device communicatively coupled to the first traffic control device, a presence of an object. The method further includes communicating, by the second traffic control device, the presence of the object to at least one of: a network controller, the first traffic control device, or another traffic control device.

A roadway device is provided. The roadway device includes a transceiver configured to communicate with one or more electronic devices. The roadway device also includes a communication interface configured to communicatively couple to at least one other roadway communication device. The roadway device further includes processing circuitry. The processing circuitry is configured to detect a presence of an object and communicate the presence of the object to at least one of: a network controller, the first traffic control device, or another traffic control device. The roadway device further includes a housing configured to contain the processing circuitry, communication interface and the wireless transceiver.

Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words or phrases used throughout this patent document: the terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation; the term "or" is inclusive, meaning and/or; the phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like; and the term "controller" means any device, system or part thereof that controls at least one operation, whether such a device is implemented in hardware, firmware, software or some combination of at least two of the same. It should be noted that the functionality associated with any particular controller might be centralized or distributed, whether locally or remotely. Definitions for certain words and phrases are provided throughout this patent document, and those of ordinary skill in the art will understand that such definitions apply in many, if not most, instances to prior as well as future uses of such defined words and phrases. While some terms may include a wide variety of embodiments, the appended claims may expressly limit these terms to specific embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, wherein like numbers designate like objects, and in which:

FIGS. **1**A and **1**B illustrate a small cell data expansion reflector (DER) according to embodiments of the present disclosure;

FIGS. **2**A, **2**B and **2**C illustrate a data expansion device that includes a solar array panel according to embodiments of the present disclosure;

FIGS. **3**A and **3**B illustrate a DER with a cylindrical housing according to embodiments of the present disclosure;

FIG. **3**C illustrates a data expansion device configured as a roadway marker according to embodiments of the present disclosure;

FIG. **4** illustrates selected electrical and electronic components of a control system inside a DER according to embodiments of the present disclosure;

FIG. **5** illustrates a string of DERs according to embodiments of the present disclosure;

FIG. **6** illustrates a network of DERs according to embodiments of the present disclosure;

FIG. 7 illustrates a process for providing mobile broadband data access according to embodiments of the present disclosure;

FIG. 8 illustrates a DER providing mobile broadband access according to embodiments of the present disclosure;

FIG. 9 illustrates a DER system according to embodiments of the present disclosure;

FIG. 10 illustrates a network of DERs according to embodiments of the present disclosure;

FIG. 11 illustrates a process for reporting vehicle velocity and identification information according to embodiments of the present disclosure;

FIG. 12 illustrates a process for reporting vehicle location and identification information according to embodiments of the present disclosure;

FIG. 13 illustrates a process for sequentially transmitting segments of a data file to a mobile station based on projected geographical location of the mobile station according to embodiments of the present disclosure;

FIG. 14 illustrates a process for controlling traffic signals and safety devices according to embodiments of the present disclosure; and

FIG. 15 illustrates a process for detecting and reporting objects according to embodiments of the present disclosure.

DETAILED DESCRIPTION

FIGS. 1 through 15, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged device. The numerous innovative teachings of the present application will be described with reference to exemplary non-limiting embodiments.

FIGS. 1A and 1B illustrate a small cell data expansion roadway device (DER) according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the DER, it should be understood that other embodiments may include more, less, or different components.

The DER **100** is a small cell device configured to provide a wireless communication link between a mobile device and a backhaul network. The DER **100** is adapted to couple to one or more mobile devices to enable the mobile devices to send and receive information, such as data and control signals, to the backhaul network. As such, the DER **100** is configured to provide one or more of: a wireless coverage area; a cellular coverage area; a hotspot, such as a WiFi hotspot; and the like.

The DER **100** can be configured as a street surface reflector (also called a surface marker, lane divider, road marker, and the like), such as a road reflector, raised pavement marker, street reflector, road stud, pavement reflector, and roadway marker used for traffic control and safety. In the example shown in FIGS. 1A and 1B, the DER **100** is configured as a roadway marker with a cylindrical housing configured to disposed in or on a roadway or pedestrian pathway. In certain embodiments, the DER **100** with a cylindrical housing is disposed in the road surface such that a highest portion of the housing is substantially flush (i.e., within one centimeter) with the road surface.

In certain embodiments, the DER **100** includes one or more surfaces that are comprised of a reflective material **120**. For example, the DER housing **110** includes a mounting surface, a top surface, and a plurality of side surfaces. In certain embodiments, the surfaces of the reflective material include the plurality of side surfaces, the top surface, or a combination thereof. The DER **100** is made up of one or more of the reflective material, plastic, a ceramic, or other suitable materials. In certain embodiments, only selected ones of the plurality of side surfaces and the top surface include the reflective material. That is, the portions of the DER **100** that are made of the reflective material are less than a whole portion. For example, in the example shown in FIGS. 1A and 1B, two rectangular sides of the DER **100** include the reflective material. In certain embodiments, the DER **100** housing can be in any of a variety of shapes, such as circular, oval, rectangular, octagonal, hexagonal, trapezoidal, or any suitable shape.

FIGS. 2A, 2B and 2C illustrate a data expansion device that includes a solar array panel according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the data expansion device, it should be understood that other embodiments may include more, less, or different components. The data expansion device shown in FIGS. 2A, 2B and 2C is configured as a data expansion roadway device (DER) **100**.

In the example shown in FIGS. 2A and 2B, the DER **100** is configured as a roadway reflector. In the example shown in FIG. 2C, the DER **100** is included with, or configured as, a roadway marker, such as a street sign or traffic control device.

In certain embodiments, the DER **100** includes a self-sustaining power source or power supply. In certain embodiments, at least one surface, such as the top surface, includes a solar panel **210** that as the self-sustaining power source. The self-sustaining power source configured as a solar panel **210** includes a number of solar cells **220**, such as a solar cell array, that include a plurality of photo-voltaic cells to form at least one solar panel **210**. Although one solar panel **210** is depicted, embodiments including more than one solar panel **210** could be used without departing from the scope of the present disclosure. In certain embodiments, the DER **100** includes a power interface configured to couple to a self-sustaining power source, such as a solar cell **220**. In certain embodiments, the power interface is configured to removably couple to the self-sustaining power source.

In certain embodiments, the DER **100** includes a housing **110** that is a truncated pyramid shape. The solar panel **210** can be disposed atop the housing **110** or coupled to the housing **110**. One or more sides of the housing can include the solar cells **220**. Reflective material **120** is disposed on one or more remaining sides of the housing **110**. The sides of the housing **110** that include the solar cells **220** can be oriented to correspond to the sides that allow the greatest amount of solar energy to be absorbed throughout a day and a year. In certain embodiments, the housing includes a clear protective cover disposed over or around the solar array panel **210**. The clear protective cover is comprised of any suitable clear material such as a PLEXIGLAS material or other hard plastic, glass or composite material. In certain embodiments, the clear material is comprised of a reflective material and configured as a portion of the reflective surfaces. In certain embodiments, the solar array panel **210** is embedded into the reflective surface or disposed beneath the clear material as a reflective surface.

In the example shown in FIG. 2C, the DER **100** includes, or is coupled to, a vertical mount. For example, the housing **110** can include a mounting interface **225** configured to couple to a vertical structure **230**. The DER **100** or vertical structure **230** can include a traffic control device, such as a street sign **235**. The housing **110** contains operating components of the DER, such as one or more of: processing circuitry, wifi transceivers, antennas, processors, interfaces and power couplings.

The DER **100** can be oriented to maximize solar energy captured by the solar cells **220** or oriented to provide maximum wireless communication coverage over a road surface or over a pedestrian surface. As with other embodiments of the present disclosure, the DER **100** depicted in FIG. **2**C is configured to provide wireless coverage, such as a wifi signal or wifi hotspot zone, to the road or pedestrian surface and couple directly to the backhaul network or couple to the backhaul network through an access point, thus bypassing a base station or enhanced Node B (eNodeB or eNB) and such that the data is not communicated through the base station or eNodeB.

FIGS. **3**A and **3**B illustrate a DER **100** with a cylindrical housing **300** according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the DER **100**, it should be understood that other embodiments may include more, less, or different components.

The DER **100** with a cylindrical housing **300** that has at least one reflective surface. In certain embodiments, the DER **100** with a cylindrical housing **300** includes a solar array panel **310** disposed atop the reflective surface or disposed beneath a clear reflective surface. The housing **300** can be a truncated sphere atop a cylinder shape. In certain embodiments, the solar array panel **310** is embedded or cut into the reflective surface. In certain embodiments, the DER **100** with a cylindrical housing **300** is disposed in the road surface such that a highest portion of the housing **300** is substantially flush (i.e., within one centimeter) with the road surface.

In certain embodiments, a portion of the DER **100** with a cylindrical housing **300** includes a reflective surface. In certain embodiments, a portion of the DER **100** with a cylindrical housing **300** includes a solar cell array **310**. In certain embodiments, a portion of the DER **100** with a cylindrical housing **300** includes a reflective material and a separate portion of the reflector **100** includes a reflective surface. In certain embodiments, the DER **100** with a cylindrical housing **300** includes a solar array **310** that is also a reflective surface.

FIG. **3**C illustrates a data expansion device configured as a roadway marker according to embodiments of the present disclosure. The DER **100** shown in FIG. **3**C is for illustration only. In the example shown in FIG. **3**C, the DER **100** is included with, or configured as, a roadway marker, such as a mile marker, roadway indicator and or traffic control device.

In the example shown in FIG. **3**C, the DER **100** includes a base **320** and a delineator post **325**. In certain embodiments, the DER **100** includes a plate **330**, such as a reflector, mile marker, or other delineator plate.

The base **320** is configured to include processing circuitry for the DER **100**. The base **320** includes a housing that encloses the processing circuitry for the DER **100**. For example, the base **320** can include one or more processors, a transceiver, such as a wifi transceiver and other suitable circuitry for forming a data hotspot, such as a wifi hotspot. The base **320** is adapted to be mounted on, or adhered to, a roadway or pedestrian surface. In certain embodiments, some or all of the base **320** is disposed beneath a surface of the roadway or pedestrian surface.

