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(54) **SPECTRUM SHARING**

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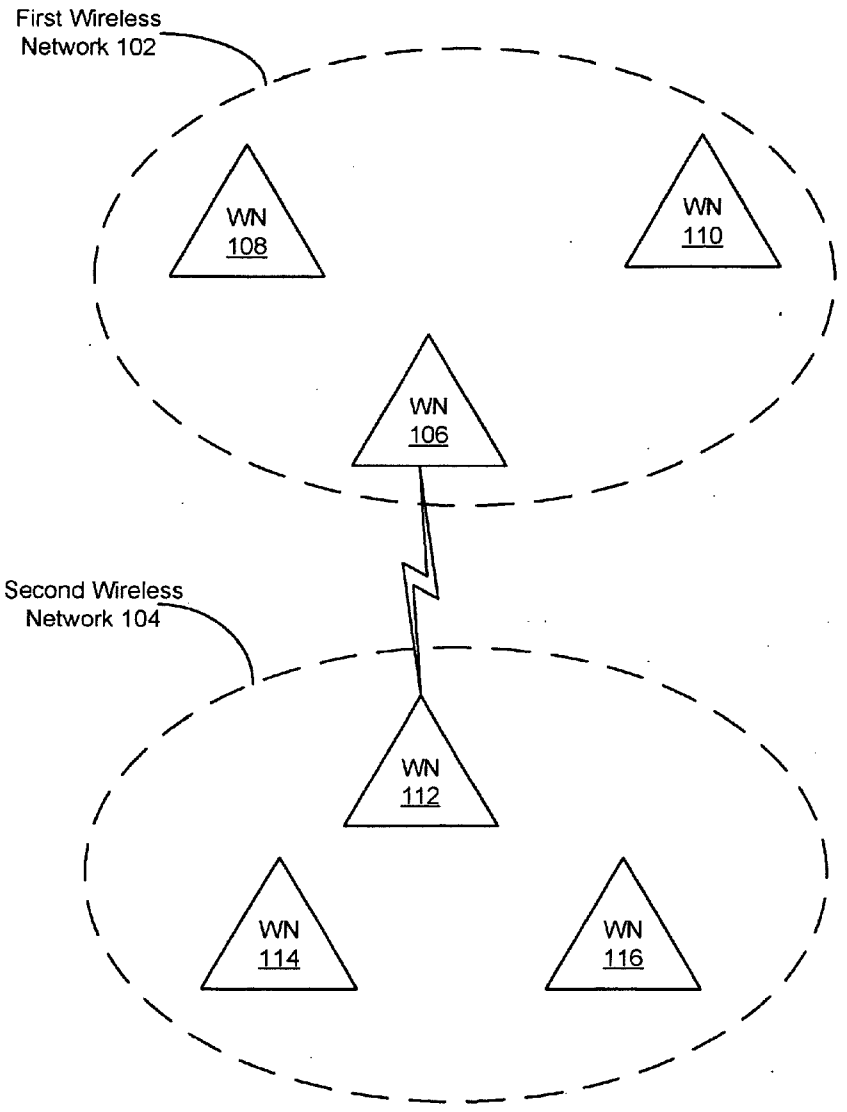
(57) **ABSTRACT**

Disclosed herein are various example methods and apparatuses. According to one example, a method may include determining, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network. The method may further include sending, to a second wireless node in a second wireless network, a request to borrow one or more of the one or more resource units, the request being based on the determining.



