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(54) HACKER-RESISTANT DENIAL OF WIRELESS DEVICE OPERATION IN RESTRICTED AREAS

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(63) Continuation of application No. 14/446,316, filed on Jul. 29, 2014, now abandoned, which is a continuation of application No. 13/763,638, filed on Feb. 9, 2013, now Pat. No. 8,965,341, which is a continuation of application No. 12/692,601, filed on Jan. 23, 2010, now Pat. No. 8,380,170.

(60) Provisional application No. 61/168,610, filed on Apr. 12, 2009, provisional application No. 61/170,626, filed on Apr. 19, 2009.

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(52) **U.S. Cl.**

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(57) ABSTRACT

A system for restricting operation of wireless devices, for example cell phones, comprises a controller and a plurality of sensors. The system restricts device usage, while permitting emergency phone calls, for example 911 calls. The sensors receive transmissions from devices, and use the transmissions for identification and determining whether a device is within a restricted zone. One disclosed method is triangulation, using time of arrival of transmissions at the sensors. If the device is within the zone, the controller sends device identification, and possibly a customized restriction request, to a remote node, for example a control node of a cell phone network operator. The operator then uses its network resources to implement the requested restrictions. Communication between the controller and the remote node is secure, possibly encrypted, to minimize malicious interference. A wireless control can define vertices of the zone and exempt certain devices from restrictions. Jamming is not required.

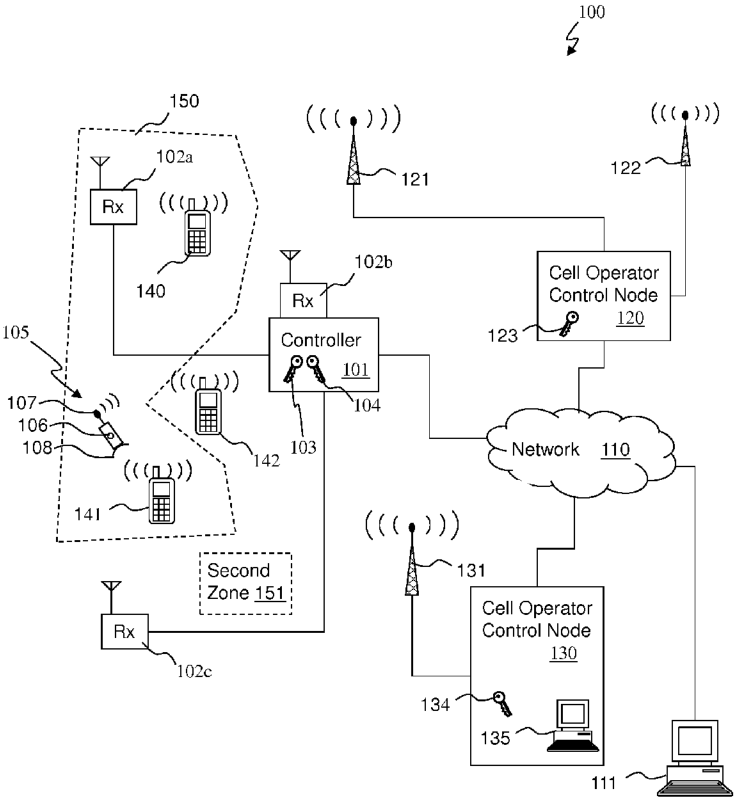


FIG. 1

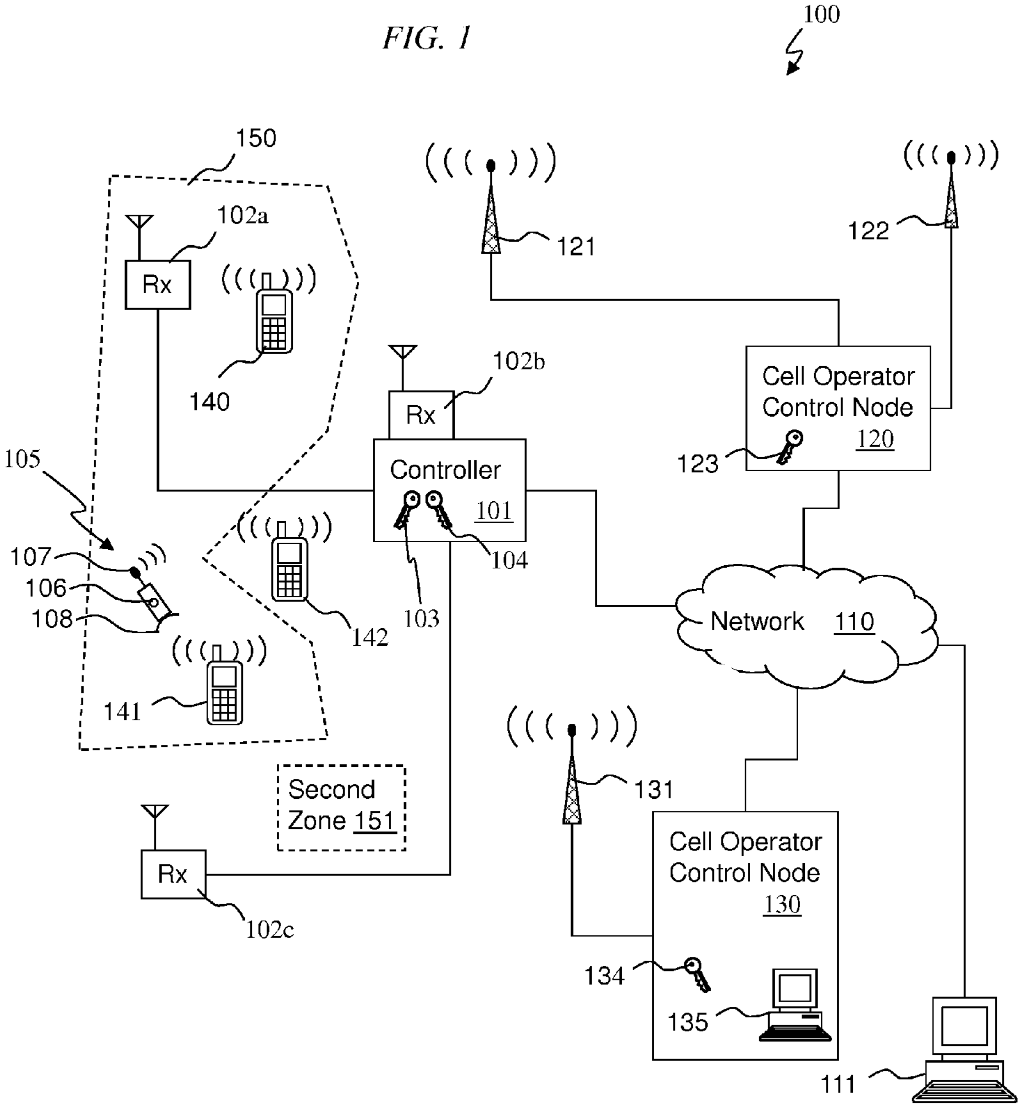

100
150
102a
Rx
140
121
122
102b
Rx
Controller
101
Cell Operator
Control Node
120
123
105
107
106
108
104
103
142
141
Network 110
131
Second
Zone 151
Rx
102c
Cell Operator
Control Node
130
134
135
111

FIG. 2
(Prior Art)

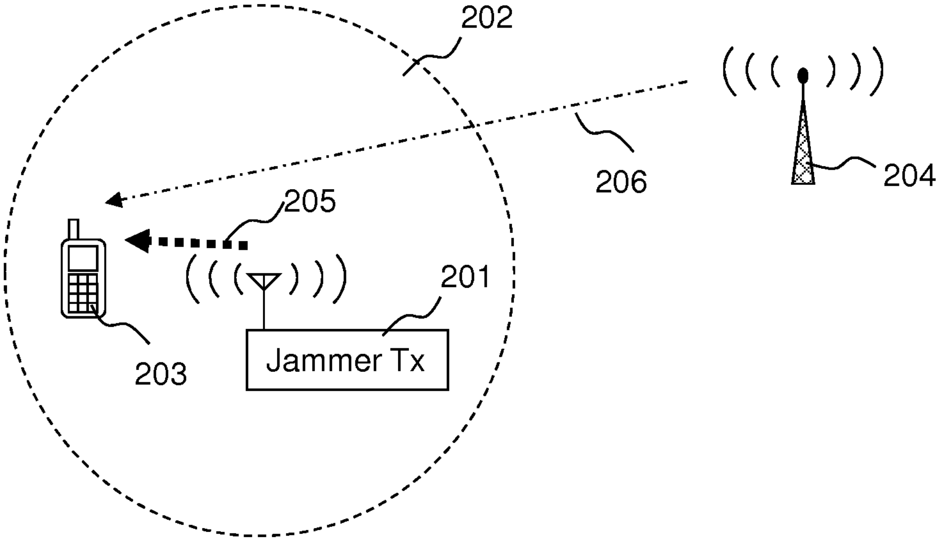


FIG. 3
(Prior Art)