The delineator post **325** can be rigid or flexible. The delineator post **325** can be formed from steel, aluminum, plastic, carbon fiber, or any suitable material. In certain embodiments, the delineator post **325** includes one or more components configured to operate as an antenna. In certain embodiments, the delineator post **325** includes one or more antennas. In certain embodiments, the delineator post **325** is configured to operate as an antenna. In certain embodiments, the delineator post **325** and plate **330** are configured to operate as an antenna.

The plate **330** can be rigid or flexible. In certain embodiments, the plate **330** includes a reflective material. In certain embodiments, the plate **330** includes traffic, roadway, or safety information. The plate **330** can be formed from steel, aluminum, plastic, carbon fiber, or any suitable material. The plate **330** is affixed to the delineator post **325** through any suitable means such as, bolts, screw, adhesives, interlocking fasteners, hook and loop connections, hooks, and the like. In certain embodiments, the plate **330** includes, or is comprised of, solar cells, such as photovoltaic cells. In certain embodiments, the plate **330** includes one or more solar panels comprised of a plurality of solar cells.

FIG. **4** illustrates components of a control system **400** inside a DER **100** according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the control system **400**, it should be understood that other embodiments may include more, less, or different components. The components of the control system **400** can be included in the embodiments of the DER **100** shown in any of FIGS. **1**A, **1**B, **2**A, **2**B, **2**C, **3**A, **3**B and **3**C or in any suitable structure configured to as a roadway marker, pedestrian marker, traffic control device configured to be disposed in, on or under a road or pedestrian traffic surface, and the like.

The DER **100** includes the control system **400**. The control system **400** is configured to enable the DER **100** to provide access to broadband data services for mobile terminals. The control system **400** includes processing circuitry **410**, a transceiver **420**, a communication interface **430**, a power source **440**, and an antenna **450**. In certain embodiments, the control system **400** includes one or more the following: a Radio Detection And Ranging (RADAR) unit **415**, a camera **425**, a global positioning system (GPS) receiver **435**, and a climate control unit **445**. The housing **460** is configured to contain the control system **400**. In certain embodiments, the housing **460** is the same as housing **110** of the DER **100**. In certain embodiments, the control system **400** also includes a network node **470**. The network node **470** operates as an access point, providing features such as access control, theft prevention, data traffic monitoring, data traffic shaping, network node to network node signaling, and various other features associated with network access and control. The network node **470**, as an access point, provides controlled access to the backhaul network, such as controlled access to an internet network.

The processing circuitry **410** is coupled to the RADAR unit **415**, the transceiver **420**, the camera **425**, the communication interface **430**, the GPS receiver **435**, the power source **440**, and the climate control unit **445**. The processing circuitry **410** is configured to establish a communication with at least one mobile terminal **490** through a coupling with the transceiver **420**. The processing circuitry **410**, communicably coupled to the mobile terminal **490**, enables communications between the mobile terminal **490** and a backhaul network **495** of computers, such as the Internet (namely, a world-wide-web; a world-wide-network) or a private network. The processing circuitry **410** forms one or more communication channels to communicate information between the mobile terminal **490** and the network **495**. The control system **400** establishes a secure channel for sending and receiving control and data signals to and from one or more mobile terminal **490**. The processing circuitry **410** provides a virtual private network (VPN) initialization and termination for communications between the control system **400** and the mobile terminal **490**. That is, the DER **100** can communicate with the mobile terminal **490** via a secured channel using a VPN. In certain embodiments, the processing circuitry **410** is configured to send encrypted data and to decipher encrypted data received from the mobile terminal **490**. That is, the processing circuitry **410** and mobile terminal **490** establish an encryption agreement or share a common encryption key used to secure the data transmitted between the mobile terminal **490** and the DER **100**.

In certain embodiments, the processing circuitry **410** includes a programmable controller. The programmable controller is configured to be reprogrammable to control one or more functions of the processing circuitry, at a later date. In certain embodiments, the programmable controller is configured, such as pre-configured, to control one or more functions of the processing circuitry **410**. In certain embodiments, the processing circuitry **410** is embodied as a programmable controller. In the present disclosure, any description of a function or coupling of the processing circuitry **410** is understood to be a function or coupling of the programmable controller.

In certain embodiments, the processing circuitry **410** includes a memory **412**. In certain embodiments, the processing circuitry **410** is coupled to the memory **412**, such as the example shown in FIG. **9**. The memory **412** includes any suitable volatile or non-volatile storage and retrieval device(s). For example, the memory **412** can include any electronic, magnetic, electromagnetic, optical, electro-optical, electro-mechanical, or other physical device that can contain, store, communicate, propagate, or transmit information. The memory **412** stores data and instructions for use by the processor or programmable controller of the processing circuitry **410**. In certain embodiments, the memory **412** stores location information. For example, the memory **412** is programmed to store a location of the DER **100**, such as a global positioning system (GPS) location or a location provide by the network. For example, the network or and operator can program the DER **100** with a geographic location at the time of installation of the DER **100**. In certain embodiments, in response to receiving a signal indicating the location of the DER **100**, the processing circuitry **410** stores the location in the memory **412**.

The control system **400** includes the RADAR unit **415** configured to perform a RADAR gun function. The RADAR unit **415** is configured to transmit RADAR waves toward one or more objects and to receive return reflected waves. That is, the RADAR unit **415** includes a radio signal transmitter configured to transmit radio waves outward from the DER **100**. When incident upon an object (for example, a vehicle, the radio waves reflect off the object and return to the control system of the DER **100**. The RADAR unit **415** includes a radio signal receiver configured to receive the return reflected waves. The RADAR unit **415** transmits waveform information corresponding to the transmitted and reflected waves to the processing circuitry **410**. The RADAR unit **415** and processing circuitry **410** use the RADAR wave information to determine the speed and direction of travel of the vehicle (together, the vehicle velocity). The RADAR unit **415** and processing circuitry **410** use the RADAR wave information to determine a proximal distance from the RADAR unit to the vehicle. The RADAR unit **415** within the DER **100** can be used to monitor the flow of traffic on streets and highways.

For example, the roadway speed limit corresponding to the location of the DER **100** is stored in the memory **412**. As vehicles, drive by the DER **100**, the RADAR unit **415** measures the speed and direction of the traffic. The processing circuitry **410** compares the speed of one or more vehicles to the stored speed limit. The control system **400** sends the vehicle speed information and the speed comparison to a network **495** computer or network user, such as a traffic law enforcement system, a government department of transportation traffic controller or a roadway traffic monitoring service system. The information can include an estimated amount of time travel between certain mile markers, or an estimated time of arrival at a highway junction or exit ramp.

The control system **400** includes a transceiver **420**. The transceiver **420** is configured to transmit data and to receive data. In certain embodiments, the transceiver **420** is a wireless transceiver, for example a WiFi transceiver. In certain embodiments, the transceiver **420** includes an antenna **450**. The antenna **450** is configured to enable the transceiver **420** to send data to mobile terminal **490** and to receive data from the mobile terminal **490**. In certain embodiments, when mounted on a vertical mount, such as the street sign shown in FIG. **2**C, portions of the antenna are included in a portion of the vertical structure **230**, such as on the traffic control device. For example, a portion of the street sign **235** can be configured to operate as antenna **450** or to operate a part of antenna **450**. In certain embodiments, when configured as a roadway marker, such as the roadway marker shown in FIG. **3**C, portions of the antenna are included in a portion of the delineator post **325**. For example, all or a portion of delineator post **325** or plate **33*o*** can be configured to operate as antenna **450** or to operate a part of antenna **450**. Alternatively, one or more antennas can be included in the delineator post **325** or plate **330**.

In certain embodiments, the transceiver **420** is coupled to antenna **450**, enabling the transceiver **420** to send data to a mobile terminal **490** and to receive data from the mobile terminal **490**. The transceiver **420** communicates data between the processing circuitry **410** and the mobile terminal **490**. That is, the transceiver **420** receives data from the processing circuitry **410** and transmits the data received from the processing circuitry **410** to the mobile terminal **490**. The transceiver **420** also receives data from the mobile terminal **490** and transmits the data received from the mobile terminal **490** to the processing circuitry **410**. The processing circuitry **410** is communicably coupled to the network node **470**. The processing circuitry **410** sends signals to the node **470** and receives signals from the node **470**. For example, in response to a signal sent from the processing circuitry **410** to the node **470**, the processing circuitry **410** receives one or more signals from the node **470**. The processing circuitry **410** sends communications to a network **495** of computers (also referred to as the Internet) and receives communications from the network **495** via the node **470**. When the processing circuitry **410** is communicably coupled to the network **495**, the processing circuitry **410** is configured to enable the mobile terminal **490** to communicate with the network **495** via the transceiver **420** and the node **470**.

The control system **400** includes a communication interface **430**. The communication interface **430** enables communications with one or more of: the processing circuitry **410**, a node **470**, the backhaul network **480**, one or a plurality of mobile terminals **490**, and the network **495**. Communications can be through a wireless data transfer communication, a wireless local area network (WLAN) Internet communication, an optic communication medium, infrared communication medium, or through wireless-fidelity (WiFi) communication.

The control system **400** includes a camera **425**. The camera is configured to capture images of the environment surrounding the DER **100**. The camera **425** is configured to capture images of vehicle that is approaching or departing from the DER **100**, including images of the vehicle license plates. For example, the processing circuitry can instruct the camera **425** to capture images of a vehicle driving faster than the speed limit or driving slower than the highway minimum speed.

For example, the processing circuitry **410** receives a targeted license plate number. The mobile phone **490** can forward an AMBER alert to the control system **400** via the link **455**, including a corresponding targeted license plate number. The processing circuitry stores the targeted license plate number in the memory **412**. The control system **400** is configured to perform image processing, including optical character recognition (OCR). That is, the camera **425** or the processing circuitry **410** performs an OCR on the images of vehicle license plates captured by the camera **425**. The processing circuitry **410** is configured to compare the license plate numbers recognized in the images to the targeted license plate numbers stored in memory **412**. When the recognized license plate number matches one or more targeted license plates numbers, the processing circuitry **410** sends the location of the DER **100**, the matching license plate information, and the corresponding image to a user in the network **495**. The network **495** user may be a law enforcement officer within close proximity to the DER **100**.