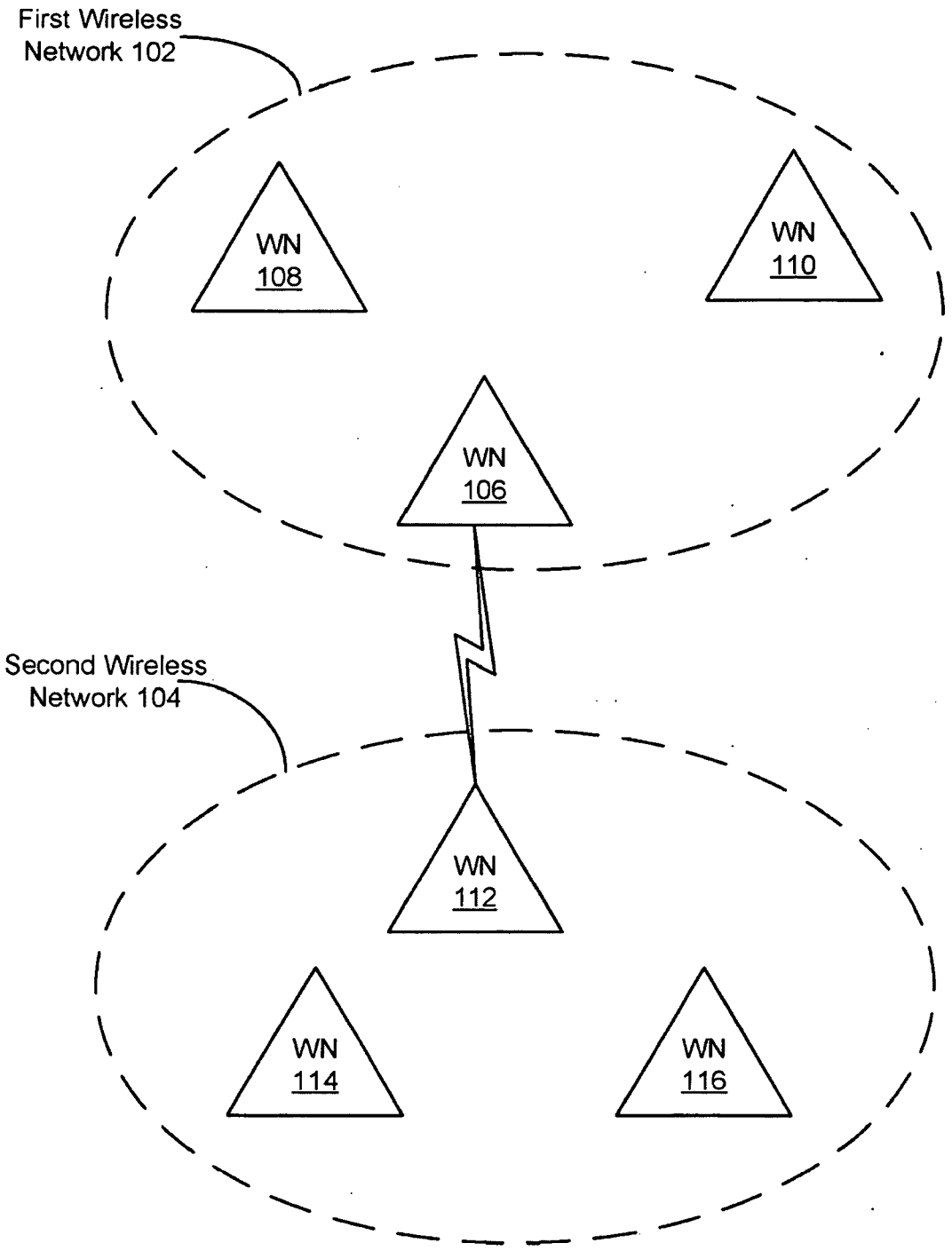

First Wireless Network 102
WN 108
WN 110
WN 106
Second Wireless Network 104
WN 112
WN 114
WN 116