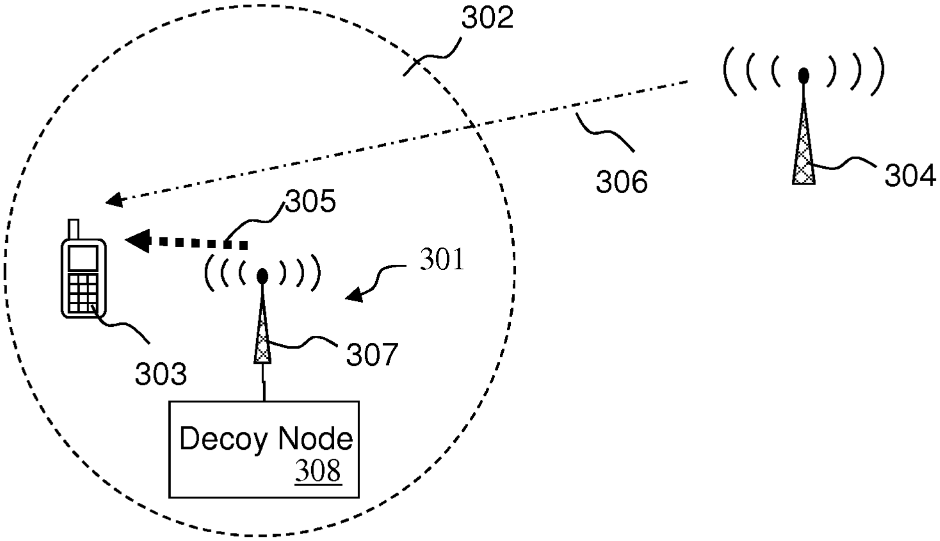


FIG. 4

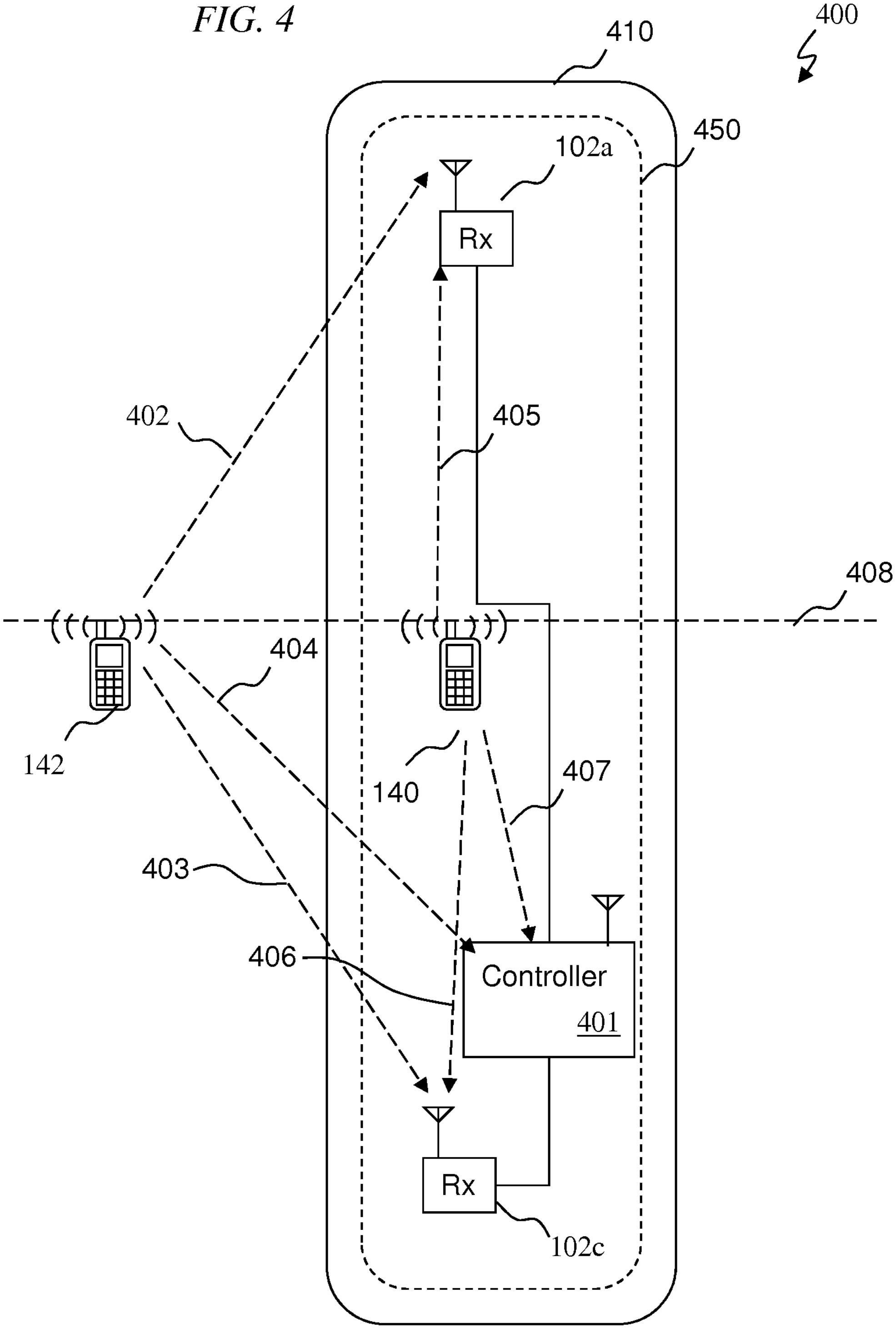

400
410
450
102a
Rx
402
405
408
404
142
140
407
403
406
Controller
401
Rx
102c

FIG. 5

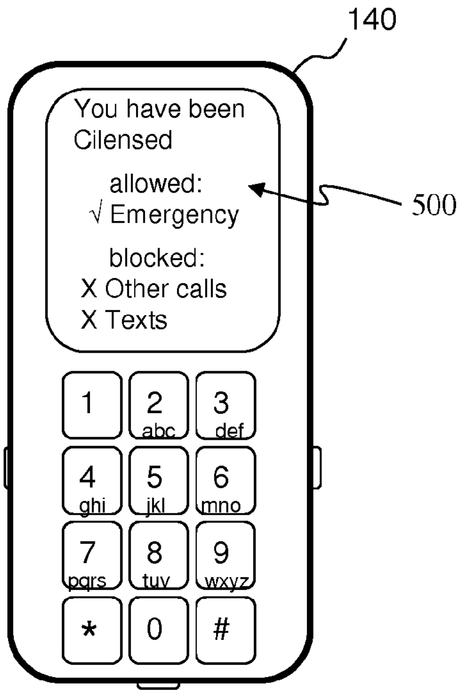

140
500
You have been
Cilensed
allowed:
√ Emergency
blocked:
X Other calls
X Texts
1
2 abc
3 def
4 ghi
5 jkl
6 mno
7 pqrs
8 tuv
9 wxyz
*
0
#
141
501
You have been
Cilensed
allowed:
√ Emergency
√ Texts
blocked:
X Other calls

FIG. 6

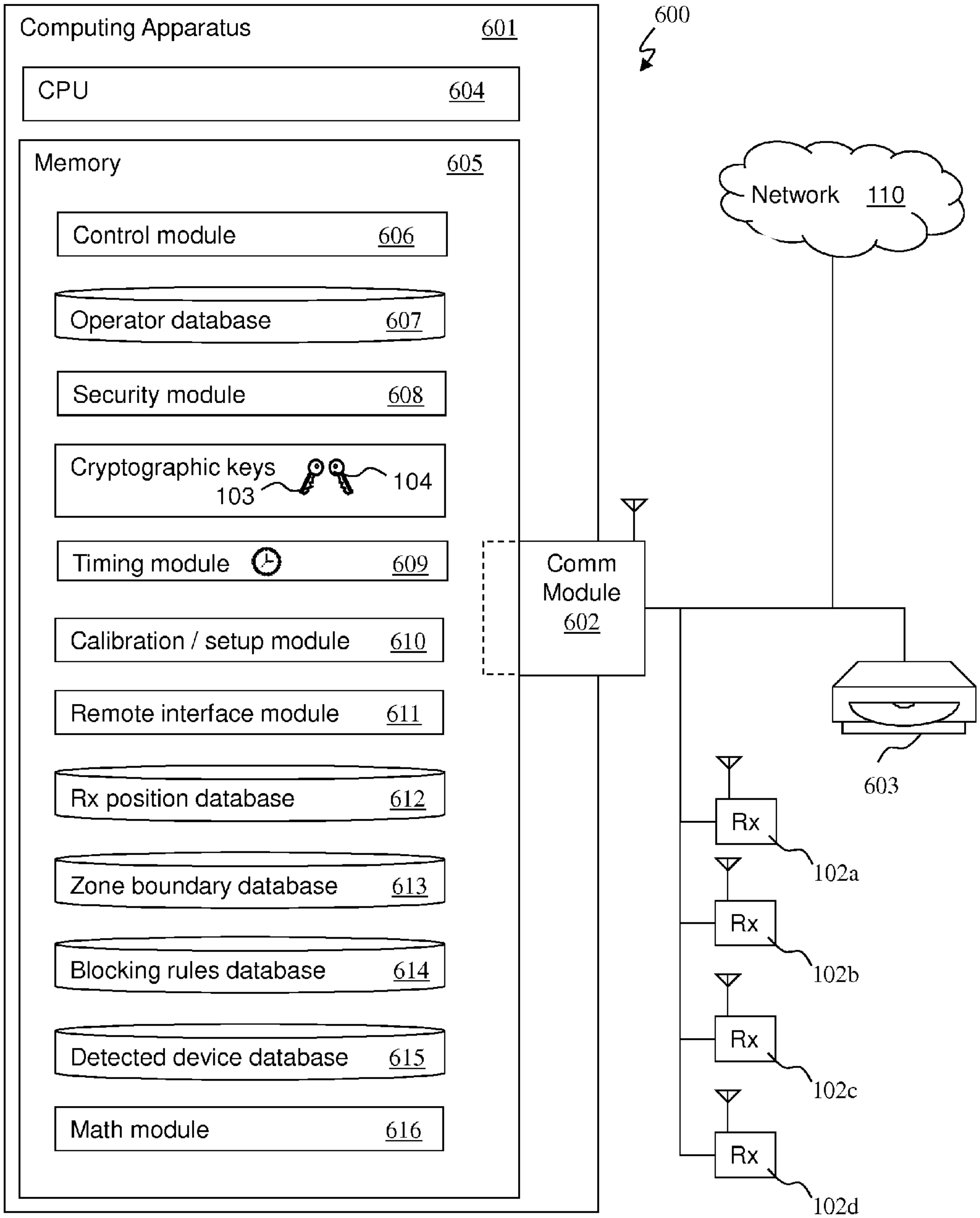

600
Computing Apparatus 601
CPU 604
Memory 605
Control module 606
Operator database 607
Security module 608
Cryptographic keys
103
104
Timing module 609
Calibration / setup module 610
Remote interface module 611
Rx position database 612
Zone boundary database 613
Blocking rules database 614
Detected device database 615
Math module 616
Comm Module 602
Network 110
603
Rx
102a
Rx
102b
Rx
102c
Rx
102d