The control system **400** includes a GPS receiver **435** configured to receive a signal indicating the GPS location of the DER **100**. The control system **400** is configured to store the received GPS location in the memory **412** as the location of the DER **100**.

In certain embodiments, the processing circuitry **410** is configured to communicate with one or more traffic control or safety devices, or both. For example, the processing circuitry **410** can send control signals, including activation signals, deactivation signals, or both, to one or more streetlights in an area or section of the roadway, send control signals, including activation signals, deactivation signals, or both, to a traffic signal or traffic control device. In certain embodiments, the control system **400** includes one or more sensors **465** configured to operate in conjunction with the processing circuitry **410** to send control signals to one or more traffic control or safety devices, or both. The one or more sensors **465** can be configured to detect one or more of: vehicles, radio frequency identifier (RFID) chips, or mobile devices. In response to detecting one or more of vehicles, radio frequency identifier (RFID) chips, or mobile devices by the one or more sensor **465**, the processing circuitry **410** communicates, via transceiver **420**, communication interface **430** or another communication interface, signals to the one or more traffic control or safety devices.

The power source **440** is configured to provide power to the control system **400**. The power source **440** is coupled to each electrical component of the control system **400**. The power source **440** can be directly coupled to each electrical component of the control system **400**. In certain embodiments, the power source is directly coupled to the processing circuitry **410**, enabling each electrical component coupled to the processing circuitry **410** to indirectly receive power from the power source **440**. The power source **440** can be a renewable energy source, such as solar energy, wind energy, geothermal energy, biomass energy, or any combination thereof. For example, the power source **440** can include a connection with a local utility company's distribution system, or an off-the-grid island distribution system, or a combination thereof. In certain embodiments, the power source **440** is a solar array panel **210**, **310**. In certain embodiments, the power source **440** is a photovoltaic source embodied as photovoltaic paint or another suitable material configured to convert solar energy into electrical energy. In particular embodiments, the power source **440** includes a port or power interface adapted to couple an external power source, which is outside the DER **100** and provides power to the control system **400**. In certain embodiments, the port or power interface is configured to removably couple to the external power source. In certain embodiments, the power source **440** includes one or more of the following: a solar-charging battery; a vibration-powered energy harvester configured to capture and store energy derived from ambient vibrations; a wireless power transmission receiver configured to couple to a wireless power transmitter; a conductor transmitting electricity generated from solar energy, geothermal energy, or heat; a number of solar cells; a number of solar cells disposed beneath a clear (e.g., PLEXIGLASS) cover of the housing; and a painted stripe on the road or pedestrian walk-way surface. In certain embodiments, a portion of the painted stripe is disposed within or beneath the housing **460**. The vibration-powered energy harvester captures energy from ambient road vibrations or vibrations from wind against the housing **460** and converts the energy into electricity for the control system **400**.

The control system **400** includes a climate control unit **445**. The climate control unit **445** includes one or more sensors configured to measure temperature and moisture levels internal and external to the housing **460**. The climate control unit **445** includes a heating element **447** configured to increase the temperature of the DER. In certain embodiments, the heating element **447** is disposed within the material of the housing **460**. In certain embodiments, the heating element **447** is disposed on top of the housing and heats the external surface of the DER **100**. In certain embodiments, the heating element **447** is disposed around a perimeter of the housing **460**. As an example, when the climate control unit **445** measures an external temperature of below freezing and senses snow or ice disposed on the surface of the DER **100**, then the climate control sensor turns on the heating element to increase the temperature of the DER **100** and to melt away the ice or snow. By melting away snow and ice, driverless vehicles can detect the lane markers of the roadway and control the vehicle to remain within the lane.

The antenna **450** is configured to communicably couple to the mobile terminal **490**. The antenna **450** can be configured to communicate with the mobile terminal **490** using a suitable wireless communication, such as a WiFi (namely, IEEE 802.11x) communication, a near field communication (NFC), a BLUETOOTH low energy (BLE) communication, a general packet radio service (GPRS) for global system for mobile communications (GSM), an Enhanced Data rages for GSM Evolution (EDGE) communication, a third generation (3G) Universal Mobile Telecommunications System (UMTS) communication, 3G High Speed Packet Access (HSPA) communication, a 3G High Speed Downlink Packet Access (HSDPA) communication, a Worldwide Interoperability for Microwave Access (WiMax) communication, a fourth generation (4G) Long Term Evolution (LTE) communication, or any other suitable wireless communications protocol. In certain embodiments, the antenna **450** is included in the transceiver **420**. In certain embodiments, the antenna **450** is coupled to the transceiver **420**. The antenna **450** can be configured with omni-directional characteristics, or uni-directional characteristics. Additionally, the antenna **450** can be a directional antenna configured to communicate data in particular directions.

In certain embodiments, the control system **400** is included in housing **460**. The housing **460** can be embodied as a raised reflective surface or a base of a roadway marker. Some examples of raised reflective surfaces include: a road reflector, raised pavement marker, street reflector, road stud, and pavement reflector, used for traffic control and safety. The housing **460** can be rectangular, cylindrical, oval, trapezoidal or any suitable shape. In certain embodiments, the housing **460** is dimensioned not to exceed (e.g., be equal in size or smaller than) four inches by four inches wide and two and a quarter inches high (4"×4"×2.25"). For example, when in a truncated sphere configuration, the housing **460** can be dimensioned to include a four inch (4") diameter and a height of two and a quarter inches (2.25"). The housing **460** is configured to contain the transceiver **420** and the processing circuitry **410**. In certain embodiments, the housing **460** is configured to contain at least a portion of the power source **440**. In certain embodiments, the housing **460** is configured to contain the entire control system **440**.

In certain embodiments, the network node **470** is communicably coupled to a backhaul network **480** (for example, a private or 3rd Party telecommunication network). The network node **470** sends signals to and receives signals from the backhaul network **480**. Through the backhaul network, the network node **470** sends signals to and receives signals from the network **495**. In certain embodiments, the control system **400** includes the network node **470**. In certain embodiments, the control system **400** is communicably coupled to the network node **470**. The network node **470** is configured to enable the control system **400**, and respective components therein, to communicate via the network node **470** to one or more of the backhaul network **480** and the network **495**. The network node **470** is configured to be connected to or communicably coupled (for example, logically coupled) with one or more other nodes of other control systems **400**, such as of different DERs. Accordingly, through the network node **470**, the control system **400** of a first DER is configured to enable a second DER to be indirectly and communicably coupled to the backhaul network **480** and the network **495**. That is, the second DER **100** is configured to couple to one or more of the backhaul network **480** and the network **495** via the first DER **100**. In certain embodiments, the network node **470** is configured to communicate to the backhaul network **480** using Ethernet, fiber, wireless communication, or any form of Local Area Network, or Wide Area Network technology.

The network node **470** operates as an access point, such as a network router, providing features such as access control, theft prevention, data traffic monitoring, data traffic shaping, network node to network node signaling, and various other features associated with network access and control. The network node **470**, as an access point, provides controlled access to the backhaul network, such as controlled access to an internet network. For example, by communicating through the network node **470**, the DER **100** is able to bypass a base station. The network node **470** verifies access permission or authority corresponding to a user, a mobile device, or both. The network node **470** can determine if a current subscription is valid for the user or the mobile device and, based on the subscription status, permit or deny access to the core network and, ultimate to the internet via the core network.

The backhaul **480** is communicably coupled to the network node **470** and the network **495**, enabling communications between the network node **470** and the network **495**. The backhaul network **480** sends signals to and receives signals from the network **495** and one or more network nodes **470**. The backhaul **480** enables two-way communication between the node **470** and the network **495**. The backhaul **480** can be a wired or wireless network.

The control system **400** is configured to communicate with a number of mobile terminals **490**. The control system **400** sends signals to and receives signals from the mobile device **490** via a link **455**. The mobile terminal **490** can be a portable computer, a "smart phone", personal data assistant, a touchscreen tablet, an electronic wallet, a vehicle or the like.

FIG. **5** illustrates a string of DERs **500** according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the string of DERs **500**, it should be understood that other embodiments may include more, less, or different components. The string of DERs **500** includes a number of DERs, such as DERs **100*a*** and **100*b***. Each of the DERs **100*a*** and **100*b*** contains a control system **400**. The DERs **100*a*** and **100*b*** are communicably coupled to a common node, such as network node **470**, thereby establishing an interlinked string of DERs **500**. As described in further detail below, a set of surface reflectors **500** may include various embodiments of DERs and DER assemblies as well as various quantities of the DERs.

DER **100*a*** is embodied as a truncated pyramid pavement marker having reflective material on at least one side. The DER **100*a*** includes a power source **440** configured as a port connected to an external power source **510*a*** via a conductor **515**. In certain embodiments, the external power source **510*a*** and **510*b*** is embodied as one or more of: a lane marker; pedestrian marker; or other road or pedestrian way markings. The solar power panels **510*a*** and **510*b*** include a photovoltaic material that converts solar light or solar energy into electricity. For example, the external power source **510*a*** and **510*b*** includes a plurality of photovoltaic cells configured to convert solar energy into electrical energy, such as a plurality of solar cells or a solar power panel. The conductor **515** can be any suitable conductor. The DER **100*a*** includes a communication interface **430** that is coupled to the external network node **470**. The connection between the communication interface **430** and the external network node **470** may be on the surface or below the surface of the object to which the DER **100** is attached.

The DER **100*b*** and the solar power panel **510*b*** together form a DER assembly **520**. The DER assembly **520** includes a plurality of power sources **440** and **510*b***.