FIG. 1

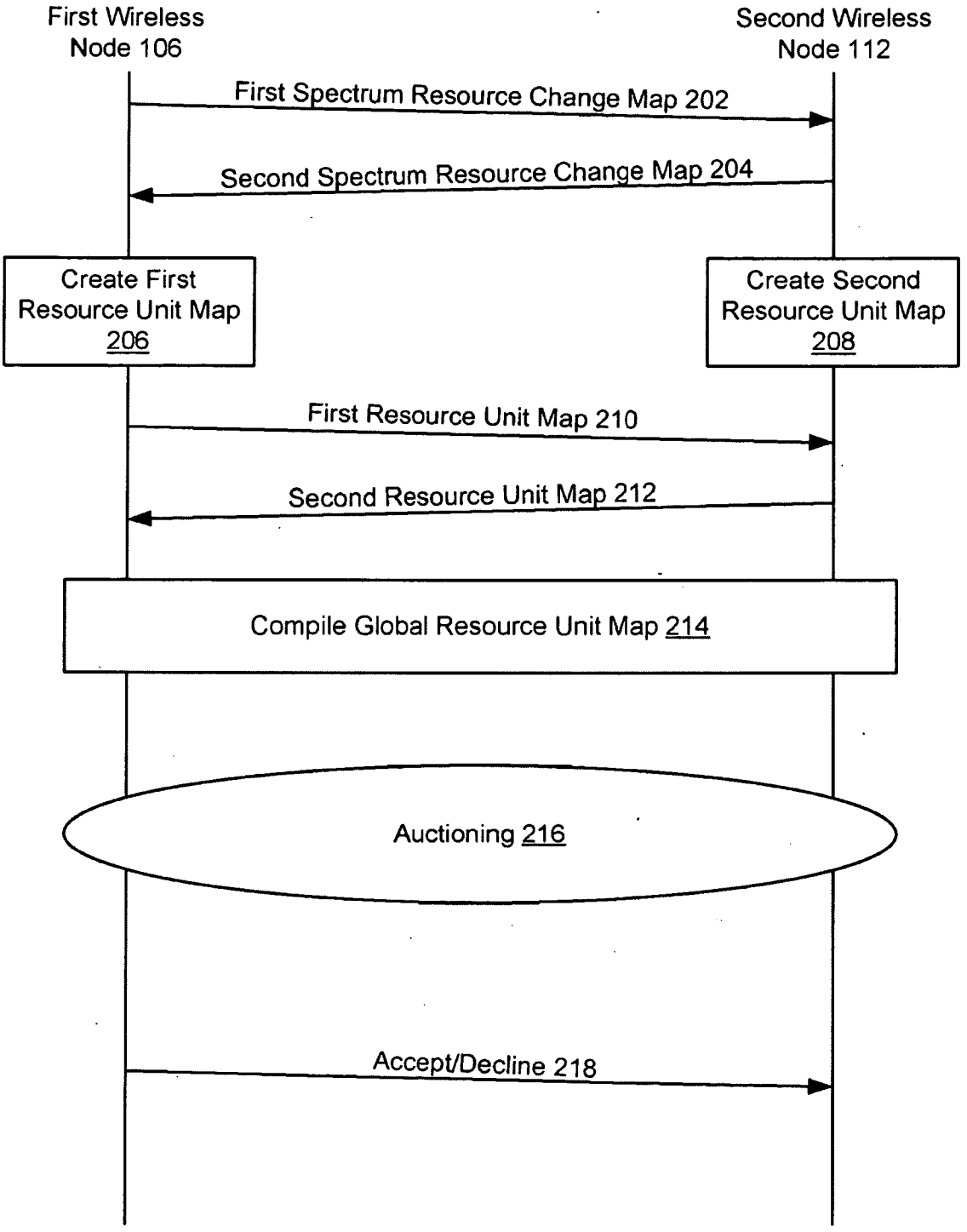

First Wireless Node 106
Second Wireless Node 112
First Spectrum Resource Change Map 202
Second Spectrum Resource Change Map 204
Create First Resource Unit Map 206
Create Second Resource Unit Map 208
First Resource Unit Map 210
Second Resource Unit Map 212
Compile Global Resource Unit Map 214
Auctioning 216
Accept/Decline 218

FIG. 2A

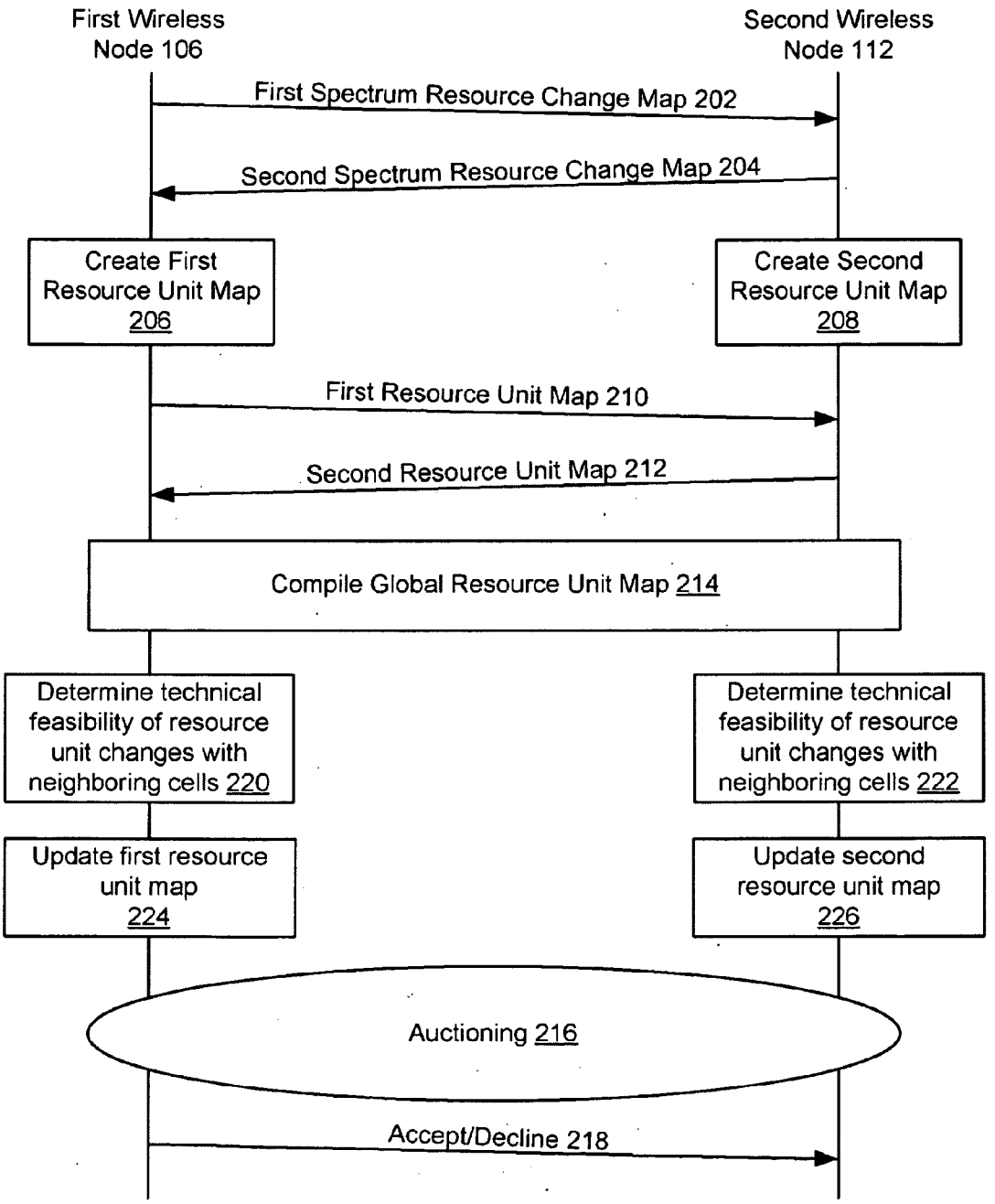

First Wireless Node 106
Second Wireless Node 112
First Spectrum Resource Change Map 202
Second Spectrum Resource Change Map 204
Create First Resource Unit Map 206
Create Second Resource Unit Map 208
First Resource Unit Map 210
Second Resource Unit Map 212
Compile Global Resource Unit Map 214
Determine technical feasibility of resource unit changes with neighboring cells 220
Determine technical feasibility of resource unit changes with neighboring cells 222
Update first resource unit map 224
Update second resource unit map 226
Auctioning 216
Accept/Decline 218