FIG. 7

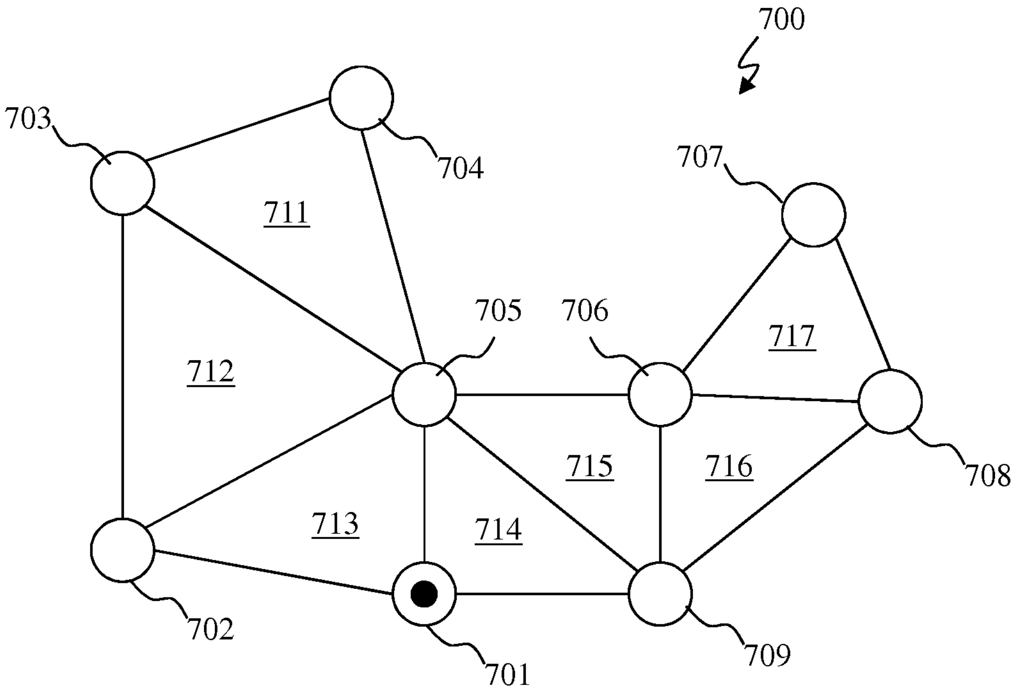

700
703
704
711
707
705
706
717
712
715
716
708
713
714
702
701
709

FIG. 8

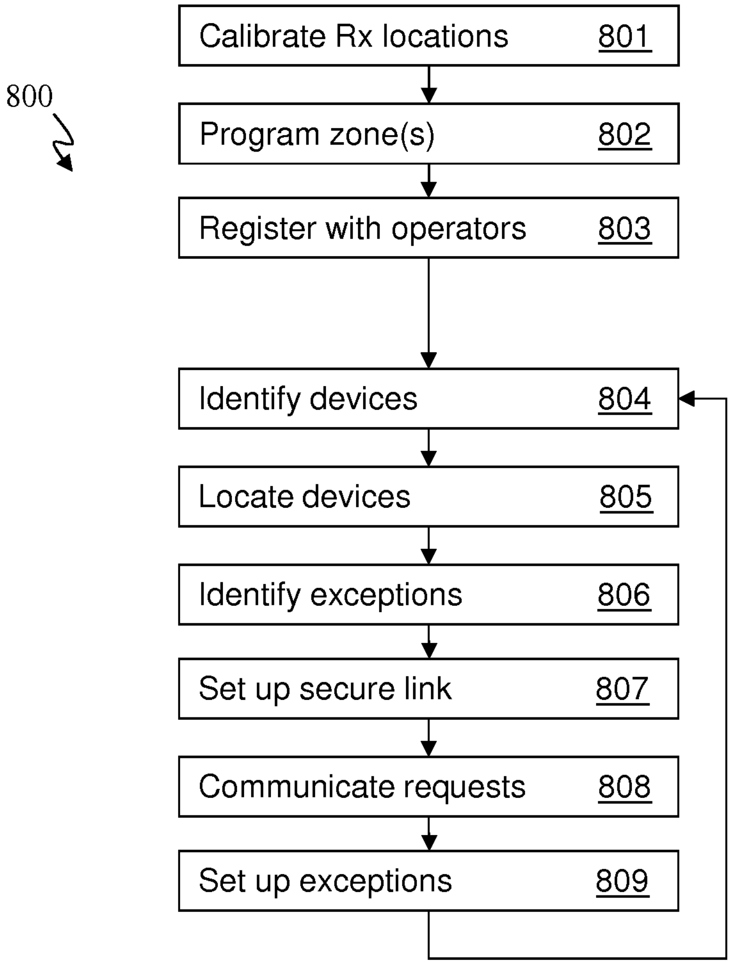

800
Calibrate Rx locations 801
Program zone(s) 802
Register with operators 803
Identify devices 804
Locate devices 805
Identify exceptions 806
Set up secure link 807
Communicate requests 808
Set up exceptions 809

FIG. 9

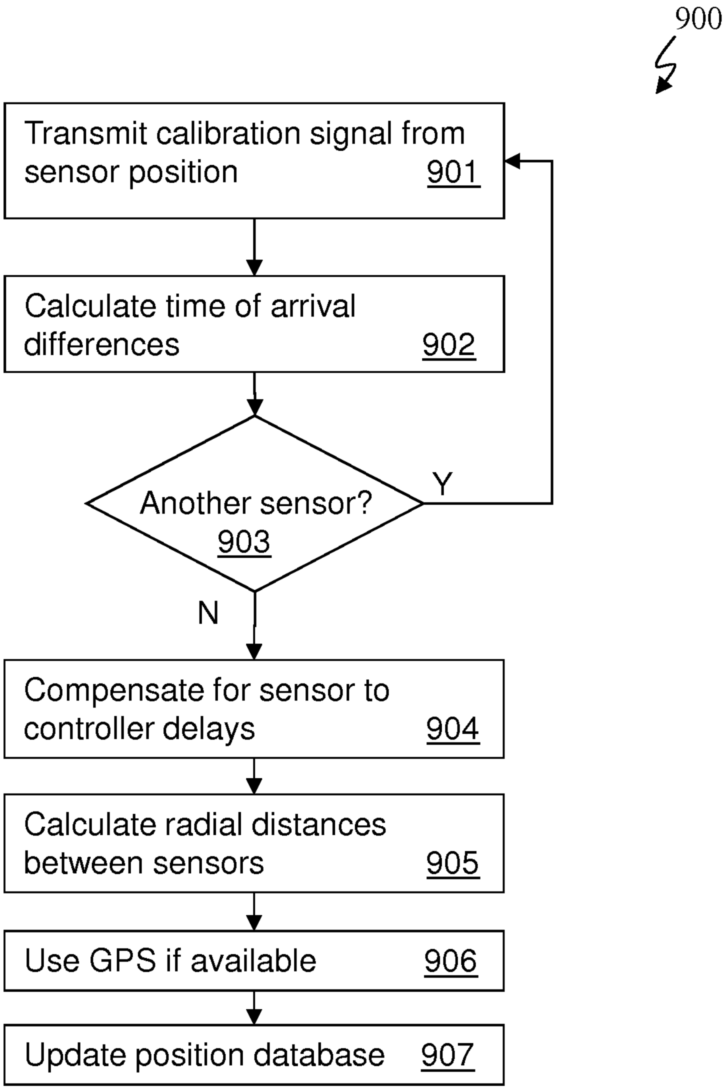

900
Transmit calibration signal from sensor position 901
Calculate time of arrival differences 902
Another sensor? 903
Y
N
Compensate for sensor to controller delays 904
Calculate radial distances between sensors 905
Use GPS if available 906
Update position database 907

FIG. 10

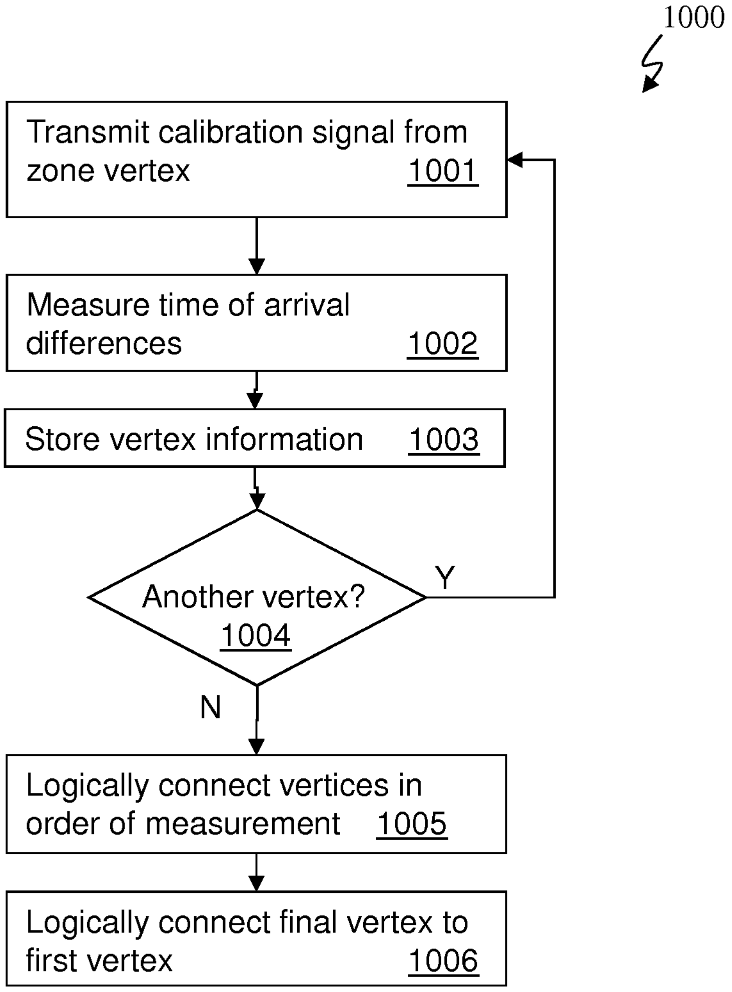
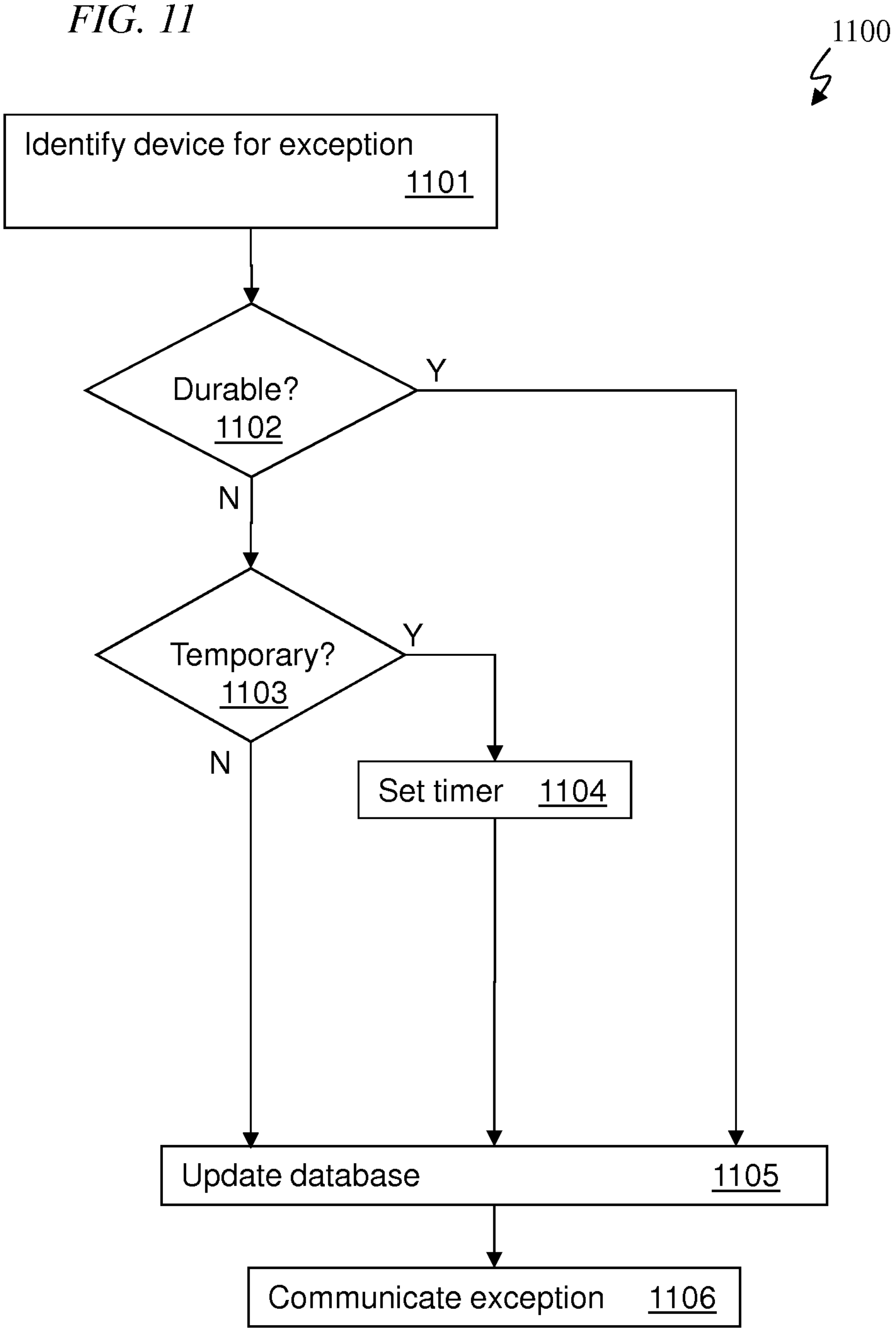