The DER **100*b*** is embodied as a truncated sphere pavement marker having a reflective material disposed on the entire surface. The DER **100*b*** includes a power source **440** configured as a power port or power interface. The power port or power interface **440** is adapted to connect to a plurality of different power sources (**510*b***, **510*a***). In certain embodiments, as illustrated in FIG. **5**, a portion the solar power panel **510*b*** is disposed beneath, or otherwise in physical contact with, the housing **460**, and another portion is disposed outside the housing **460**. In certain embodiments, the DER assembly **520** does not include a portion of the external power source (e.g., solar power panel) **510*b*** contained within the housing **460**.

The DER **100***b* includes communication interface **430***b*. The communication interface **430***b* of DER **100***b* is coupled to (e.g., in data communication with) the communication interface **430***a* of DER **100***a*, which is connected to a node **470**. Where one of the communication interfaces **430***a* and **430***b* is connected to the network node **470**. The connection between the communication interfaces **430***a* and **430***b* of the DERs **100***a* and **100***b*, forms a daisy chain **530**. In certain embodiments, the daisy chain **530** is a logical daisy chain. The daisy chain **530** enables a communication interface **430***b* that is not directly connected to the network node **470** to connect to the node **470** via the connection to a communication interface **430** of the first DER **100***a*, which is coupled to the network node **470**. The daisy chain **530** may extend by connecting a subsequent DER **100***c* to one of the communication interfaces **430***b* and **430***a* of either the surface reflector **100***b* or the surface reflector **100***a*.

FIG. **6** illustrates a network of DERs according to embodiments of the present disclosure. The embodiment of the DER network **600** shown in FIG. **6** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure. Although in FIG. **6**, each set of DERs **610** includes four surface reflectors, a set of DERs **610** can include any number of DERs. In certain embodiments, a set of DERs **610** spans a quarter of a mile (1609 meters).

The network of DERs **600** includes a plurality of sets of DERs. For example, the network of DERs **600** includes a first set of DERs **610***a* and a second set of DERs **610***b*. Network node **470***b* of a second set of DERs **610***b* is connected to network node **470***a* of a first set of DERs **610***a*. In certain embodiments, the network nod **470***b* is logically connected to network node **470***a*. The first set of DERs **610***a* is connected to the backhaul network **480**. The connection **620** between the network nodes **470***a* and **470***b*, in which one of the first network nodes **470***a* is connected to the backhaul **480**, forms a daisy chain **620** of nodes. The daisy chain **620** enables network node **470***b* to connect to the backhaul **480** via the connection to the network node **470***a* of the first set of DERs **610***a*, which is coupled to the backhaul **480** directly (for example, wherein a signal from the network node **470***a* is not received by an intermediary before the backhaul network receives the signal). In certain embodiments, the daisy chain **620** is a logical daisy chain such that the second network node **470***b* sends signals to and receives signals from the first network node **470***a* via the backhaul network **480** and the network **495**. The daisy chain **620** can be extended by connecting a subsequent network node **470** of another set of DERs **610** to either the network node **470***a* or the network node **470***b*. In certain embodiments of the network of DERs **600**, the first network node **470***a* is connected to the backhaul network **480**, and the second network node **470***b* is directly coupled to the backhaul network **480** independent of the daisy chain **620** connection. In certain embodiments of the network of DERs **600**, the first network node **470***a* is connected to the backhaul network **480**, and the second network node **470***b* is coupled to the backhaul network **480** through one or more of a direct connection independent of the daisy chain **620** and through the first network node **470***a* via the daisy chain **620**. For example, the second set of DERs **610***b* select to the backhaul network via the independent direct connection to the backhaul network **480** or alternatively via the daisy chain to the first network node **470***a*. In certain embodiments of the network of DERs **600**, the daisy chain is extended by connecting either the network node **470***a* or the network node **470***b* to a third network node **470** (of a third set of DERs **610**) that is directly connected to the backhaul network **480**. In certain embodiments, when a plurality of network nodes **470***a* and **470***b* have established a communication (such as a channel of communication) with the network **495**, each network node **470** sends signals to and receives signals from the other network nodes **470**. For example, the first network node **470***a* sends signals to and receives signals from the second network node **470***b* via one or more of the backhaul network **480** and the network **495**.

The set of DERs **610***a* includes truncated pyramid shaped surface reflectors. Each DER of **610***a* includes a communication interface **430** that is coupled to the network node **470***a*. The second set of DERs **610***b* includes truncated sphere shaped DERs. Each DER of the set **610***b* includes a communication interface **430** coupled to the communication interface **430** of an adjacent DER, creating a daisy chain to the communication interface **430** that is coupled to the network node **470***b*. In certain embodiments, the coupling is a logical daisy chain between a first communication interface **430** of a DER of the set **610***b* and a second communication interface **430** of a second DER of the set **610***b* that is coupled to the network node **470***b*.

FIG. **7** illustrates a process for providing mobile broadband data access according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process depicted in the example depicted is implemented by a processing circuitry in, for example, a data expansion roadway device.

The process **700** can be performed, for example, by one or more control systems **400**, hereinafter referred to in the singular as "the system." The process **700** can be implemented by executable instructions stored in a non-transitory computer-readable medium that cause one or more surface reflector control systems **400** to perform such a process.

In block **705**, when a mobile terminal **490** is within a range close enough to communicably couple to at least one control system **400** of a surface reflector, the processing circuitry **410** is within a communicable coupling range and will initialize and establish a wireless connection with the mobile terminal **490**. The processing circuitry **410** is configured to determine when the mobile terminal **490** is within a communicable coupling range, such as based in part on the strength of the signal between the mobile terminal **490** and the antenna **450**.

In block **710**, once a mobile terminal **490** is communicably coupled to at least one DER **100**, the DER **100** transmits data back and forth between the mobile terminal **490** and the network **495**. The data communication path includes the mobile terminal **490**, the antenna **450**, the transceiver **420**, the processing circuitry **410**, the communication interface **430**, the node **470**, the backhaul **480**, and the network **495**.

In block **715**, as the mobile terminal **490** moves, the mobile terminal **490** moves out of a communicable coupling range of a first DER to which the mobile terminal **490** is connected. The mobile terminal **490** moves into a communicable coupling range of a second DER that belongs to the same set **610** of DERs as the first surface reflector. In certain embodiments, the second DER initiates and establishes a wireless connection with the mobile terminal **490**. In response to the establishment a connection of the mobile terminal **490** to the second DER, the first DER terminates the data connection to the mobile terminal **490**. This process is referred to as a same-node handover.

In certain embodiments, the processing circuitry **410** is configured to perform a different-node handover in block **720**. As the mobile terminal **490** continues to move, the mobile terminal **490** moves out of a communicable coupling range with all of the DERs in the first set of DERs that are coupled to the node of the first DER. In the different-node handover **720**, in response to the establishment of a connection with a second DER that does not belong to the same set **610** of DERs as the first DER (e.g., not included in the first set of DERs), the first DER terminates the data connection between the mobile terminal **490** and the first DER. In certain embodiments, the different-node handover process is conducted using a hardwire handover in which the first node and second node are communicably coupled via a wired connection. In certain embodiments, the different-node handover process is conducted using a wireless handover—in which the first node and second node are communicably coupled via a wireless connection. In certain embodiments, one or more of the same node handovers and different node handovers are controlled by a central switch. In certain embodiments, one or more of the same node handovers and different node handovers are controlled by one of the network nodes **470**. In certain embodiments, one or more of the same node handover and different node handover are controlled in part by the mobile terminal. In certain embodiments, one or more of the same node handover and different node handover are controlled by one or more components in the backhaul network **480**.

FIG. **8** illustrates a DER **100** providing mobile broadband access to a vehicle **800** according to embodiments of the present disclosure. In certain embodiments, the mobile terminal **490** is a vehicle **800** (e.g., car; truck; van; bus) that includes an antenna **810** adapted to receive wireless data signals from one or more DERs **100**. The control system **400** of the DER **100** sends signals to and receives signals from the vehicle **800** via a link **850***a*.

The vehicle **800** includes a transmitter **820** to send wireless data signals to one of more DERs **100**. In certain embodiments, the vehicle's antenna **810** and transmitter **820** (together "vehicle transceiver" **830**) are located physically close to the ground, such as at or near the bottom of the vehicle, under the passenger cabin. When the DER **100** is located on the street and the vehicle transceiver **830** is disposed under the vehicle, the vehicle can receive a stronger signal link **850***a* from the DER **100** as compared with the strength of the signal link **850***b* to the mobile terminal **860** within the passenger cabin. In certain embodiments, the vehicle's antenna **810** positioned on the vehicle in any one or more of: atop, on a side, internally, externally, beneath, the so forth, to enhance transmission and reception of signals between the antenna **810** and the DER **100**.

In certain embodiments, the antenna **810** is coupled to a control unit located in the vehicle **800**. The vehicle's control unit **840** includes processing circuitry, a memory **842**, and an interface **844** to link **870** to a mobile terminal **860** within the passenger cabin of the vehicle. The link **870** can be a wired or wireless link, such as via BLUETOOTH Low Energy, infrared, Universal Serial Bus (USB), or any other suitable data transmission medium link. The control unit **840** is adapted to boost the strength of the signal from the DER **100** to the mobile terminal **860**. For example, when the signal strength link **850***b* (between the DER **100** and the mobile terminal **860** within the passenger cabin of the vehicle) is weak compared to the signal strength of link **850***a* (between the DER **100** and the vehicle **800**), then the DER **100** sends signals to the mobile terminal **860** through the control unit **840** and through the vehicle interface link **870** to the mobile terminal **860**.

In certain embodiments, the control unit **840** includes a memory **842** adapted to buffer data transferred from the network **495** to the mobile device **860**. The control unit **840** monitors a transfer of data from the network **495** to the memory of the mobile terminal **860**. In the event a connection between the mobile terminal **860** and the control unit **840** is lost or severed during a download of a file from the network **495**, the control unit **840** continues to download data from the network **495** via the connection **850***a* between the control unit **840** and the DER **100**. The control unit **840** stores the download data in the memory **842** for retrieval by the mobile terminal **860**. Upon a re-connection between the mobile terminal **860** and the controller **840**, the downloaded data stored in the memory **842** is transferred to the mobile terminal **860**.