FIG. 2B

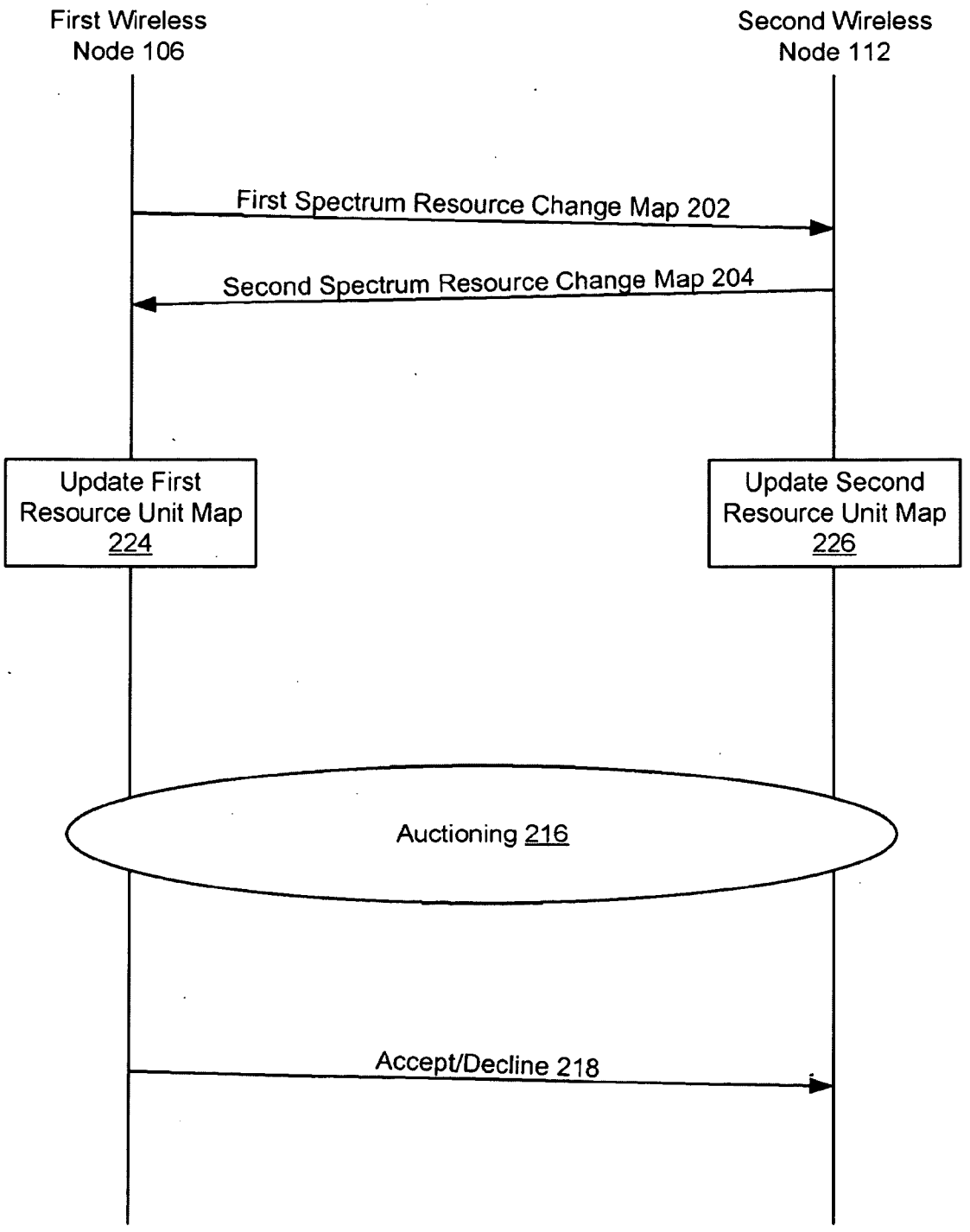

First Wireless Node 106
Second Wireless Node 112
First Spectrum Resource Change Map 202
Second Spectrum Resource Change Map 204
Update First Resource Unit Map 224
Update Second Resource Unit Map 226
Auctioning 216
Accept/Decline 218