1000
Transmit calibration signal from zone vertex 1001
Measure time of arrival differences 1002
Store vertex information 1003
Another vertex? 1004
Y
N
Logically connect vertices in order of measurement 1005
Logically connect final vertex to first vertex 1006

FIG. 11


1100
Identify device for exception 1101
Durable? 1102
Y
N
Temporary? 1103
Y
N
Set timer 1104
Update database 1105
Communicate exception 1106

HACKER-RESISTANT DENIAL OF WIRELESS DEVICE OPERATION IN RESTRICTED AREAS

RELATED APPLICATIONS

[0001] This a continuation of U.S. patent application Ser. No. 14/446,316, filed on Jul. 29, 2014, which is a continuation of U.S. patent application Ser. No. 13/763,638, filed on Feb. 9, 2013, now U.S. Pat. No. 8,965,341, which is a continuation of U.S. patent application Ser. No. 12/692,601, filed on Jan. 23, 2010, now U.S. Pat. No. 8,380,170, and claims priority thereto, and further claims priority from U.S. Provisional Patent Application Ser. No. 61/168,610, filed on Apr. 12, 2009 and U.S. Provisional Patent Application Ser. No. 61/170,626, filed on Apr. 19, 2009.

TECHNICAL FIELD

[0002] The present invention relates generally to cellular device detection and control by a third party, and more particularly to limiting cellular device usage, within a defined control zone, to predetermined allowable actions.

BACKGROUND

[0003] "Please silence your cell phones." But people don't. Either they forget, or they're just plain inconsiderate. So, cell phones ring in theaters, libraries, during church services and even during funerals. Sometimes, the bright light of a cell phone screen can irritate movie-goers, if someone is typing a text message or email in an otherwise dark theater. The requests and signs, displayed in areas intended for a disturbance-free experience, simply do not work much of the time.

[0004] In other situations, cell phone usage has more dire consequences. Cell phones in prisons can facilitate criminal activity, enabling violent prisoners to plan escapes or control gang activity outside prison walls. An Oct. 22, 2008 Associated Press release, titled "Prison Officials Hindered by Pro-Cell-Phone Rules", documented a murder that was facilitated by a cell phone used within a prison. A Nov. 21, 2008 USA Today article, titled "Smuggled phones flourish in prisons—Federal law bans signal jamming", describes escapes, drug deals, and harassment of victims by prisoners using cell phones.

[0005] Prison officials are currently searching for ways to address the problem of cell phone usage within prisons and, according to both articles referenced above, some state officials have even considered the use of cell phone jammers that violate the Federal Communications Act. Besides their illegality, such jammers can also interfere with emergency calls, which can create new dangers.

[0006] The current situation, that state officials are considering violating federal laws and are willing to block even access to emergency services in some areas, in order to combat a more pervasive threat posed by cell phone usage, is clear evidence that there has been a failure by others to effectively curtail cellular device usage within defined control zones, while still permitting access to emergency services.

[0007] Further evidence, that there has been a failure of others to solve the problem of cell phone usage in certain areas, includes recent incidents of jurors using cell phones to surf the internet to look for outside evidence on a case. A Mar. 17, 2009 New York Times article, titled "As Jurors Turn to Web, Mistrials Are Popping Up", quoted the president of the American Society of Trial Consultants as stating "It's really impossible to control it."

[0008] Not any more.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0010] FIG. **1** illustrates an embodiment of a system for restricting operation of wireless devices.

[0011] FIGS. **2** and **3** illustrate prior art systems for restricting operation of wireless devices.

[0012] FIG. **4** illustrates another embodiment of a system for restricting operation of wireless devices.

[0013] FIG. **5** illustrates wireless devices showing indications of restricted operation.

[0014] FIG. **6** illustrates another embodiment of a system for restricting operation of wireless devices.

[0015] FIG. **7** illustrates another embodiment of a system for restricting operation of wireless devices.

[0016] FIG. **8** illustrates a method of restricting operation of wireless devices.

[0017] FIG. **9** illustrates a method associated with restriction of wireless device operation.

[0018] FIG. **10** illustrates another method associated with restriction of wireless device operation.

[0019] FIG. **11** illustrates another method associated with restriction of wireless device operation.

DETAILED DESCRIPTION OF THE INVENTION

[0020] FIG. **1** illustrates an embodiment of a system **100** for restricting operation of wireless devices, and includes an embodiment of a Cilense™ system. However, the prior art systems, illustrated in FIGS. **2** and **3**, will be described first, in order to assist in understanding the novelty of the present invention.

[0021] FIG. **2** illustrates a prior art jamming device **201**, which transmits high power radio waves to create an interference zone **202**, intended to prevent usage of a wireless device **203**, shown as a cellular phone. Other wireless devices could also be affected. Base station tower **204** would be the serving base station, if not for the operation of jammer **201**. One principle of operation is that the radio signal **205** from jammer **201** overpowers the radio signal **206** from tower **204**, preventing device **203** from properly processing any communications from tower **204**. Alternatively, or additionally, jammer **201** could interfere with tower **204** receiving communications from device **203**. Only one direction of the communication path between device **203** and tower **204** needs to be interrupted, in order to prevent usage of most cellular devices.

[0022] FIG. **3** illustrates a prior art decoy system **301**, which tricks wireless device **303**, shown as a cellular phone, into registering with a decoy base station node **308**, thereby dropping communication with the proper serving base station tower **304**. Decoy base station node **308** will not accept calls initiated by a user of device **303**, and once device **303** has dropped registration with tower **304**, any ongoing calls will be dropped and incoming calls from the operator of tower **304** will not connect.

[0023] The principle of operation is that within zone **302**, the radio signal **305** from decoy base station transmitter **307**

is stronger than the radio signal **306** from proper serving base station tower **304**. Since older models of cell phones typically attempt to register with the strongest serving cell tower, this system relies on that programmed-in behavior to cause the cell phone to swap to decoy system **301**, comprising decoy base station node **308** and decoy base station transmitter **307**. Presumably, decoy base station node **308** has processing capability necessary to trick device **303** into completing a hand-off from proper serving base station tower **304** to decoy system **301**.

[0024] Other systems use GPS signals, received by a cell phone, to determine whether a person is in a moving vehicle, and if so, to prevent the use of the cell phone. Still other systems rely on local transmitters to send a signal, which is received by the cell phone, to instruct the cell phone to restrict functionality.

[0025] All of these systems suffer from severe drawbacks. Jammers are illegal, and can present significant safety problems, because they prevent even critical, legitimate emergency calls, such as calls to 911 in the US. Jammers can also create interference that prevents operation of even devices that should not have their usage restricted. It is difficult to tailor the size and shape of a restriction zone controlled by a jammer solution. Further, multipath and shadowing effects can defeat a jammer, even sometimes within the intended restriction zone.

[0026] The decoy system is effectively impractical for many situations in need of a restriction zone. Transmitting on cellular telephone frequencies typically requires a government-issued license, and such activity is heavily regulated. Due to radio frequency interference issues, licenses may not be available for potential customers of a decoy solution. Decoy solutions also suffer from the same zone boundary definition problems as jammer solutions, as well as risks that multipath and shadowing effects will disable the decoy's ability to present a luring target for a device within the intended restriction zone. Users of both jammer and decoy solutions are likely to be inundated with complaints by their local area neighbors, as unwanted transmitted energy, from the jammer or decoy, spills out of the area that is under the ownership or control of the person or entity, who is entitled to create a restriction zone on their own property.

[0027] Further, decoy systems operate on an assumption that may not be valid in future generations of cellular devices. A possible change in the operation of cellular devices is that base station hand-off may not be based on which of multiple, nearby base stations provides the strongest signal, but rather, which one can provide the highest data rate or lowest bit error rate. This additional hand-off criterion requires significant additional complexity for a decoy system because, for a decoy system to function with such newer phones, the decoy will need to spoof replies to network communication parameter inquiries from the cell phone, with better answers than the legitimate serving base station. Otherwise, there may be no hand-off, even if the decoy provides a stronger signal.

[0028] Systems using GPS signals are subject to easy override by a cell phone user, simply by disabling the GPS receiver. Also, at times when the cell phone's GPS receiver is enabled, but not tracking GPS satellites well enough to obtain a position or speed measurement, a GPS-based system simply will not work. Systems which rely on local transmitters to send a restricted-use signal to a cell phone, for example using ultrasonic waves or Bluetooth, are subject to over-ride if the cell phone user makes any modifications to the cell phone that interferes with the reception or processing of a restricted-use signal.

[0029] Returning now to FIG. **1**, system **100** will be described. In contrast with the shortcomings of the described prior art, the inventive system described herein (a) does not cause radio interference for neighbors; (b) provides for an easily-tailored restriction zone—even a zone that can move at appreciable speeds, for example within an airplane passenger cabin; (c) does not rely on reception and processing by the wireless device of potentially unavailable signals, for example GPS signals; and (d) is not subject to such easy defeats, as described above.

[0030] Embodiments of the disclosed system for restricting operation of wireless devices, for example cell phones, comprise a controller and a plurality of sensors, for example three or more. Embodiments of the system can therefore restrict device usage, even while permitting emergency phone calls, for example 911 calls in the US and other emergency telephone numbers in other locations. The system operates remotely from a cellular base station site, and so may remain under control of an entity that is not a cellular network operator and does not have access to cellular base station site equipment.

[0031] The sensors receive transmissions from wireless devices, and use data within the transmissions to identify particular devices, for example device identification or registration data, which the device is transmitting to a base station. The transmissions can also be used to determining whether an identified device is within a restricted zone. One disclosed method is triangulation, using time of arrival of transmissions at the sensors, although other methods are disclosed, such as using transmission time slot information from time domain multiplexing systems, to estimate the range of a device from a sensor. For triangulating systems, sensor-to-controller communication delays are accounted for, to enable more accurate position calculation of the device. Direction of arrival may be used in some systems, by incorporating directional antennas in one or more sensors.