As an illustrative and non-limiting example: a user commences downloading a movie. During the download of the movie, the user exits the vehicle **800** along with the mobile terminal **860**, thus severing the connection between the mobile terminal **860** and the control unit **840**. Thereafter, the control unit **840** continues to download and store the remaining portion of the movie. When the user returns to the vehicle and re-connects the mobile terminal **860** to the control unit **840** via the interface **844**, the remaining portion of the movie is downloaded to the mobile terminal. The mobile terminal can prompt the user to request a download of the buffered data after the marker. Alternatively, in response to a re-establishment of the link **870**, the controller **840** can initiate the download of the buffered data without user interaction. Therefore, the user is able to complete the download without being required to re-start the entire download.

In certain embodiments, the control unit **840** stores a file marker indicating when the download was interrupted. The control unit **840** stores a first file marker in the memory **842**. The file marker identifies the portion (transferred portion) of the file that has been transferred to the memory of the mobile terminal **860** and the portion (un-transferred portion) of the file that has not been transferred to the memory of the mobile terminal **860**. If before the entire file is transferred to the memory of the mobile terminal **860**, the user removes the mobile terminal **860** from the vehicle **800** or otherwise disconnects the mobile terminal **860** from interface link **870**, then the control unit **840** will continue to download the un-transferred portion and store or buffer the un-transferred portion in the memory **842** of the control unit **840**. When the mobile terminal **860** re-establishes the link **870** to the control unit **840** through the interface **844**, then un-transferred portion of the data is downloaded to the memory of the mobile terminal **860**. That is, in response to a reconnection of the mobile terminal **860** with the control unit **840**, the download is re-initiated at the point indicated by the marker. The mobile terminal can prompt the user to request a download of the un-transferred portion of the data after the marker. Alternatively, in response to a re-establishment of the link **870**, the controller **840** can initiate the download of the un-transferred data after the marker without user interaction. In both cases, however, the data downloaded prior to the marker is not required to be downloaded again.

FIG. **9** illustrates a DER system **900** according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the DER system **900**, it should be understood that other embodiments may include more, less, or different components. The DER system **900** includes a DER **100** coupled to a mobile terminal **490** and to a controller unit **905**. The DER **100** includes the control system **400**.

The controller unit **905** operates as an access point, providing features such as access control, theft prevention, data traffic monitoring, data traffic shaping, network node to network node signaling, and various other features associated with network access and control. In certain embodiments, the controller unit **905** includes the features and functions of the node network **470**. In certain embodiments, the controller unit **905** and the network node **470** are interchangeable. The controller unit **905** is coupled to the backhaul network **480** via a wire line or wireless connection. The controller unit **905** couples to one or more computer networks via the backhaul network **480**.

The controller unit **905** includes processing circuitry **910** configured to control components within the controller unit **905**. In certain embodiments, the processing circuitry **910** controls the memory **920***a*-*b*, the communication interface **930**, and the energy unit **940**. The controller unit **905** establishes a secure channel for sending and receiving control and data signals to and from one or more DERs **100**. The processing circuitry **910** provides a virtual private network (VPN) initialization and termination for communications between the controller unit **905** and the DER **100**. That is, the controller unit **905** communicates with the DER **100** via a secured channel using a VPN. In certain embodiments, the processing circuitry **910** is configured to send encrypted data and to decipher encrypted data received from the DER **100**. That is, the processing circuitry **910** and control system **400** establish an encryption agreement or share a common encryption key used to secure the data transmitted between the controller unit **905** and the DER **100**.

The controller unit **905** includes memory **920** configured to store instructions for the processing circuitry **910** and to store information used in functions performed by the processing circuitry **910**. In certain embodiments, the processing circuitry **910** includes the memory **920***a* within the same integrated circuitry. In certain embodiments, the processing circuitry **910** is coupled to the memory **920***b*.

The controller unit **905** includes a communication interface **930** configured to send and receive control signals and data between the DER **100** and the controller unit **905**. The communication interface **930** is coupled to the backhaul network **480** via a wire line or wireless connection. The controller unit **905** uses the communication interface **930** to send signals to and receive signals from the network **495** via the backhaul network **480**. That is, the controller unit **905** is communicably coupled to the network **495** through the backhaul network **480**. The communication interface **930** includes the network node **470**, a GPS receiver **950**, and an optical communication terminal **960**.

The GPS receiver **950** is configured to locate GPS satellites and to deduce the location of the controller unit **905** using signals received from the satellites. In certain embodiments, the controller unit **905** sends a message indicating the location to each DER **100** within the set of DERs **610** controlled by that controller unit **905**. The location message can include a GPS location, a geographic coordinate system coordinate pair, an approximate address, and an intersection. In response to receiving the location message, the DER **100** saves the location information in memory **412**.

For example, the DER **100** receives and stores the location information derived from the GPS **950** from the controller unit **905**. The user of the mobile terminal **490** uses a maps or navigation application to track a selected path from point A to point B. Between point A and point B, the mobile terminal **490** loses connection with GPS satellites and cannot determine the location of the mobile terminal. The DER **100** forwards the location information to the mobile terminal **490**, thereby enabling the mobile device's maps or navigation application to determine the location of the mobile terminal. Accordingly, the DER system **900** enhances the user's GPS navigation experience.

The optical communication terminal **960** configured to send and receive signals via light, wherein the signals comprise data or control signals. That is, the optical communication terminal **960** sends and receives signals by way of an optical communication channel. The optical communication terminal **960** includes an input/output (I/O) terminal configured for receiving input signals via a light input and sending output signals via a light output. In certain embodiments, the optical communication terminal **960** is configured to communicate using laser I/O signals. In certain embodiments, the optical communication device is configured to communicate using white space frequency. As an example, when television channel 4 and channel 5 represent the government designated frequencies of 8.0 mega-Hertz and 9.0 mega-Hertz, then white space frequency represents band of 8.5-8.9 mega-Hertz that the government has not reserved for a specified purpose (e.g., television channel 4 and 5).

In certain embodiments, the optical communication terminal **960** is configured to communicate photonically, using photons of light. Photonic communication uses a subset of a light wave and transmits signals faster than signals transmitted via laser light. The optical communication terminal **960** is configured to detect a breach in the security of the signal transmission channel. For example, the optical communication terminal **960** detects an interruption of light within the transmission path and interprets the interruption as an indication of a breach of security. As another example, the optical communication terminal **960** detects a change in polarity of the photons of a photonic signal within the transmission path and interprets the changed polarity as an indication of a breach of security.

In certain embodiments, the communication interface **430** of the control system **400** includes an optical communication terminal **960**. For example, a first DER **100***a* and a second DER **100***b* each include an optical communication terminal **960** and communicate by laser or photonically with each other using the respective optical communication terminals **960**. As another example, the DER **100** includes an optical communication terminal **960***b* and sends and receives signals by laser or photonically with the optical communication terminal **960***a* of the controller unit **905**.

The controller unit **905** includes an energy unit **940** configured to provide electric energy to the constituent electrical components of the controller unit **905**. The energy unit **940** receives electricity from one or more of the following sources: a local utility power line, heat, such as geothermal heat, and vibrations. In certain embodiments, the energy unit **940** is configured to convert geothermal energy into electricity for the controller unit **905**. In certain embodiments, the energy unit **940** is configured to convert energy from road vibrations into electricity for the controller unit **905**. In certain embodiments, the energy unit **940** is configured to transmit wireless power signals to the power source **440**, and the wireless power signals charge an energy storage device within the power source **440**. The wireless power transmission transmitter of the energy unit **940** is configured to couple to the wireless power receiver of the DER's power source **440**, such as a shared frequency coupling.

That is, in certain embodiments, the power source **440** within the control system **400** is configured to receive and use wireless power to supply electricity to components within the control system **400** and to charge an energy storage device, such as a battery.

According to embodiments of the present disclosure, The DER system **900** is configured to receive information from a police officer mobile **490**, such as information regarding the geographical location of a police officer. In certain embodiments, the DER system **900** is configured to determine the proximal distance of the police officer from the DER **100** based on the geographical location of a police officer.

The DER system **900** is configured to implement a process for reporting vehicle velocity and identification information as will be described more particularly in reference to FIGS. **9** and **11**.

FIG. **10** illustrates a network of DERs **1000** according to embodiments of the present disclosure. Although certain details will be provided with reference to the components of the network of DERs **1000**, it should be understood that other embodiments may include more, less, or different components. Although in FIG. **10**, the network of DERs **1000** includes four controller units **905***a-d*, each controlling a corresponding set of DERs **610***a-d* of four surface reflectors each, the network of DERs **1000** can include any number of sets of DERs **610**. The components of FIG. **10** share the features and functions of the components of FIG. **6**.

The network of DERs **1000** includes a plurality of sets of DERs. For example, the network of DERs **1000** includes a first set of DERs **610***a*, a second set of DERs **610***b*, a third set of DERs **610***c*, and a fourth set of DERs **610***d*. The first controller unit **605***a* controls the first set of DERs **610***a*; the second controller unit **605***b* controls the a second set of DERs **610***b*; the third controller unit **605***c* controls the third set of DERs **610***c*; and the fourth controller unit **605***d* controls the a fourth set of DERs **610***d*.

The controller unit **905***a* of a first set of DERs **610***a* is connected to controller unit **905***b* of the second set of DERs **610***b* via a wire line or a wireless connection, forming a daisy chain from the controller unit **905***a* to the backhaul network **480**. That is, the controller unit **905***a* is not directly connected to the backhaul network **480**, but instead, the second controller unit **905***b* is an intermediary between the backhaul network **480** and the first controller unit **905***a*. The first controller unit **905***a* is coupled to the controller units **905***c* and **905***d* via a logical connection in combination with the wire line or wireless connection to the backhaul network **480**. The first controller unit **905***a* sends control signals and data signals to the controller units **905***c* and **905***d* via the logical connection (through **905***b* and **480**) and in return, receives response messages from the controller units **905***c* and **905***d*.