FIG. 2C

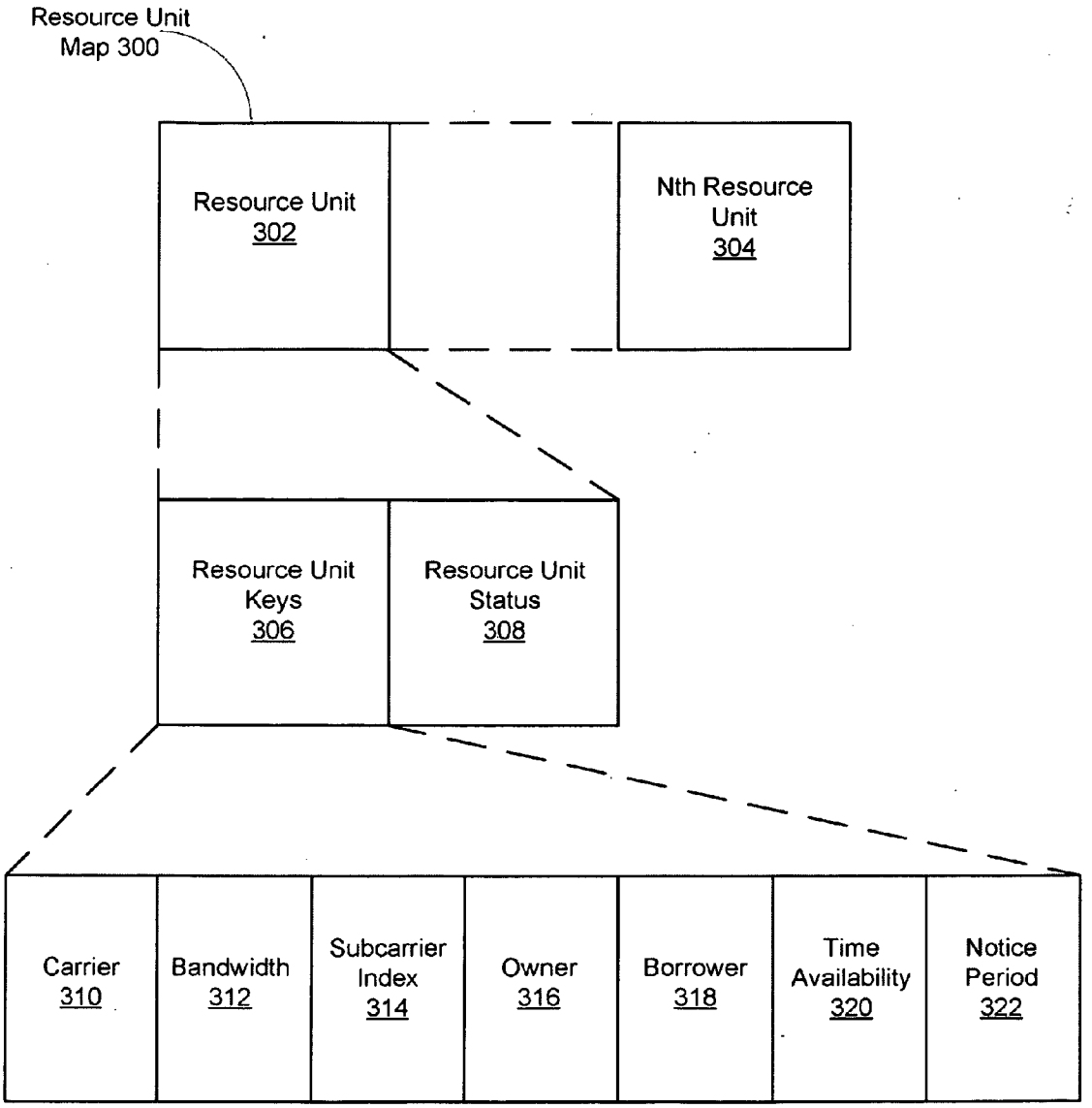

Resource Unit Map 300
Resource Unit 302
Nth Resource Unit 304
Resource Unit Keys 306
Resource Unit Status 308
Carrier 310
Bandwidth 312
Subcarrier Index 314
Owner 316
Borrower 318
Time Availability 320
Notice Period 322