[0032] If a wireless device is within the restriction zone, the controller sends device identification, and possibly a customized restriction request, to a remote node, for example a control node of a cell phone network operator. The cell phone network operator then uses its network resources to implement the requested restrictions. This reduces the chance that user modification of the wireless device can defeat the operation of the system to restrict device usage.

[0033] In some embodiments, communication between the controller and the remote node is secure, possibly encrypted, to minimize malicious interference, for example from hackers who would attempt to disable the cell phone of someone who is not in a restriction zone, or prevent disabling of a device that is within a restriction zone. In some embodiments, a wireless control can define vertices of the zone, exempt certain devices from restrictions or customize restrictions, and even assist with calibrating sensor positions during system setup.

[0034] System **100** comprises a controller **101** and three sensors, **102**_a_-**102**_c_, each of which includes a radio receiver capable of intercepting signals from cellular devices **140**, **141**, and **142**. Additional sensors may be used. Each sensor should have a way to uniquely identify itself to controller **101**, such as by using a sensor-specific communication channel, or providing some type of encoding on data sent to controller

101. In the illustrated embodiment, sensors **102***a* and **102***c* are illustrated as being coupled to controller **101** with lines. The coupling between sensors **102***a*-**102***c* may be wired or wireless, including radio and infrared data links. Sensor **102***b* is illustrated as attached to controller **101**. In some embodiments, a sensor may be attached physically to a controller, for ease of transportation and setup, although this is not required.

[0035] Controller has two defined restriction zones, zone **150** and zone **151**, which is separate from zone **150**. This is possible because, in the illustrated embodiment, controller **101** can enforce multiple, arbitrarily-shaped restriction zones. The restriction zones are defined within the memory of controller **101**. When the position of a wireless device is calculated, controller **101** determines whether that wireless device is inside or outside of a restriction zone. As illustrated, wireless devices **140** and **141** are within zone **150**, while wireless device **142** is outside of both zones **150** and **151**, even though device **142** is within a triangle defined by the positions of sensors **102***a*-**102***c*. It should be noted that, since even positions can be determined for wireless devices that are outside of a triangle defined by the positions of sensors **102***a*-**102***c*, zone **150** extends past sensor **102***a*.

[0036] Simple triangulation schemes could be used, which have lower computational requirements, such as systems that define a restriction zone such that the sensors comprise the vertices of the restriction zone. A nearly arbitrarily-shaped zone can be created with such a system, by using a plurality of sensors, such that each combination of three sensors forms a sub-zone. Thus, a rectangular exclusion zone could be formed using four sensors, A,B,C,D, with A,B,C forming the vertices of one triangular sub-zone, and B,C,D forming the vertices of a second, adjacent triangular sub-zone.

[0037] Because devices **140** and **141** are inside zone **150**, controller **101** will identify them, using their transmissions to base station towers **121** and **134**, which are intercepted by one or more of sensors **102***a*-**102***c*. Controller may also obtain identification information for device **142**, because it is in range of at least one of sensors **102***a*-**102***c*. Since cell phones identify themselves when attempting to register with a base station, or initiate a communication session, and typically radiate in multiple directions, controller **101** can listen to the attempted registration or communication date traffic, and identify the devices using information available to base station towers **121** and **122**. The identification information for at least devices **140** and **141** will be communicated to the cellular network operators, so that the cellular network operators can restrict communication between their base station and any devices that are using that operator's network.

[0038] These restrictions may include blocking voice calls, while allowing emergency calls, blocking outgoing text (SMS) messages, blocking incoming text messages, and blocking other data transactions, such as incoming and outgoing non-voice communication. Additional restrictions could be blocking voice calls, either incoming or outgoing, unless they are on a list of pre-approved numbers. Other restrictions could be that calls are blocked unless an urgent call fee is paid to allow the urgent call through. This enables urgent calls in some restriction zones, but provides an incentive for the users to minimize their time and duration. The urgent call fee may be per call, with an optional per-minute additional charge. This potential revenue stream can serve as an incentive for cellular phone network operators to comply with a third party request to block a call to a customer. Some restrictions may be that a predefined total talk time is permitted, or a pre-approved number of calls and texts may be permitted. In some embodiments, non-communication functionality may be restricted, for example, in dark areas, having a brightly illuminated screen may be a distraction.

[0039] Other restrictions could be that phones are set to vibrate mode, automatically, just in case the owners forget to do it themselves, but calls are still permitted though. Then considerate people, aware that a call is coming in, can move to a more secluded area to take the call. However, non-communication functionality restriction may require that the wireless device receive and comply with an instruction, from either the cellular operator network or controller **101**, to restrict the functionality.

[0040] The restrictions are possible to implement in cellular network equipment, because the cellular networks handle the communication traffic received at a base station tower from a cellular device. Typical cellular networks already have the ability to block traffic from a particular cellular device upon, the device owner's account being suspended for non-payment of a bill. Yet, even for such an account suspension emergency calls, for example calls to 911 in the US, are still supported. Upon receiving a request from controller **101**, a cellular network operator can perform actions somewhat similar to those taken for a delinquent account, but on a considerably shorter term basis.

[0041] Controller **101** has security tokens, for example encryption keys **103** and **104**, which may comprise keys for symmetric encryption, asymmetric encryption, or both. This is because, in the illustrated embodiment, controller **101** is connected to a cellular network operator control node **120** and a cellular network operator control node **130** through a public computer network **110**. Nodes **120** and **130** have counterpart keys **123** and **134**, respectively. Public computer network **110** may be the internet, which is filled with malicious threats. For example, hacker computer **111** is also connected to computer network **110**. If a more private connection was available, for example a dedicated connection between controller **101** and node **120** or node **130**, it might be a desirable solution, based on security requirements. This is because hacker computer **111** could be used to undermine the operation of controller **101**, for example by sending modified usage restriction requests for a particular wireless device to one of nodes **120** and **130**, or by spoofing one of nodes **120** and **130**, so that controller **101** sends restriction requests and device identity information to hacker computer **111**, instead of nodes **120** and **130**. Without proper safeguards, an external hacker could either prevent system **100** from functioning, or maliciously cause a wireless device to endure restricted operation, even if it is outside all restriction zones. Further, controller **101** may include a decoy ad-hoc network node, so that if device **140** attempted to set up a self-assembling network with device **142**, to leverage the connectivity of device **142**, this attempt would be frustrated. Controller **101** could also send out instructions to devices **140**-**142**, and any other devices within range, to disable self-assembling or any other ad-hoc network capability, in order to isolate device **140**. However, if controller **101** continues its self-assembling network attempts, it can identify any of devices **140**-**142** that are not complying with the network disabling, and then request that nodes **120** and **130** restrict operation of the non-compliant devices.

[0042] Node **120** is connected to serving base station tower **121** and distant base station tower **122** through a cellular network infrastructure. Serving base station tower **121** is the base station that serves wireless devices in the area of zones

150 and **151**, whereas tower **122** is a on the same network, but likely too far away to provide service in that area. Tower **122** could be a metacell though, that provides fill-in coverage for areas shadowed from tower **121**, and thus could cover portions of zones **150** and **151**. Node **130** is similarly connected to serving base station tower **130**. Multiple cellular operator nodes and serving base station towers are illustrated, because different cellular network operators often use different towers and different control nodes to serve overlapping geographical areas. Thus, node **120** is owned and operated by one cellular carrier, and node **130** is owned and operated by another.

[0043] If controller **101** cannot determine which carrier is associated with a particular one of devices **140** and **141**, identifying information for both devices **140** and **141** can be sent to both nodes **120** and **130**. The computational equipment at each of nodes **120** and **130** can then identify whether device **140** or **141** is a subscriber device being served by that network and, if so, take the requested blocking actions. Otherwise, if nodes **120** and **120** do not recognize one of devices **140** and **141**, the request for that device can be ignored.

[0044] In order to provide the service of blocking data traffic for a subscriber, upon the request of a third party, the cellular network operators must have both some motivation to comply, as well as some degree of certainty that the request is coming from a valid source. For places such as prisons, courthouses, streets within school zones, other areas where cell phone usage can impact public safety, and even temporary locations with visiting dignitaries, operator compliance may become a legislated requirement. For non-legislated blocking, the fee arrangement for urgent calls, described above, may provide some motivation. Even with a government-mandated compliance policy though, the network operator will still request reasonable assurance that the request for restricted operation of a device is coming from an authorized source.

[0045] One option for ensuring authorization is that, when controller **101** moves into a new area, it registers with all of the operators who are operating towers in the area. Network operators then have a database of the operational systems, such as controller **101**, which are associated with towers in close proximity. Part of this process may include the exchange or distribution of encryption keys or other security tokens, so that the controller and the network control nodes may engage in a challenge-response process when setting up a channel to communicate restriction requests. There may also be responses from the network nodes, acknowledging the requests and indicating compliance or refusal to comply. If the messages and responses are encrypted, then encryption provides not only security from eavesdropping by a hacker, but proper decryption indicates authenticity of the claimed sender. Public key encryption can be used, so that each a tower (such as 121, 122 and 131) can digitally sign its recent transmitted security code, and controller **101** can digitally sign its request. This provides 2-way authentication between controller **101** and one of the nearby network operators.

[0046] Other options include that the towers, such as **121**, **122** and **131**, send a security code that changes rapidly, and information from this security code must be included with a restriction request as a time-changing security authentication credential, so that only systems having a reception capability within the vicinity of a serving tower can send a valid request for device operation restriction. Using this option, controller **101** may need to identify the base stations attached to towers **121**, **122**, and **131**, or at least those providing signal strength sufficient to serve cellular devices within at least a portion of zones **150** and **151**. Network operators can reduce their vulnerability to replay attacks by requiring that a recent security code, sent out from one of its towers, be used in construction of the restriction request. This can include using a hash value of a transmitted security code as an encryption key for at least a portion of data sent by controller **101**, and other authentication schemes. A replay attack could occur if hacker computer **111** intercepts a message from controller **101** to node **120**, stores it, and then transmits it to node **120** at a later time. The result would be that a device could have restricted operation, even if it moved outside zone **150**. Having time-varying security codes, along with a cellular network operator verifying that a device had been recently registered to a base station in proximity of controller **101**, can reduce the likelihood that malicious attempts to interfere with the proper operation of system **100** will be successful. Thus, a network operator may verify that a request from controller **101** include recent security information transmitted from a network tower operated by the network operator, along with security information identifying controller **101**, prior to complying with any request. Since the network operator knows the location of each of its towers, if a first request associated with a first tower came in from a device purporting to be controller **101**, and then another request associated with a second tower, that was far removed from the first tower, arrived immediately afterward, the network operator might suspect the presence of a hacker attempting to maliciously disable cellular devices and not comply with the request. However, since a legitimate controller might be mobile, such as within an airplane, boat, train or bus, some means is needed to ensure that a controller can be registered with the network operator to be within the vicinity of different towers at different times. For mobile versions of controller **101**, controller **101** would need to register with networks automatically under circumstances similar to a cellular device tower hand-off, except controller **101** would register with multiple carriers and possibly multiple towers of the same carrier, simultaneously.