In reference to FIGS. **10** and **13**, the network of DERs **1000** is configured to implement a process for sequentially transmitting segments of a data file to a mobile station **860** within a vehicle **800** based on projected geographical location of the vehicle **800**.

FIG. **11** illustrates a process **1100** for reporting vehicle velocity and identification information according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process depicted in the example depicted is implemented by a processing circuitry in, for example, a data expansion roadway device.

A vehicle **800** travels in near proximity to a DER **100** at a velocity $\vec{v}$, including a direction and a speed. In block **1105**, the DERs **100** broadcasts one or more RADAR signals. When the RADAR signals are incident upon a vehicle **800** or other object, the signals reflect off the vehicle **800** and return toward the RADAR transceiver within the RADAR unit **415**.

In block **1110**, the RADAR unit **415** receives the reflected return RADAR signals. In certain embodiments, block **1110** further comprises receiving an image associated with the reflected return RADAR signals. The processing circuitry **410** is configured to instruct the camera **425** to capture a picture of the object the broadcasted RADAR waves were incident upon. That is, the camera captures an image of the vehicle **800** or vehicle license plates corresponding to the reflected return RADAR signals.

In block **1115**, the control system **900** determines the velocity $\vec{v}$ of the vehicle **800**. In certain embodiments, the control system **400** of the DER **100** determines the velocity $\vec{v}$ of the vehicle using the waveform information from the RADAR unit **415**. In certain embodiments, the controller unit **905** determines the direction and speed of the vehicle **800**. The controller unit **905** makes the determination using information received from the RADAR unit **415** of the DER **100**.

In block **1120**, the control system **900** compares a threshold speed to the vehicle speed determined in block **1115**. Examples of the threshold speed include: a user determined speed to be monitored, a specified speed stored within the control system, a speed limit corresponding to the location of the DER **100**, a speed above the speed limit selected by a law enforcement officer seeking to confront or issue citations to speed limit violators. The control system **900** determines whether the vehicle speed is greater than or equal to the threshold speed. When the vehicle speed is at least the threshold speed, then the control system **900** moves to block **1125**. When the speed is less than the threshold speed, the control system moves to block **1105**.

In certain embodiments, in block **1125**, the control system **900** sends the speed information to an external device. For example, the control system **900** can send the speed information to one or more of a computer within the network **495**, a network user, an operator of the vehicle, or a third party. The speed information includes the image of the vehicle captured in block **1110**, the velocity $\vec{v}$ of the vehicle determined in block **1115**, and the results of the speed comparison derived in block **1120**.

FIG. **12** illustrates a process **1200** for reporting vehicle location and identification information according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process depicted in the example depicted is implemented by a processing circuitry in, for example, a data expansion roadway device.

At the start, a vehicle **800** travels nearby a DER **100** at a velocity $\vec{v}$, including a direction and a speed. In block **1205**, the control system **400** of the DER **100** receives a targeted license plate number. For example, the mobile phone within the vehicle receives an AMBER (America's Missing. Broadcast Emergency Response) alert containing the color and license plates number of a vehicle of interest and forwards the AMBER alert information to the control system **400** via the link **455**. As another example, the network **495** includes a government law enforcement system or a government department of transportation system. A computer within the network sends a message to the controller unit **905** indicating targeted license plates numbers of one or more vehicles used in an illegal act. The controller unit **905** forwards the targeted license plates numbers to at least one of the DERs **100** within the set of DERs **610** controlled by the controller unit **905**. The targeted license plates numbers are stored in memory **412**, **920***a-b*.

In block **1210**, the camera **425** captures an image of the vehicle **800**, including the vehicle license plate and the color of the vehicle. The image received for processing by processing circuitry **410** or **910**.

In block **1215**, the processing circuitry **410** or **910** recognizes the string of characters within the image that was captured in Block **1210**. The processing circuitry **410**,**910** uses an OCR capability to determine the characters in within the image of the vehicle license plate. In certain embodiments, the processing circuitry **410**,**910** is configured to determine a color of the car bearing the license plate in the image.

In block **1220**, the processing circuitry **410** or **910** compares one or more targeted license plate numbers to the string of characters recognized in image of the vehicle license plate. When the string of characters recognized in image of the vehicle license plate is substantially similar to or equal to a targeted license plate number, the control system moves to block **1225**. When matching license plate number is found, the control system moves to block **1205**. In certain embodiments, the processing circuitry **410**,**910** looks for matching colors by comparing the color of the car to the color in the AMBER alert.

In block **1225**, the control system **900** sends location information and the vehicle information to a computer within the network **495** or a network user. The vehicle information includes the color of the vehicle, the string of characters recognized in the image of the vehicle license plate. The location information includes the location of the DER. In certain embodiments, the vehicle information includes the velocity $\vec{v}$ of the vehicle.

FIG. **13** illustrates a process **1300** for sequentially transmitting segments of a data file to a mobile station based on projected geographical location of the mobile station according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process depicted in the example depicted is implemented by a processing circuitry in, for example, a data expansion roadway device.

In block **1305**, mobile terminal **860** sends a request to the DER **100** to download a file from the network **495**. In certain embodiments, the mobile terminal can be associated with a user that is not within a motor vehicle **800**. The DER **100** receives the request to download a file from the mobile terminal **860**.

In block **1310**, the control system **400** of the DER retrieves the requested file from the network **495** via the control unit **905** and the backhaul network **480**. The processing circuitry **910** of the controller unit **905***a-d* is configured to receive request to retrieve a file from the network **495**. In response to receiving the request to retrieve the file, the controller unit **905***a-d* retrieves the file from a location within the network **495**. The processing circuitry **910** of the controller unit **905***a-d* is configured to determine the number of file segments into which the retrieved file is divided. The processing circuitry **910** is configured to assemble scrambled file segments into a time dependent sequential order when the retrieved file is divided in to file segments and transmitted out of time dependent order for increased the speed of transmission. For example, a movie file may be divided into four file segments A-D. The network computer storage of the movie file may transmit to the controller unit **905***a* the file segment A (containing the first 10 minutes of the movie), followed by the file segment D (containing the fourth 10 minutes of the movie), then file segment C (containing the third 10 minutes of the movie), and then file segment B (containing the second 10 minutes of the movie). The processing circuitry **910** uses a marker within each file segment to determine the time dependent order of the file segments, such as determining that file segment A contains the first portion of the file. The processing circuitry **910** assembles file segment D to be immediately follow file segment C; assembles file segment C to be immediately follow file segment B; and assembles file segment B to be immediately follow file segment A. That is, processing circuitry **910** receives a scrambled set of file segments {A, D, C, B} and assembles the file segments into a time dependent sequence {A, B, C, D}.

In block **1315**, the controller unit **905***a* determines the number of file segments to be transferred to the mobile station **860**. In some instances, the computer (within the network **495**) from which the controller unit **905***a* retrieves the file divided the file into a number of file segments before the controller unit **905***a* retrieved the file. In some instances, the controller unit **905***a* retrieves the requested file from the computer (within the network **495**) as one large undivided file. The controller unit **905***a* is configured to divide the retrieved file into a number of file segments to hasten transmission of the retrieved file to the mobile station **860**. The controller unit **905***a* is configured to further divide the retrieved file segments into a larger number of file segments to hasten the transmission.

Also in block **1315**, the controller unit **905***a* determines a sequence in which the file segments should be transferred to the mobile station **860**. For example, the controller unit **905** can determine to first transmit two small, non-consecutive (e.g., file segments A and D) to a DER **100**, and next transmit a single file segment C.

In block **1320**, the DER **100** broadcasts RADAR signals **1320**, such as in block **1105**. In block **1325**, the DER **100** receives reflected return radar signals, such as in block **1110**. In block **1330**, the processing circuitry **410**, **910** of the DER or the controller unit **905***a* determines the velocity $\vec{v}$ of the vehicle **800**, such as in block **1115**.

In block **1335**, the controller unit **905***a* determines a schedule of times at which each file segment should be transmitted to the mobile terminal **860** from a DER **100**. The controller unit **905***a* makes this determination by using the speed and direction of the vehicle **800** that was determined in step **1330**, by using the speed of data transfer, and by using the size and number of file segments to be transferred.

For example, the controller unit **905***a* determines that at a first time t**1**, the file transfer should begin by transferring file segment A to the mobile terminal **860** and should end before t**2**. That is, each scheduled file transfer should end before the next schedule file transfer begins. At a second time t**2**, file segment B should be transferred to the mobile terminal **860**. At a third time t**3**, file segment C should be transferred to the mobile terminal **860**. At a fourth time t**4**, the last file segment D should be transferred to the mobile terminal **860**.

In block **1340**, the controller unit **905***a* determines projected locations of the vehicle **800** based on the velocity $\vec{v}$ of the vehicle. For example, a first reference time t**1**, the controller unit **905***a* determines that the vehicle **800** is located at a first location L**1** using the reflected RADAR signals of block **1325**. The controller unit **905***a* calculates a forecast of the locations of the vehicle **800** at times t**2**, t**3**, and t**4** (as scheduled in block **1335**). The controller unit **905***a* calculates that the vehicle **800** will be located at projected location L**2** at time t**2**, will be located at projected location L**3** at time t**3**, and will be located at projected location L**4** at time t**4**.

In block **1345**, the controller unit **905***a* determines which control unit would be coupled to the mobile station at each scheduled filed transfer time. The determination is based on the velocity $\vec{v}$ of the vehicle. For example, the controller unit **905***a* is coupled to the mobile station **860** via the first set of DERs **610***a* determines that at a first time t**1**, and that the first controller unit **905***a* should instruct the first set of DERs **610***a* to begin transferring file segment A to the mobile terminal **860**. The controller unit **905***a* determines that at a second time t**2**; that the second controller unit **905***b* will be coupled to the mobile station **860** via the second set of DERs **610***b* and should instruct the second set of DERs **610***b* to begin transferring file segment B to the mobile terminal **860**. The controller unit **905***a* determines that at a third time t**3**; that the third controller unit **905***c* will be coupled to the mobile station **860** via the third set of DERs **610***c* and should instruct the third set of DERs **610***c* to begin transferring file segment C to the mobile terminal **860**. The controller unit **905***a* determines that at a fourth time t**4**; that the fourth controller unit **905***d* will be coupled to the mobile station **860** via the fourth set of DERs **610***d* and should instruct the fourth set of DERs **610***d* to begin transferring file segment D to the mobile terminal **860**.