FIG. 3

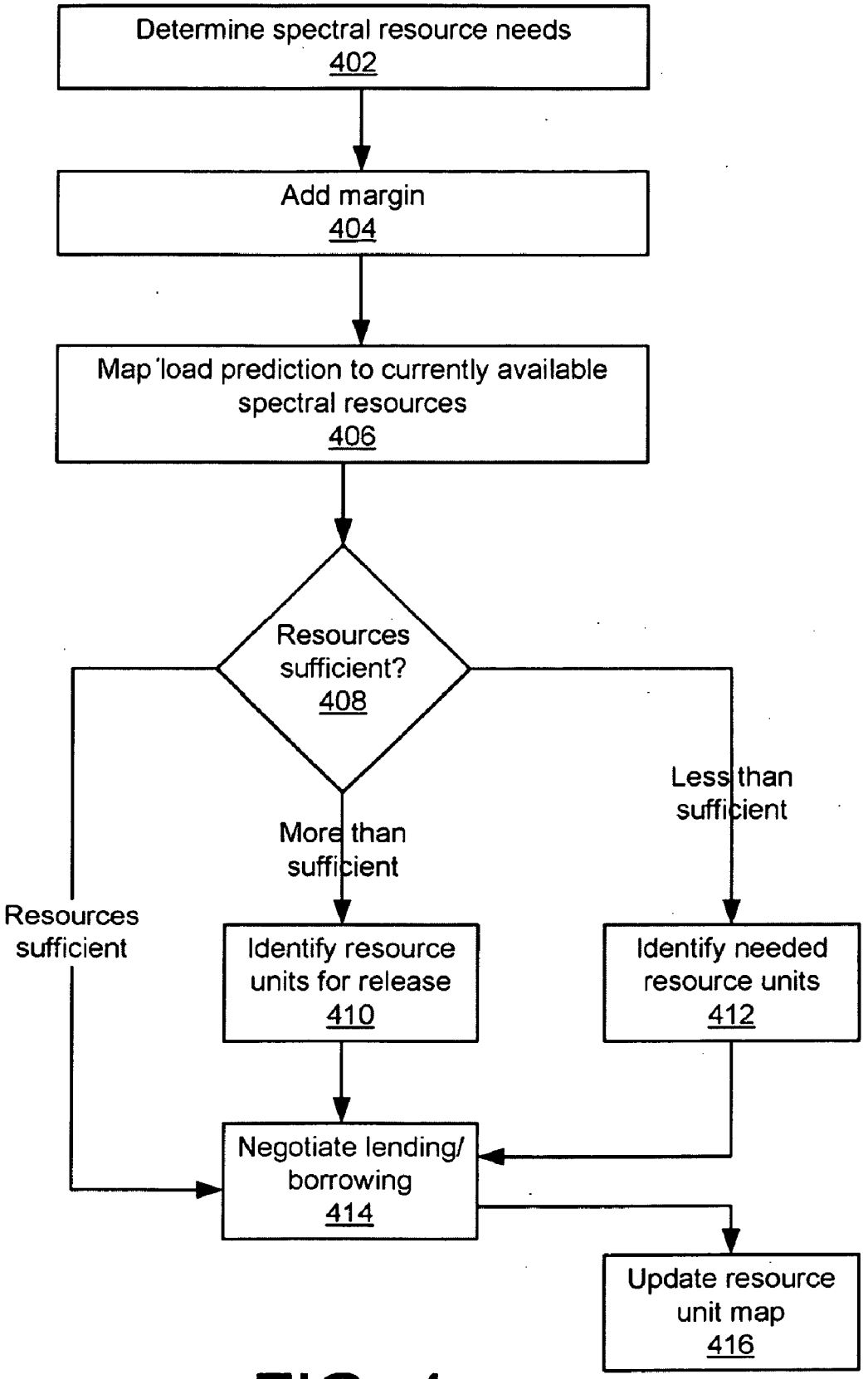

Determine spectral resource needs
402
Add margin
404
Map load prediction to currently available spectral resources
406
Resources sufficient?
408
Resources sufficient
More than sufficient
Less than sufficient
Identify resource units for release
410
Identify needed resource units
412
Negotiate lending/ borrowing
414
Update resource unit map
416