[0047] Other security considerations include controller **101** informing the users of devices **140** and **141** whether they are restricted, and possibly also the user of device **142** that it may be restricted if device **142** enters nearby zone **150**. Part of this communication could include controller **101** identifying itself to the affected devices **140-142**, for example, by communicating an identification code, associated with controller **101**.

[0048] In the illustrated embodiment, encryption keys **103** and **104**, installed in controller **101**, can be used to communicate securely with nodes **120** and **130**. Key **103** is a security counterpart to key **123**, so that using keys **103** and **123**, controller **101** and node **120** can communicate securely. Similarly, key **104** is a security counterpart to key **134**, so that controller **101** and node **130** can communicate securely. If public key encryption is used, controller **101** could encrypt messages for both nodes **120** and **130** with the same private, asymmetric key. This provides authentication, but maybe not privacy, because anyone having a copy of the public, asymmetric key could decrypt the messages and learn which wireless devices are within zones **150** and **151**. It may be desirable to restrict public access to this information. However, if the public asymmetric key is only "public" to nodes **120** and **130**, then an asymmetric key system could work.

[0049] Embodiments of a controller, such as controller **101**, may send requests in various ways. Controller **101** may simply forward device identification, which nodes **120** and **130** will interpret as a request to enforce pre-arranged default usage restrictions. Another option may be to identifying specific restrictions, such as permitting some functionality out of SMS, email, voice, and other data exchanges, while blocking others. Multiple options also exist for relaxing, or lifting usage restrictions, when a device moves from inside zone **150** to the outside. Nodes **120** and **130** may operate in such a manner that the restriction requests time out after a predetermined period, for example a minute, and if another restriction request has not been received from controller **101** by that time, the restrictions are lifted. In this situation, controller **101** repeatedly communicates identifying information for devices **140** and **141**, within zone **150**, to one or both of remote nodes **120** and **130**, for however long both of devices **140** and **141** remains within zone **150**. Upon a device moving outside of zone **150**, controller **101** merely fails to update the identification. The time-out will expire, and the device that moved outside of zone **150** will resume operation upon the expiration of the time-out period. Alternatively, controller **101** could affirmatively inform one or both of nodes **120** and **130** that a device has moved outside a zone, so that service to that device can resume more rapidly.

[0050] System **100** also comprises a wireless user control **105**, although in some embodiments, a user control may have a wired connection to controller **101**. User control may be used for a plurality of functions, including (a) calibrating the locations of sensors **102***a*-**102***c* during system setup or maintenance, (b) defining vertices of restriction zones **150** and **151**, and (c) identifying a particular wireless device, such as device **141**, for exemption or modified restriction rules. For example, if restriction zone **150** encompasses a prison, device **141** may belong to someone who is authorized to carry a cellular device into the area, for example a guard or an attorney visiting a client. For some embodiments, the different functions may be accomplished with different controls. In some embodiments, controller **101** will support multiple user controls **105**. For security, controller **101** and user control **105** may encrypted communications between them. Additional security arrangements and data compression, applicable to both wireless and wired network communications, should also be considered for improving system **100**.

[0051] User control **105** includes a user input control **106**, which may include a plurality of buttons, a touch screen, a trackball, or any suitable input system for receiving input from a user. Input functions may include triggering a calibration function within the controller, to identify the location of a sensor. For example, during setup and initial calibration, a user may position sensors **102***a*-**103***c*, then visit each of the sensors in turn, actuating user input **106**, when the user control **105** is in close proximity with a sensor, to transmit a calibration signal from user control **105** to sensors **102***a*-**102***c*. If user control **105** is adjacent to sensor **102***a*, then sensor **102***a* will be the first to receive any calibration signals transmitted by user control **105**, possibly through wireless communication system **107**. Communication system **107** may also be used to communicate with controller **101**.

[0052] By measuring the time delay to the other sensors, **102***b* and **102***c*, the relative distance between sensors **102***a* and **102***b*, as well as the relative distance between sensors **102***a* and **102***c* may be determined. By then moving user control **105** to be adjacent to sensor **102***c*, and repeating the calibration signal transmission process, the relative distance between sensor **102***c* and **102***b* may further be determined.

[0053] Calibrating the sensor positions in this manner may result in controller **101** calculating different time of arrival information from sensor **102***a* to sensor **102***c* than the reverse path, from sensor **102***c* to sensor **102***a*. This is because the communication delays between controller **101** and each of sensors **102***a* and **102***c* may be different. There are a number of options for compensating for this delay. One is to use only relative communication delay differences. Another is to use precise knowledge of communication delay between one of the sensors **102***a*-**102***c* and controller **101**, to calculate exact delay for each of the sensors **102***a*-**102***c*. This second option is easier if predetermined cable lengths, with known propagation delay times, are used, and if the sensors' and controller's response times are also known. If sensor **102***b* is attached to controller **101** and connected with a hard-wired communication interface, then moving user control **105** adjacent to sensor **102***b* and repeating the calibration transmission process can provide the final data needed for the position calibrations. If none of the absolute communication delays are known, then relative delay information must be used.

[0054] For calibration at sensor **102***a*, the absolute time delays are Ta=Ca; Tb=Cb+Pab; Tc=Cc+Pac, where Ta is the time delay between sensor **102***a* receiving a calibration signal from user control **105**, and controller **101** receiving it, Ca is the communication delay between sensor **102***a* and controller **101**; Tb is the time delay between sensor **102***b* receiving a calibration signal, and controller **101** receiving it, Cb is the communication delay between sensor **102***b* and controller **101**, Pab is the propagation delay between sensor **102***a* and sensor **102***b*; and Tc is the time delay between sensor **102***c* receiving a calibration signal, and controller **101** receiving it, Cc is the communication delay between sensor **102***c* and controller **101**, Pac is the propagation delay between sensor **102***a* and sensor **102***c*. The propagation delay between user control **105** and sensor **102***a* is assumed to be zero, for simplification. Propagation delay is the physical distance, multiplied by the speed of light, which is a constant value. Thus, distance measurements may be obtained easily, once propagation times are calculated.

[0055] The relative delays, calculated by controller **101** are Tab=Cb+Pab−Ca and Tac=Cc+Pac−Ca, where Tab is the time between the calibration signal arriving from sensor **102***a* and sensor **102***b*, and Tac is the time between the calibration signal arriving from sensor **102***a* and sensor **102***c*. If the communication delay from sensor **102***a* is long enough, either or both of Tab and Tac may be negative.

[0056] For calibration at sensor **102***b*, the absolute time delays are Ta=Ca+Pba; Tb=Cb; Tc=Cc+Pbc, and the relative time delays are Tba=Ca+Pba−Cb and Tbc=Cc+Pbc−Cb. For purposes of calibration, Pba can be assumed to be identical to Pab. Thus, Tab, the delay between sensors **102***a* and **102***b* when calibrating at sensor **102***a*, will differ from Tba, the delay between sensors **102***a* and **102***b* when calibrating at sensor **102***b*, by twice the difference between Ca and Cb.

[0057] For calibration at sensor **102***c*, the absolute time delays are Ta=Ca+Pca; Tb=Cb+Pcb; Tc=Cc, and the relative time delays are Tca=Ca+Pca−Cc and Tcb=Cb+Pcb−Cc. For purposes of calibration, Pca can be assumed to be identical to Pac, and Pcb can be assumed to be identical to Pbc. Thus, Tac, the delay between sensors **102***a* and **102***c* when calibrating at sensor **102***a*, will differ from Tca, the delay between sensors **102***a* and **102***c* when calibrating at sensor **102***c*, by twice the difference between Ca and Cc. Similarly, Tbc, the delay between sensors **102***b* and **102***c* when calibrating at sensor

102*b*, will differ from Tcb, the delay between sensors **102***b* and **102***c* when calibrating at sensor **102***c*, by twice the difference between Cb and Cc.

[0058] If at least one of Ca, Cb, and Cc is known, then the others may be calculated using measured Tab, Tba, Tac, Tca, Tbc, and Tcb. For simplification, assume sensor **102***b* is attached to controller **101** by a short enough cable that Cb can be approximated as zero. Ca is then just half of the difference between Tab and Tba, and Cc is half of the difference between Tbc and Tcb. In this manner, baseline calculations can be made that are needed for later triangulation calculations.

[0059] As an alternative calibration scheme, one or more of sensors **102***a*-**102***c* could have a calibration transmitter, which is triggered by controller **101**. This could be useful if frequent position calibration is expected, or the sensors are in positions that are difficult to reach, and it is inconvenient to send someone to visit each sensor, whenever a calibration is needed. For this scheme, which is made easier if sensor **102***b* is co-located with controller **101**, so that Cb is small enough, controller **101** sends out instructions to each of sensors **102***a* and **102***c*, I turn, instructing them to transmit a calibration signal. The delays can be calculated similarly as described for calibration with user control **105**.

[0060] The next process in the setup of the illustrated embodiment is defining restriction zones. Defining zone **150** can be accomplished by moving user control **105** to each of the vertices of the desired restriction zone, and actuating user input **106**. One method to define the zone would include circumnavigating the desired zone in a single direction, and actuating user input **106** at each desired vertex. The positions of user control **105** at each vertex can be calculated by triangulation, or whatever other method is employed for position calculation by system **100**. Then, the final vertex can be connected, within a zone boundary database in controller **101**, to the first vertex. The process can be repeated, if additional restriction zones, for example second restriction zone **151**, are desired.

[0061] After system **100** is set up and operating, it may be desirable to make exceptions to the typical set of restrictions. For example, device **141** may be treated by system **100** differently than device **140**. To enable this, user control **105** has a short range, directional wireless sensor **108**, which enables identification of a wireless device in close proximity, and on the proper side of, user control **105**. Actuating user input **106**, when pointing user control at nearby device **141**, then flags to controller **101** that device **141** is to be treated differently than device **140**. The restrictions may be more severe, more lenient, or even totally waived. Thus, user control **105** and controller **101** are jointly configured to identify a device for restriction exceptions when user control **105** is in close proximity with the device. This need not be after controller **101** has already requested restricted device operation. It could occur prior to a device entering a restriction zone, so that, when the device enters the zone, the initial restriction request is already modified or won't be sent.

[0062] One example use would be in a dark theater, in which the restrictions are not to block calls, but rather that all phones are set on vibrate mode. This allows people within the theater to be aware that someone is calling, and to step outside to take the call. However, one person may not be so considerate, and may be speaking loudly during a call. If a theater worker requests that the person be quiet, and that person does not comply, then the theater worker can use user control **105** to instruct controller **101** to request odes **120** and **130** to terminate the call. A similar arrangement can be used for people having excessive text message conversations in a dark theater, while not making reasonable accommodations to limit the bright light shining in other people's eyes. A theater worker can then easily disable the text message ability of the phone, until the owner steps outside the restriction zone, and controller **101** releases the cell phone from the restrictions. Enhanced or relaxed restrictions for a particular device may be permanent, for the duration that the device is within the restriction zone, or temporary, so that enhanced or limited privileges expire before the device leaves the restriction zone.