In block **1350**, the control unit **905***a* causes each control unit **905***a-d* to receive an assigned file segment to be transferred by that control unit to the mobile station. The control unit **905***a* uses the determination of block **1345** that the file segment B is assigned to be transferred by the second controller unit **905***b*. Accordingly, the controller unit **905***a* causes the second controller unit **905***b* to receive the second file segment to be transferred, file segment B. Likewise, the controller unit **905***a* causes the third controller unit **905***c* to receive the third file segment to be transferred, file segment C. The controller unit **905***a* causes the fourth controller unit **905***d* to receive the fourth file segment to be transferred, file segment D.

In certain embodiments, the controller unit **905***a* causes the second controller **905***b* to receive the assigned file segment by sending the assigned file segment to the second controller **905***b* via mutual coupling. In certain embodiments, the controller unit **905***a* causes the second controller **905***b* to receive the assigned file segment by sending an signal to the second controller **905***b* instructing the second controller **905***b* to retrieve the assigned file segment from the network.

In block **1355**, the controller unit **905***a* instructs each control unit **905***a-d* to transfer the respective assigned file segment to the mobile station **860** at the scheduled time (according to the schedule of block **1335**).

FIG. **14** illustrates a process for controlling traffic signals and safety devices according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process depicted in the example depicted is implemented by a processing circuitry in, for example, a data expansion roadway device.

In certain embodiments, a data expansion device (DED) is configured to communicate with or control traffic control or safety devices, or both. The traffic control or safety devices can include street lights, pedestrian lights, parking lot lights, traffic signals, traffic control gates, and the like. The traffic control or safety devices can be in a sleep or idle state and activate in response to an approaching vehicle or pedestrian. For example, a street light can be in an idle state, such as in a low energy state or off even though it is during a night time hour and ambient light levels would dictate that the streetlight should be on. As a vehicle or pedestrian approaches, the streetlight receives a signal from the DED that causes the streetlight to transition to an active state and activate in sufficient time to properly illuminate a respective area or section of the road. After the vehicle or pedestrian passes through the area or section of road, the streetlight receives another signal from the DED to return to the idle state.

In block **1405**, a data expansion device (DED), such as DER **100**, detects an on-coming vehicle. The DED can be configured as any one of the DER's **100** shown in FIGS. **1**A, **1**B, **2**A, **2**B, **2**C, **3**A, **3**B and **3**C and include control system **400** shown in FIG. **4**, or DER system **900** shown in FIG. **9**. The DED is coupled to one or more traffic control or safety devices, or signage, or a combination of these in the area. For example, the DED can be coupled to a traffic signal at a proximate intersection, coupled to one or more street lights or traffic signs that are designed to illuminate a section of road that includes or is proximate to the DED, or coupled to one or more billboards or pedestrian lights that are designed to illuminate a section of walkway that includes or is proximate to the DED. The traffic control or safety devices, or signage may be in a sleep state such that, even though the ambient light is low enough to require artificial illumination, such as during night time hours, the traffic control or safety devices, or signage are in an off-state or other low-voltage consumption state in which minimal illumination is generated or minimal power consumed for operation. As an example, a traffic signal may be in an idle state in which the signals in one direction are flashing yellow and the signals in another direction are flashing red, or the traffic signal may be configured to have the lights in one direction off or set to green and the lights in another direction set to red, or any other suitable variation as determined by transportation officials. The DED can be a single DER **100** or be a part of a system of DERs **100**, such as shown in FIGS. **6** and **10**. The DER **100** detects an oncoming vehicle or pedestrian. The DED can detect the on-coming vehicle or pedestrian via a communication signal with a mobile device included in the vehicle or carried by the pedestrian. In certain embodiments, the mobile device is in previous communication with the DED or a system of DERs **100** that include the DED. In certain embodiments, the mobile device has been handed over from another DER **100** or system of DERs **100**. The DED also can detect the on-coming vehicle or pedestrian via the RADAR unit **415** or camera **425**.

In block **1410**, the DED transmits a control signal to the traffic controls or safety devices, or signage, or a combination of these in the area. The control signal can be a signal indicting that the recipient devices needs to activate or transition to an active mode or and be a signal directing the recipient device how to operate. For example, when the DED detects an oncoming emergency response vehicle, the DED can transmit the control signal to a traffic signal to indicate to it that the light facing the oncoming emergency response vehicle should be green and the others red. As another example, the control signal can cause the street lights to illuminate in a section of roadway on which the vehicle is about to traverse. In certain embodiments, the DED activates the traffic controls or safety devices, or signage, or a combination of these in the area in stages. The DED computes the vehicle speed and determines a number of traffic signals and street lights to activate based on the expected arrival time of the vehicle in a certain area. As such, the DED can minimize energy consumption until such energy is required to illuminate the specified roadway. In certain embodiments, when the DED detects that a pedestrian is approaching, the DED activates pedestrian lights and crosswalk signals, while appropriately controlling the traffic signals, to enable the pedestrian to safely traverse the walkway. In certain such embodiments, the street lights may not be activated. Alternatively, when detecting a vehicle and no pedestrian, the DED can transmit one or more control signals that cause the traffic control devices and street lights to activate while leaving the pedestrian lights dormant. In certain embodiments, when the DED detects a subscribed member, such as by identifying an identifier in the mobile device or in response to a communication between the mobile device and the DED, the DED transmits the control signal corresponding to a user profile. For example, based on a known address of the subscriber member in the user profile, the DED can compute a most probable route for the vehicle or pedestrian and communicate with various traffic control devices, lights, signage and other DERs **100** to coordinate illumination along the path. In certain embodiments, based on a most probable path, or in response to communication from the mobile device coupled to a navigation system having a planned route, the DED communicates with one or more other DERs **100**, such as other DER chains, to determine traffic congestion and uncongested alternative routes. In certain such embodiments, the route calculations are performed in a central server or in an access point, such as node **407**.

In block **1415**, the respective traffic controls, safety devices, or signage in the area operate in response to the control signal. Based on the control signal, the traffic controls, safety devices, or signage transition to an active state or operational mode. The devices can illuminate such that one or more devices are active while others are inactive. The devices can illuminate for a specified period of time or until a second control signal is received instructing deactivation of the device. In certain embodiment, in response to the control signal, one or more billboards operate and display specified advertisements or messages, such as public service announcements.

In block **1420**, the respective traffic controls, safety devices, or signage in the area are returned to an idle, off or low energy consumption state. In certain embodiments, the respective traffic controls, safety devices, or signage in the area remain on for a specified period of time. In certain embodiments, the DED calculates a time period for the respective traffic controls, safety devices, or signage in the area to remain in the active states and communicates such time period as part of the control signal. In certain embodiments, after the time period has elapsed, the DED transmits a second control signal to the respective traffic controls, safety devices, or signage in the area causing the respective traffic controls, safety devices, or signage in the area to transition to the idle, off or low energy consumption state. In certain embodiments, the DED detects that the vehicle or pedestrian has left the area and transmits the second control signal causing the respective traffic controls, safety devices, or signage in the area to transition to the idle, off or low energy consumption state. In certain embodiments, when a second or subsequent DED detects the same vehicle or pedestrian, such as via an identification of an identifier in the mobile device, the DED transmits the second control signal to the respective traffic controls, safety devices, or signage in the area causing the respective traffic controls, safety devices, or signage in the area to transition to the idle, off or low energy consumption state.

FIG. **15** illustrates a process for detecting and reporting objects according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process depicted in the example depicted is implemented by a processing circuitry in, for example, a data expansion roadway device.

In certain embodiments, a second (i.e., another) DED in communication with the DED that detects a presence of a pedestrian to a nearby vehicle. That is, in accordance with the principles herein, the second DED is in communication with a vehicle or mobile device within the vehicle. The second DED communicates the presence of the pedestrian based on the information reported by the first DED, which detected the pedestrian, and based on the location of the first DED that detected the pedestrian. For example, the second DED can be aware of the location of the first DED that detected the pedestrian and, as such, determine that the pedestrian and the vehicle are in a near proximity although a driver of the vehicle and the pedestrian may be otherwise unaware of each other.

In block **1505**, a data expansion device (DED), such as a first DER **100**, detects an object near the device. The object may be a pedestrian, group of pedestrians, cyclist, vehicle, animal, or any object that has moved into proximity of the first DED. The first DED can be configured as any one of the DER's **100** shown in FIGS. **1**A, **1**B, **2**A, **2**B, **2**C, **3**A, **3**B and **3**C and include control system **400** shown in FIG. **4**, or DER system **900** shown in FIG. **9**. The first DED is coupled to one or more other DEDs, such as via DER network **600**, or coupled to one or more traffic control or safety devices, or signage, or a combination of these in the area. For example, the DED can be a single DER **100** or be a part of a system of DERs **100**, such as shown in FIGS. **6** and **10**. The first DER **100** detects an object. In certain embodiments, the first DER **100** include one or more sensors, such as motion, infrared or other optical, that can detect the object based on the movement of the object approaching the first DER **100**. In certain embodiments, the first DER **100** includes one or sensors, such as motion, thermal, optical, infrared, that detect an object when the object is within a certain distance from the first DER **100**. The first DER **100** also can detect the on-coming vehicle or pedestrian via the RADAR unit **415** or camera **425**.

In block **1510**, the first DER **100** transmits information regarding the detected object to one or more neighbor devices. The information can be a signal indicting that the object is detected. In certain embodiments, the information includes attribute information regarding the object, such as speed and direction the object is moving, size of the object, or an image of the object. For example, when the first DER **100** detects an oncoming object, the first DER **100** can capture a picture of the object and determine its speed and direction. The first DER **100** then can communicate the image of the object and the determined speed and direction to the neighbor DERs in a likely path of the object or every neighbor DER. In certain such embodiments, the first DER **100** communicates the information to a central server or to an access point and route calculations are performed in the central server or in the access point, such as node **407**.