FIG. 4

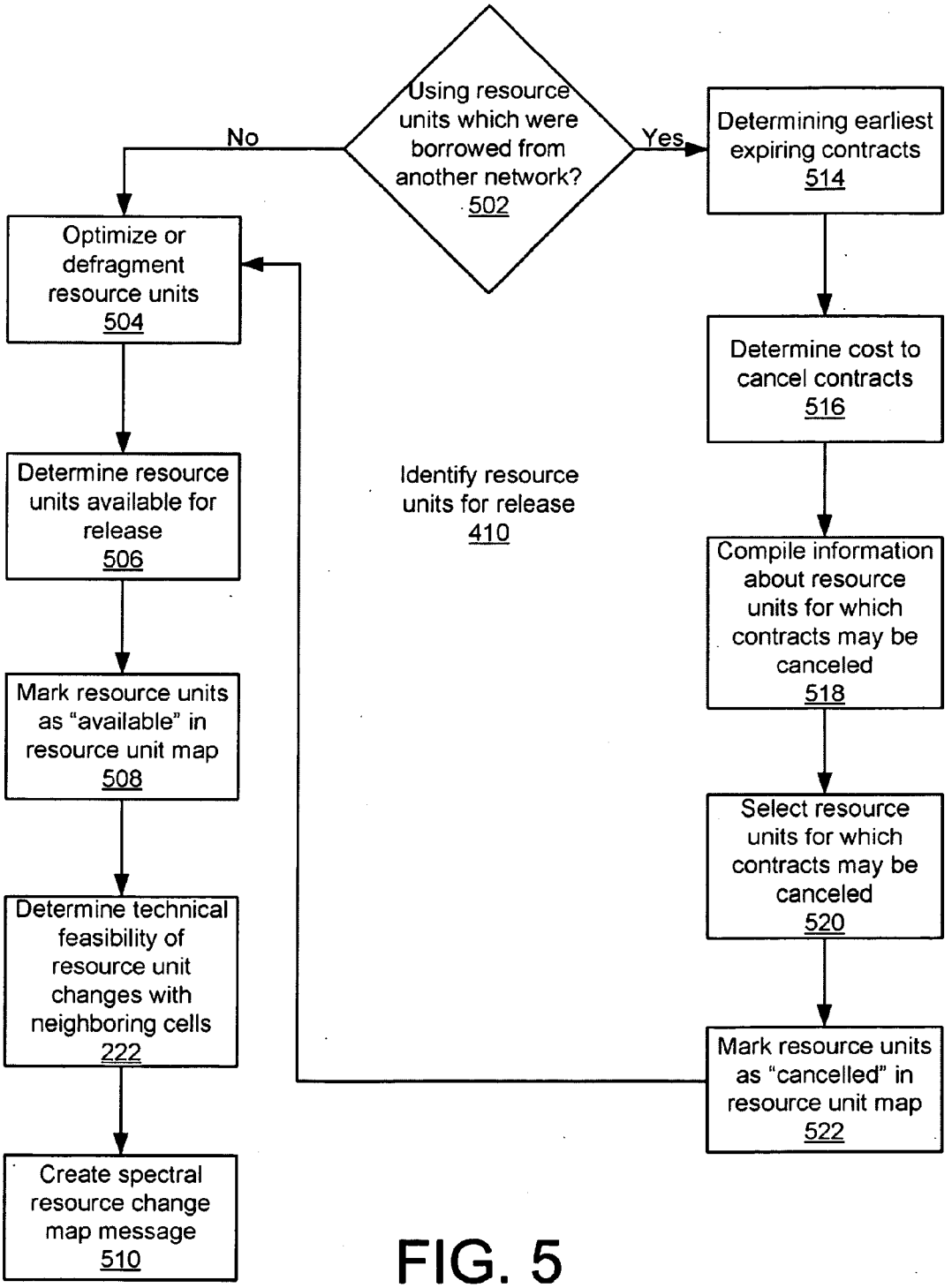

Using resource units which were borrowed from another network? 502
No
Yes
Optimize or defragment resource units 504
Determine resource units available for release 506
Mark resource units as "available" in resource unit map 508
Determine technical feasibility of resource unit changes with neighboring cells 222
Create spectral resource change map message 510
Identify resource units for release 410
Determining earliest expiring contracts 514
Determine cost to cancel contracts 516
Compile information about resource units for which contracts may be canceled 518
Select resource units for which contracts may be canceled 520
Mark resource units as "cancelled" in resource unit map 522