[0063] Other methods for determining the positions of devices **140**-**142** exist, which could be used if all three of sensors **102***a*-**102***c* are not able to simultaneously pick up transmissions. If devices **140**-**142** operate using time domain duplexing (TDD) or time domain multiple access (TDMA), they will have an assigned transmission time slot, controlled by the serving base station's clock. Using the assumption that the device will begin to transmit at its scheduled time, and if controller is synchronized to the same clock, a range from the device to a sensor can be estimated. This gives a radial distance from one sensor. If two sensors can intercept the transmission, then radial distance measures from two sensors can be compared, and may allow determination of whether a device is within zone **150**.

[0064] Multipath effects make using direction of arrival an unreliable sole source of information. This is because a bounce path, from a different direction than the true direction from a sensor to a wireless device, could provide a stronger signal. However, even in this situation, the true path will provide the earliest signal. Making direction of arrival measurements requires directional sensors, which can be provided with an antenna array arrangement on one of the sensors. If each of the multipath signals received by a sensor is compared against the others, not only for power levels, but also for time of arrival, then direction of arrival information can be used to assist with location. For example, consider the possibility that sensor **102***c* does not receive a transmission from device **141**. Attempting to calculate the position of device **141**, using merely time of arrival information for signals received by sensors **102***a* and **102***b*, will result in two possible locations for device **141**. One position will be in its illustrated position, within zone **150**. The other position will be outside zone **150**, slightly above and to the left of the illustrated position of tower **121**. Using direction of arrival information, if sensor **120***b* is able to identify that device **141** is located counter-clockwise from a reference line between sensors **120***a* and **120***b*, or sensor **120***a* is able to identify that device **141** is located clockwise from that same reference line, then the position of device **141** can be fixed as within zone **150** and not nearby tower **121**. The law of cosines is a well-known equation that can be used using a combination of range and angle information, and a related derivation can also be applied in some situations using only range information.

[0065] Ascertaining identifying information of a device, or determining an identity of a device, by controller **101** may not involve determining a unique number or address associated with a device. Identification information for a wireless device may be data uniquely associated with a wireless device, such as an assigned phone number or an address, but may also be other identifying information, such as general information that is specific enough to enable a remote processor to ascertain the identity of the device. Examples include a time of a recent transmission, a copy of recently transmitted data, transmission channel information, and physical location relative to nearby towers. Thus, if controller **101** can communicate that device **141** recently transmitted a certain data stream, even if the data stream were encrypted and controller **101** could not interpret the contents, and that device **141** was likely visible to a certain sector of tower **131**, then controller **101** has provided enough information that processor **135** at node **130** could potentially identify that controller **101** was referencing device **141**—if node **130** is within the network that device **141** is using. If device **141** was using the other network, node **120**, then node **120** would be able to identify device **141**. Processor **135** may therefore need to maintain a history of recently received data from served wireless devices, and have other logic necessary to determine a specific device from a description of its behavior, which is received from controller **101**. In some situations, controller **101** may be able to ascertain unique data associated with a wireless device, for example, possibly if a device were to attempt to register with a base station, if nodes **120** and **130** shared information with controller **101** about devices registered with towers **121** and **131**, to enable exact device identification, or if controller **101** were connected to a decoy node, such as node **301**, illustrated in FIG. **3**.

[0066] FIG. **4** illustrates another embodiment of a system **400** for restricting operation of wireless devices, for example in an airplane passenger compartment **410**. This illustrated system **400** can help enforce an airline policy that passengers turn off phones when airplane is ready to take off. As an added bonus, the restriction zone **450** actually moves along with airplane **410**, automatically. In airplane passenger compartment **410**, system **400** comprises controller **401** and remote, external sensors **102***a* and **102***c*, which can all operate within a moving vehicle. A third sensor is integrated within controller **401**. Controller **401** uses its antenna to wirelessly communicate with nodes **120** and **130** though network **110**, while operating within a moving vehicle, such as within airplane passenger compartment **410**, while the airplane is moving away from a passenger boarding gate.

[0067] To highlight the need for multiple sensors to solve positions using time of arrival information alone, as inputs to triangulation calculations, consider the possibility that controller **401** has not activated its internal sensor. As before, the user of device **140** is within a restriction zone, but this time it is zone **450**, because the user of device **140** is a passenger. The user of device **142** is outside the plane, possibly waiting to board. Assume, for this explanation, that transmissions from device **142** can enter airplane passenger compartment **410**, possibly through the windows. In this situation, when the airplane flight crew wishes to restrict cell phone operation, device **140** should be restricted, but device **142** should not be.

[0068] As illustrated, the distance **402** between device **142** and sensor **102***a* is the same as the distance **403** between device **142** and sensor **102***c*. Similarly, the distance **405** between device **140** and sensor **102***a* is the same as the distance **406** between device **140** and sensor **102***c*. Thus, the time of arrival differences between sensors **102***a* and **102***c* are identical for both devices **140** and **142**. Controller **401** will then calculate the positions of both devices **140** and **142** to be on the same set of possible points. These points will form a plane, exactly half way between sensors **102***a* and **102***c*, and perpendicular to a straight line connecting sensors **102***a* and **102***c*. As viewed from above, according to the perspective of the illustration, this plane becomes straight line **408**. Thus, the position of a wireless device at any point on line **408** will be indistinguishable from the position of any other device at a different point that same line **408**. Line **408**, in two dimensions, is a line of ambiguity. Considered in three dimensions, it is a plane of ambiguity.

[0069] Now, adding the time of arrival measurement for a sensor within controller **401**, distance differences become apparent. The distance **404** between device **142** and controller **401** is shorter than distance **403**, but not by much. In contrast, the distance **407** between device **140** and controller **401** is considerably shorter than distance **406**. Thus, using the difference between distances **407** and **406**, controller **401** can determine that device **140** is inside zone **450**, while using the difference between distances **404** and **403**, controller **401** can determine that device **142** is outside zone **450**. Controller **401** can just use a threshold as decision criteria, based on the maximum distance difference for a hypothetical device exactly on the boundary of zone **450**.

[0070] It should be noted that, even with this third measurement, if only time of arrival information is available, controller **401** cannot necessarily determine which side of airplane passenger compartment **410** that device **142** may actually be. If controller **401** is positioned poorly, for example, it is positioned on a straight line between sensors **102***a* and **102***c*, the ambiguity plane for the position of device **142** will become an ambiguity circle on the former ambiguity plane, centered on a line connecting sensors **102***a* and **102***c*, with a radius determined by the difference between distances **403** and **404**. This ambiguity circle will surround airplane passenger compartment **410**, but if airplane passenger compartment **410** is the nearly-circular cross-sectioned tube, typical for airplanes, then controller **401** will properly determine that device **142** is outside zone **450**. That is, even if controller **401** cannot determine whether device **140** is to the left, right, above, or below airplane passenger compartment **410**.

[0071] Fortunately, for many situations, controller **401** can operate with the assumption that all wireless devices are at approximately the same height. This assumption is valid enough in open air areas, such as wide, flat, level fields where most people are standing on the ground at the same height, and vertical variations are minimal in comparison to horizontal positional variations. In tall, multi-level buildings though, vertical displacement can be an issue. Systems operating in those environments will require more sensors to solve vertical displacement ambiguities. In order to solve vertical displacement ambiguities, there must be some vertical diversity in the sensors. Merely adding more sensors in the same plane will not solve ambiguities as to whether a device, not in the same plane as all of the sensors, is above or below that plane.

[0072] FIG. **5** illustrates wireless devices **140** and **141** showing indications of restricted operation. Wireless device **140** is displaying a message **500**, indicating that emergency callas are allowed, but other phone calls and text messages are not allowed. The message could have been triggered by communication from controller **101** or one of nodes **120** and **130**. Other information could be displayed, including whether vibrate mode has been activated, or whether email and internet access are affected, and whether non-communication functionality has been restricted. Wireless device **141** displays a message **501**, indicating different restrictions than are imposed on device **140**. This may be because device **140** had been pre-registered with controller **101**, for lesser restrictions than device **140**, prior to entering zone **150**, or because the exception process, described above in the discussion of FIG.

1, had been performed after device **141** had already been restricted similarly to device **140**.

[0073] FIG. **6** illustrates another embodiment of a system **600** for restricting operation of wireless devices. System **600** comprises a computing apparatus **601**, which may be an embodiment of controller **101**, described in the discussion of FIG. **1**. Computing apparatus **601** comprises a communication module **602**, which communicatively couples apparatus **601** to a media drive **603** for computer readable media, illustrating an optical disk, as well as network **110** and sensors **102***a*-**102***d*. Other types of computer readable media, such as non-volatile memory devices and magnetic media may also be used. Communication module **602** is illustrated as having an antenna for wireless communication with user control **105**. Communication module **602** may be a single module or may comprise many different modules, and may comprise hardware, such as connectors, firmware, and even software, such as internet connectivity software.

[0074] Apparatus **601** also comprises at least one central processing unit (CPU) **604**, although multiple processors may be used, and a memory **605**. Memory **605** may comprise volatile and non-volatile memory, and even other computer readable media. In the illustrated embodiment, memory **605** holds part of communication module **602**. Memory **605** holds other modules and data sets used in the operations described above, although many of the illustrated modules may also have hardware or firmware components. These include a control module **606**, which can interface with other illustrated modules, and coordinate their operations for sensor position calibration, zone definition, restriction request communication, device exception handling, position calculations, and other functions.

[0075] Operator database **607** has information relevant to communication with nodes **120** and **130** and any other cellular network operations nodes. This may include internet addresses of node computers and security protocols. Security module **608** has security functionality, possibly including encryption and hash routines. It is used for securing communications with remote operator control nodes, for example nodes **120** and **130** and, in the illustrated embodiment, has access to keys **103** and **104**. As a clarification to the differences between security module **608** and keys **103** and **104**, security module **608** contains algorithms, and possibly hardware random number generators. Timing module **609** is used as a time reference, and may be used to keep a clock synchronized with a base station clock for use in the TDD and TDMA enabled range-finding systems previously described. However, timing module **609** may have its own internal clock, which is free from external synchronization with base station clocks. Timing module can be used for both the time of arrival calculations, as well as the tracking time-out periods for devices within a restriction zone, so that timely updates can be sent to nodes **120** and **130**.