In block **1515**, the first DER **100**, or one of the neighbor DERs identifies that a subscriber mobile device also is in proximity the respective DER. Based on the proximity of the subscriber mobile device, the respective DER communicates detected object information. In certain embodiments, the detected object information is the same as the information regarding the detected object, as discussed herein above. In certain embodiments, the detected object information includes information identifying a current or projected location of the object. In certain embodiments, the detected object information is displayed on a display of the subscriber mobile device and, optionally, includes an audible signal warning that can be broadcast from a speaker in or coupled to the subscriber mobile device. In certain embodiments, the DERs include an illumination element configured to provide a visual indication that the presence of the object has been detected. For example, upon receiving the information regarding the detected object from the first DER **100**, the respective DER activates the illumination element to provide a visual indication to any individuals in proximity, including a user of the subscriber mobile device. The DERs can illuminate for a specified period of time or until a second signal is received instructing deactivation of the DER, such as in response to the object leaving a proximity of the DERs. The DERs can be configured with multicolor illumination devices, such as a multicolor light emitting diode (LED), configured to provide a visual indication in different colors. For example, the DERs can use a first color to indicate a moving object, a second color for a stationery object, a third color for an approaching object, a fifth color for a retreating object, a sixth color to indicate a possible collision course with the detected object, flashing same or different colors for certain conditions, and so forth for any of a number of different specified conditions. For example, the illumination element can include a colour changing LED assembly that is capable of emitting different colors in response to different signals or different applied voltages. That is, each colour changing LED includes at least three LEDs in a package along with a small computer or processor to drive them. The three LEDs include a red LED, a green LED and a blue LED, each of which can be controlled by a microcontroller or processor. A similar assembly can be used for the other types of light sources.

In certain embodiment, the DERs are configured to not communicate detected object information to the subscriber mobile device upon a determination by the DER that the detected object is the subscriber mobile device. For example, one or more of the DERS can compare information in the detected object information (or information regarding the detected object) with information regarding the subscriber mobile device. For example, a second DER **100** can compare a physical location of the detected object received from the first DER **100** with position information of a subscriber mobile device in communication with the second DER **100** and determine the positions or speed and direction match. After determining the object is the subscriber mobile device, the second DER **100** refrains from sending any detected object information to the subscriber mobile device. In certain embodiments, the second DER **100** communicates the determination that the object is the subscriber mobile device to another neighbor DER, such as a third DER **100**. The third DER **100** is configured to then provide additional detected object information to another subscriber mobile device regarding a presence of the subscriber mobile device.

In block **1520**, upon a determination that the object is no longer in proximity, the first DER **100** returns to an idle, observation, or detection ready state, off or low energy consumption state. The first DER **100** can deactivate any illumination devices are transition a color of the illumination devices for a specified period of time to indicate that an object recently was in the area but is now departed.

Although various features have been shown in the figures and described above, various changes may be made to the figures. For example, the size, shape, arrangement, and layout of components shown in FIGS. **1** through **6** and **8** are for illustration only. Each component could have any suitable size, shape, and dimensions, and multiple components could have any suitable arrangement and layout. Also, various components in FIGS. **1** through **6** could be combined, further subdivided, or omitted and additional components could be added according to particular needs. For instance, a system using GTDs could support only cellular or satellite communications. Further, each component in a device or system could be implemented using any suitable structure(s) for performing the described function(s). In addition, while FIGS. **7**, **11**, **12**, **13**, **14** and **15** illustrate various series of steps, various steps in FIGS. **7**, **11**, **12**, **13**, **14** and **15** could overlap, occur in parallel, occur multiple times, or occur in a different order.

Although an exemplary embodiment of the present disclosure has been described in detail, those skilled in the art will understand that various changes, substitutions, variations, and improvements disclosed herein may be made without departing from the spirit and scope of the disclosure in its broadest form.

None of the description in the present application should be read as implying that any particular element, step, or function is an essential element which must be included in the claim scope: the scope of patented subject matter is defined only by the allowed claims. Moreover, none of these claims are intended to invoke paragraph six of 35 USC §112 unless the exact words "means for" are followed by a participle.

What is claimed is:

1. A system comprising:

a first traffic control device comprising processing circuitry configured to couple via a first WiFi network to a first mobile terminal in a first vehicle and to couple to a backhaul network through a first communication interface, wherein first vehicle attribute information is provided from the first mobile terminal to the first traffic control device via the first WiFi network, and wherein the first vehicle attribute information comprises first vehicle location, speed or direction information; and a second traffic control device communicatively coupled to the first traffic control device and configured to detect a presence of an object in the proximity of the second traffic control device and to detect object attribute information comprising object location, speed and direction information;

wherein the second traffic control device is configured to communicate the presence of the object and the object attribute information to a network controller connected to the backhaul network, the first traffic control device, or a third traffic control device.

2. The system of claim **1**, wherein each of the first and second traffic control devices comprise a roadway reflector; a pedestrian pathway marker; a street sign; a traffic signal; or a streetlight.

3. The system of claim **1**, wherein a connection between the first traffic control device and the second traffic control device comprises a daisy chain.

4. The system of claim **1**, wherein the third traffic control device comprises a traffic signal, street lights, pedestrian lights, crosswalk signals, safety signage or a billboard.

5. The system of claim **1**, wherein the object comprises a vehicle, a pedestrian, or an animal.

6. The system of claim **1**, wherein the vehicle comprises a moving vehicle and the second traffic control device is configured to:

communicatively receive from the first traffic control device the first vehicle attribute information via the backhaul network or a daisy chain connection;

compare the first vehicle attribute information with the object attribute information and determine whether the first vehicle is on a possible collision course with the object; and

wherein when a possible collision of the vehicle with the object is determined, communicate possible collision information to the network controller connected to the backhaul network, the first traffic control device, or the third traffic control device.

7. The system of claim **6**, wherein a safety device or sign proximate to a path of the first vehicle's possible collision with the object and in communication with the backhaul network, the first traffic control device, or the third traffic control device is activated upon receipt of the possible collision information from the second traffic control device.

8. The system of claim **1**, wherein the first traffic control device is configured to communicate the detected presence of the object and the detected object attribute information to the first mobile terminal in the first vehicle.

9. A method comprising

communicating over a first WiFi network, by a first traffic control device, with a first mobile terminal in a first vehicle;

detecting, by a second traffic control device communicatively coupled to the first traffic control device by a backhaul network or a daisy chain, a presence of an object in proximity of the second traffic control device and object attribute information comprising object location, speed and direction information; and

communicating, by the second traffic control device, the presence of the object and the object attribute information to a network controller connected to the backhaul network, the first traffic control device, or a third traffic control device.

10. The method of claim **9**, wherein each of the first and second traffic control devices comprise a roadway reflector, a pedestrian pathway marker, a street sign, a traffic signal or a streetlight.

11. The method of claim **9**, wherein the third traffic control device comprises a traffic signal, street lights, pedestrian lights, crosswalk signals, safety signage or a billboard.

12. The method of claim **9**, wherein the object comprises a vehicle, a pedestrian, or an animal.

13. The method of claim **9**, wherein detecting the presence of the object in proximity of the second traffic control device and the object attribute information comprises:

detecting, using a motion sensor, a moving object in the proximity of the second traffic control device;

determining by the motion sensor the object attribute information;

receiving the first vehicle attribute information from the backhaul network or a daisy chain connection with the first traffic control device;

comparing the first vehicle attribute information with the object attribute information and determining whether the first vehicle is on a possible collision course with the object; and

when a possible collision of the first vehicle with the object is determined, communicating information regarding the possible collision course to the network controller connected to the backhaul network, the first traffic control device, or the third traffic control device.

14. The method of claim **13**, further comprising:

in response to the communication of information regarding the possible collision course, activating, at least one safety device or sign that is proximate to the path of the first vehicle's possible collision with the object, the at least one safety device or sign being in communication with the backhaul network, the first traffic control device, or the third traffic control device.

15. The method of claim **9**, further comprising:

communicating, by the first traffic control device, the detected presence of the object in proximity to the second traffic control device and the object attribute information to the mobile device in the first vehicle via the WiFi network.

16. A first roadway device comprising:

a wireless transceiver configured to communicate with an electronic device in a vehicle using a WiFi network;

a communication interface configured to communicatively couple to a second roadway communication device using a backhaul network or a daisy chain connection;

processing circuitry configured to:

detect a presence of an object in proximity of the first roadway device and further determine object attribute information comprising an object location, speed, or direction of the detected object; and

communicate the detected presence of the object and the determined object attribute information to a network controller connected to the backhaul network or the second roadway device; and

a housing configured to contain the processing circuitry, communication interface and the wireless transceiver.

17. The roadway device of claim **16**, wherein the housing comprises a roadway reflector, a pedestrian pathway marker, a street sign, a traffic signal or a streetlight.

18. The roadway device of claim **16**, wherein the second roadway device comprises a traffic signal, street lights, pedestrian lights, crosswalk signals, safety signage or a billboard.

19. The roadway device of claim **16**, wherein the object comprises a vehicle, a pedestrian, or an animal.

20. The roadway device of claim **16**, wherein the vehicle comprises a moving vehicle and the processing circuitry is further configured to:

determine vehicle attribute information comprising vehicle location, vehicle speed or vehicle direction of travel; and

communicate the vehicle attribute information to the network controller connected to the backhaul network or the second roadway device.

21. The roadway device of claim **20**, wherein in response to the vehicle attribute information, the processing circuitry is configured to cause one or more safety devices or signs in proximity of the second roadway device to be activated.

22. The roadway device of claim **16**, wherein the processing circuitry is further configured to communicate, via the wireless transceiver, information regarding the presence of the object to the electronic device in the first vehicle.

23. The roadway device of claim **20**, wherein the processing circuitry is further configured to determine the vehicle speed, the vehicle direction of travel or vehicle location from vehicle information communicated from the electronic device in the vehicle using the WiFi communication network.

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