[0076] Calibration and setup module **610** can be configured to operate with remote interface module **611**, which handles communication with user control **105**, sensor position database **612**, and zone boundary database **613**. Sensor position database **612**, and zone boundary database **613** may be based on time of arrival information only, and therefore have only relative positions, such as radial distances, or may have GPS coordinates, if any of sensors **102***a*-**102***d* or user control **105** had GPS data and sent it to apparatus **601** during calibration and setup. Data in some embodiments of zone boundary database **613** will comprise the vertices of at least one closed polygon. Remote interface module **611** also works with blocking rules database **614** and detected device database **615** to handle exceptions for selected devices. For example, blocking rules database **61** could permanently store the identity of device **641**, so that the next time device **641** entered zone **150**, it would go to relaxed restrictions, rather than default restrictions. Math module **616** may comprise standard triangulation calculation routines, which are known in the art. For example, U.S. Pat. No. 5,327,144 by Stilp et al. and U.S. Pat. No. 5,890,068 by Fattouche et al. disclose triangulation schemes for locating cellular devices.

[0077] FIG. **7** illustrates another embodiment of a system **700** for restricting operation of wireless devices. System **700** comprises a controller **701**, which also comprises a sensor. System also comprises sensors **702**-**709**, numbered clockwise. The restriction zone is the entire area covered by the set of triangular sub-zones **711**-**717**. The combination of zones **714** and **715**, formed by controller **701** and sensors **705**, **706** and **709**, illustrates how a rectangular-shaped region can be set up using triangles. During setup, each sensor is paired with two others, in the memory of controller **701**, to form the triangular sub-zones. When a triangular sub-region is formed in this manner, the triangle will have no reflexive angles.

[0078] During operation, when a wireless device is identified, controller **701** sequentially solves an inside/outside calculation for each of the sub-zones, until one calculation returns an inside condition, or all sub-zones have been considered. If a device is within any of the sub-zones, then a usage restriction is requested. In some embodiments, a controller, for example controller **701**, may send a usage restriction request directly to a wireless device rather than involving the network operator. For this to work though, the device must comply with the request. Using a network operator to implement the request takes compliance by the device out of primary consideration as a defeat to the system's operation. Other variations can exist, if controller **701** is the only sensor available. If controller uses the TDD and TDMA range finding method, described earlier, then the restriction zone can be a sphere around controller **701**. Adding direction of arrival discrimination to the sensor on controller **701** enables the shape of the restriction zone to be tailored, such that it extends further in range in some directions.

[0079] FIG. **8** illustrates a method **800** of restricting operation of wireless devices. In block **801**, the sensor positions are calibrated. A method for performing this has been described previously, and a method is also illustrated in FIG. **9**. In block **802**, the restriction zones are defined. A method for performing this has been described previously, and a method is also illustrated in FIG. **10**. In block **803**, the controller registers with cellular network operators, for example by exchanging security tokens between controller **101** and each of nodes **120** and **130**, illustrated in FIG. **1**.

[0080] In the illustrated method, normal operations of the system begin in block **804** and cycle while the system remains in operation. It should be understood that variations in the order of the blocks of method **800** may occur. Devices are identified in block **804**, and their positions calculated in block **805**. For those devices within a restriction zone, the exceptions from restrictions, as well as restriction customizations are identified in block **806**. In block **807**, a secure communication link is set up between the controller **101** and at least one of node **120** and node **130**, if a secure link does not exist. The secure link may use encryption, and be, for example, a Secure Socket Layer (SSL) session. Alternatively, data could be sent over unsecured sessions, but the data should be secured, such as by encryption. The requests are communicated to the network operators in block **808**, and may be just identification information, if a default restriction type has been previously defined, or may be relaxation requests or restriction customization requests. In block **809**, exceptions for certain devices are stored, perhaps in blocking rules database **614** of FIG. **6**. A method for performing this has been described previously, and a method is illustrated in FIG. **11**. Therefore, a method of restricting the operation of a radio communication device may comprise determining an identity of a device, using a radio transmission from the device; determining whether the identified device is within a predefined usage restriction zone, using time of arrival information from a plurality of sensors, for a radio transmission from the device; and securely communicating the identity of the identified device to a remote node, across a public computer network. The method may further comprise repeatedly communicating the identity of the identified device to the remote node, while the identified device remains within the usage restriction zone.

[0081] FIG. **9** illustrates a method **900** of calibrating sensor positions. In block **901**, a calibration signal is sent from the location of a sensor. This can be the sensor itself, or a user control adjacent to a sensor. In block **902**, the time of arrival differences are measured. In decision block **903**, it is determined whether enough sensor positions have been measured in order to complete the calculations. For a system having four or more sensors, or sensors with known communication delay times, there may not be a need to send calibration signals from all of the sensors. In block **904**, the data for time of arrival differences are adjusted for communication delays between each of the sensors and the controller. In some systems, multiple controllers or sub-controllers can be used, with time of arrival compensations including the transit times for routing information to other places, rather than directly to a single controller. In block **905**, distances between the sensors are determined, using the propagation delays of the calibration signals. GPS information can be used to establish actual position data, rather than just relative position data in block **906**, if the information is available. The results of the sensor position calibration process are then stored in RX position database **612**, of FIG. **6**.

[0082] FIG. **10** illustrates a method **1000** of defining a restriction zone. In block **1001**, a calibration signal is sent from the location of a vertex of the desired restriction zone, possibly from wireless user control **105**. In block **1002**, the time of arrival differences are measured from that vertex to each of the sensors, and are compensated for with communication delay information found earlier, in method **900**. In block **1003**, vertex positions are determined and stored in zone boundary database **613**, of FIG. **6**. In decision block **1004**, it is determined whether all the vertices have been defined for the zone. If not, then another calibration signal is sent from the next desired vertex, as method **1000** returns to block **1001**. When all the vertices have been set, the restriction zone is then defined as a closed polygon with vertices in the order of measurement, except that the final vertex is connected with the first, to close the polygon. This is accomplished in blocks **1005** and **1006**.

[0083] FIG. **11** illustrates a method **1100** of handling exceptions to the restrictions. In block **1101**, a wireless device is identified for exceptional treatment, whether exemption from restriction, more sever restriction, or less severe restriction. This can be accomplished with user control **105** in close proximity, and pointing at the device, as described in relation to FIG. **1**. In decision block **1102**, it is determined whether the exception will be durable, that is, it will endure even after the device has left a restriction zone, so that the exceptions are automatically applied when the device next enters a restriction zone. If the exceptions are not durable, then in decision block **1103**, it is determined whether they are temporary, and will expire after a set period of time. If so, then a timer is set in block **1104**, perhaps using timing module **609** of FIG. **6**. The exception information regarding the device identity, durability, and duration, is then stored in block **1105**, and if necessary, communicated to a network node in block **1106**.

[0084] Network operators play a crucial role in the operation of some of the disclosed embodiments. They make a restriction decision after receiving a request from a Cilense™ system, and may insist on verifying the authenticity and authorization of the request. In some situations, an operator may over-ride the requested restrictions and substitute a different set. The operator may then communicate back to the requester confirming or denying the request, or informing about a modification. In some situations, a network operator may cooperate with restaurant ad theater owners willingly, and therefore may reserve the right to deny or modify the restriction request. In other situations, the requester may have police or government authority, so the operator may have a duty to comply.

[0085] The operator may inform the restricted device of the restriction, possibly informing the device about the ability to send or receive urgent calls for a fee. This may be automatic, or in response to an attempted call or sending of a message, and may be displayed or sent as an audio message. Outside callers may be informed about the restrictions by the network equipment, when attempting to call the restricted device. The device may be provided instructions by the network to enter a battery-saving mode, dim the screen, enter vibrate or silent mode, display a message on the screen of the device, or return from restricted operation modes, or refrain from participating in any self-assembling, peer-to-peer or ad-hoc networks, and then comply if the instructions satisfy security screening criteria. The restriction on network participation is to prevent a cellular device within a restriction zone from communicating through another nearby cellular device that is outside the restriction zone, and riding on that nearby cellular device's network connectivity to send and receive prohibited messages, thereby thwarting the operation restrictions. Wireless devices nearby a restriction zone, but located outside, or else within the restriction zone and exempt from the restrictions, which are also range of the ad-hoc network connectivity of restricted devices, may receive and acquiesce to requests to temporarily disable self-assembling or ad-hoc network capability, or to deny connectivity to identified devices within the restriction zone. The wireless device may further display the authority or some identifying information about the entity requesting the restriction, and may receive this from either the entity itself or from the serving network. The status of the device with in a restriction zone may be returned as part of a chaperone service, which enables someone to remotely ascertain the location of another person's cell phone.

[0086] Although the present invention and its advantages have been described above, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments described in the specification.

What is claimed is:

1. A system for restricting operation of a cellular device in restricted areas without requiring cooperation from the cellular device, the system comprising:

a plurality of at least three sensors, each sensor remotely located from all serving cellular base station sites and remotely located from the cellular device, each sensor configured to receive a radio transmission from the cellular device; and

a controller, communicatively coupled to each sensor of the plurality of sensors, the controller remotely located from all serving cellular base station sites and remotely located from the cellular device, the controller comprising a memory;

the memory containing a definition of a first usage restriction zone;

the controller configured to:

receive, from the plurality of sensors, information about a radio transmission from the cellular device;

determine, using the received information, an identity of the cellular device, without requiring reception and processing of any wireless signals by the device;

determine, using the received information, whether the cellular device is within the first usage restriction zone, without requiring reception and processing of any wireless signals by the device; and

responsive to determining that the cellular device is within the first usage restriction zone, securely communicate the identity of the cellular device to a remote node across a public computer network and request that all serving cellular networks restrict service to the cellular device;

such that restriction of the operation of the cellular device occurs without requiring cooperation from the cellular device.

2. The system of claim **1** wherein the information about a radio transmission from the cellular device comprises angle of arrival information at a sensor.

3. The system of claim **1** wherein the information about a radio transmission from the cellular device comprises time of arrival information at a sensor.

4. The system of claim **1** further comprising:

a definition of a second usage restriction zone, the second usage restriction zone separate from the first usage restriction zone, and wherein the controller is further configured to restrict operation of the cellular device responsive to the cellular device being located within the second usage restriction zone.

5. The system of claim **1** further comprising:

a definition of usage restriction rules within the memory, wherein the controller is further configured to securely communicate the type of usage restriction for cellular device to the remote node, the type of usage restriction being in accordance with the usage restriction rules.

6. The system of claim **5** wherein the usage restriction rules permit texting and block phone calls.

7. The system of claim **5** wherein the usage restriction rules permit phone calls and block texting.

8. The system of claim **1** further comprising:

a device exception list within the memory, wherein the controller is further configured to:

determine whether the cellular device identity is within the exception list; and

responsive to the cellular device identity being found within the exception list, not send a usage restriction request for the cellular device, even if the cellular device is within a usage restriction zone.

9. The system of claim **1** further comprising:

a remote user control having a user input control, separate from the sensors and the controller and the cellular device, wherein the user remote control is configured to transmit a calibration signal upon actuation of the user input control; and

wherein the controller, upon receiving the calibration signal through the plurality of sensors, determines a position of the remote user control and uses the determined position to define a vertex of a usage restriction zone.

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