FIG. 5

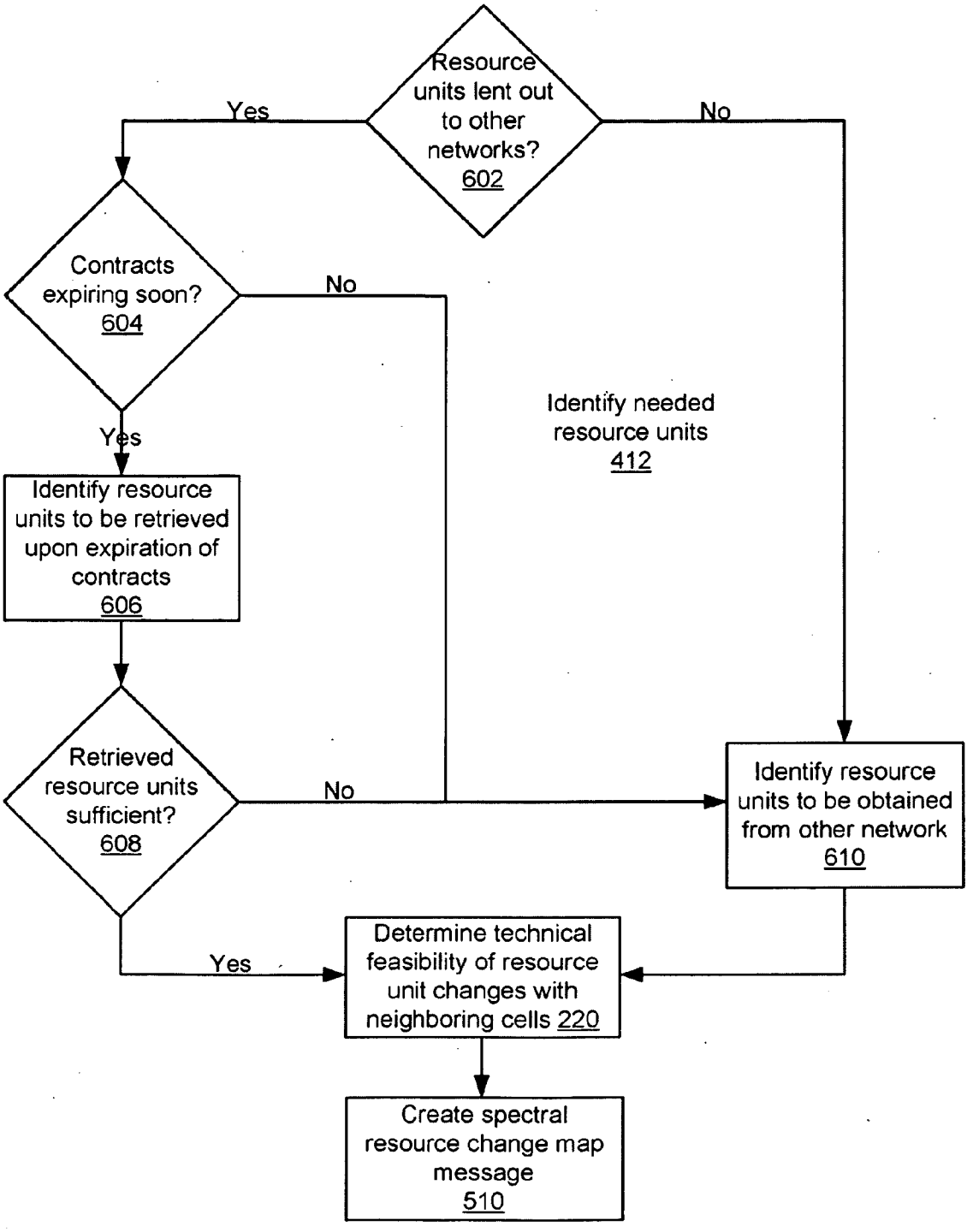

Resource units lent out to other networks? 602
Yes
No
Contracts expiring soon? 604
No
Yes
Identify needed resource units 412
Identify resource units to be retrieved upon expiration of contracts 606
Retrieved resource units sufficient? 608
No
Identify resource units to be obtained from other network 610
Yes
Determine technical feasibility of resource unit changes with neighboring cells 220
Create spectral resource change map message 510

FIG. 6

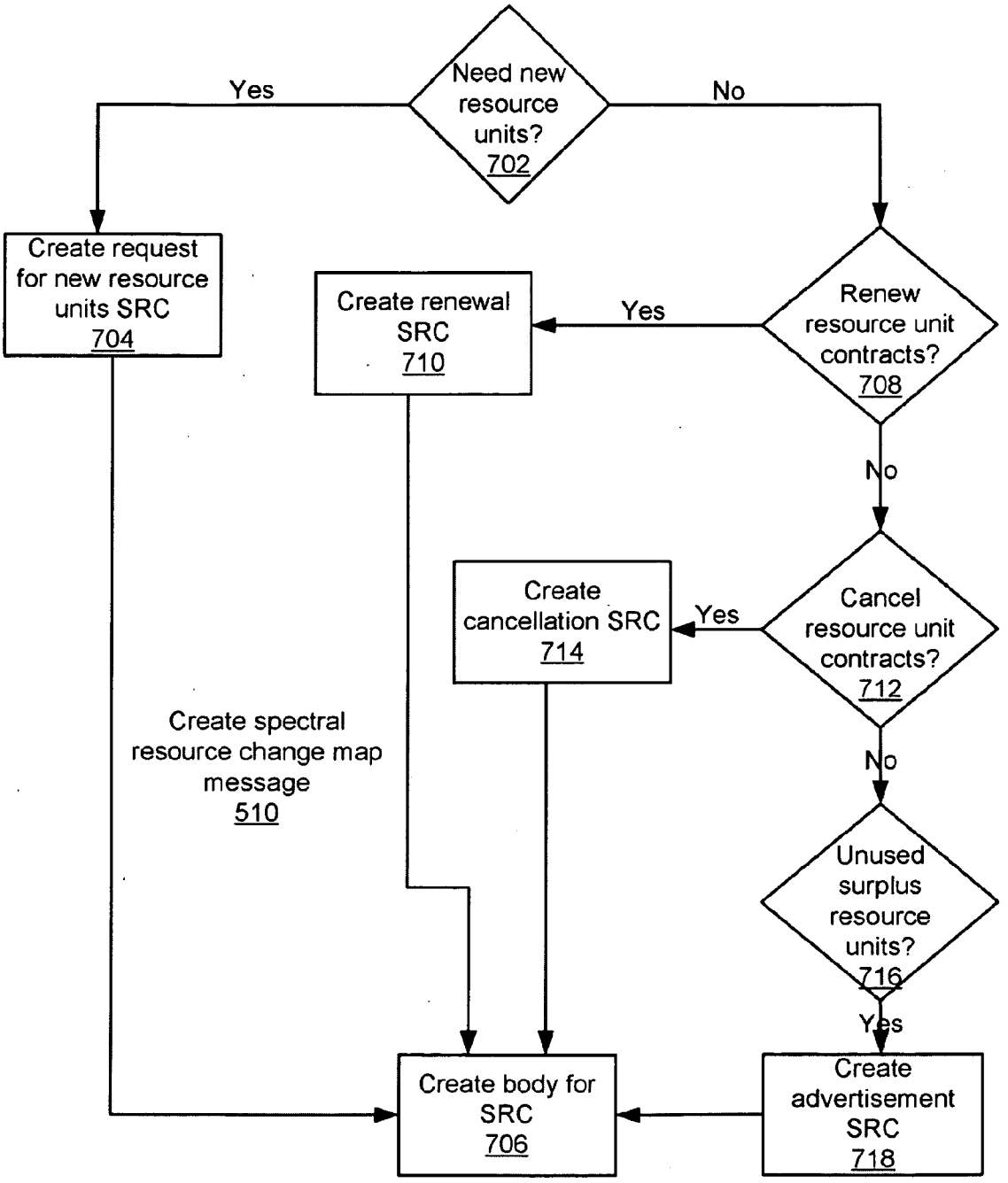

Need new resource units? 702
Yes
No
Create request for new resource units SRC 704
Create renewal SRC 710
Yes
Renew resource unit contracts? 708
No
Create cancellation SRC 714
Yes
Cancel resource unit contracts? 712
No
Create spectral resource change map message 510
Unused surplus resource units? 716
Yes
Create body for SRC 706
Create advertisement SRC 718

FIG. 7

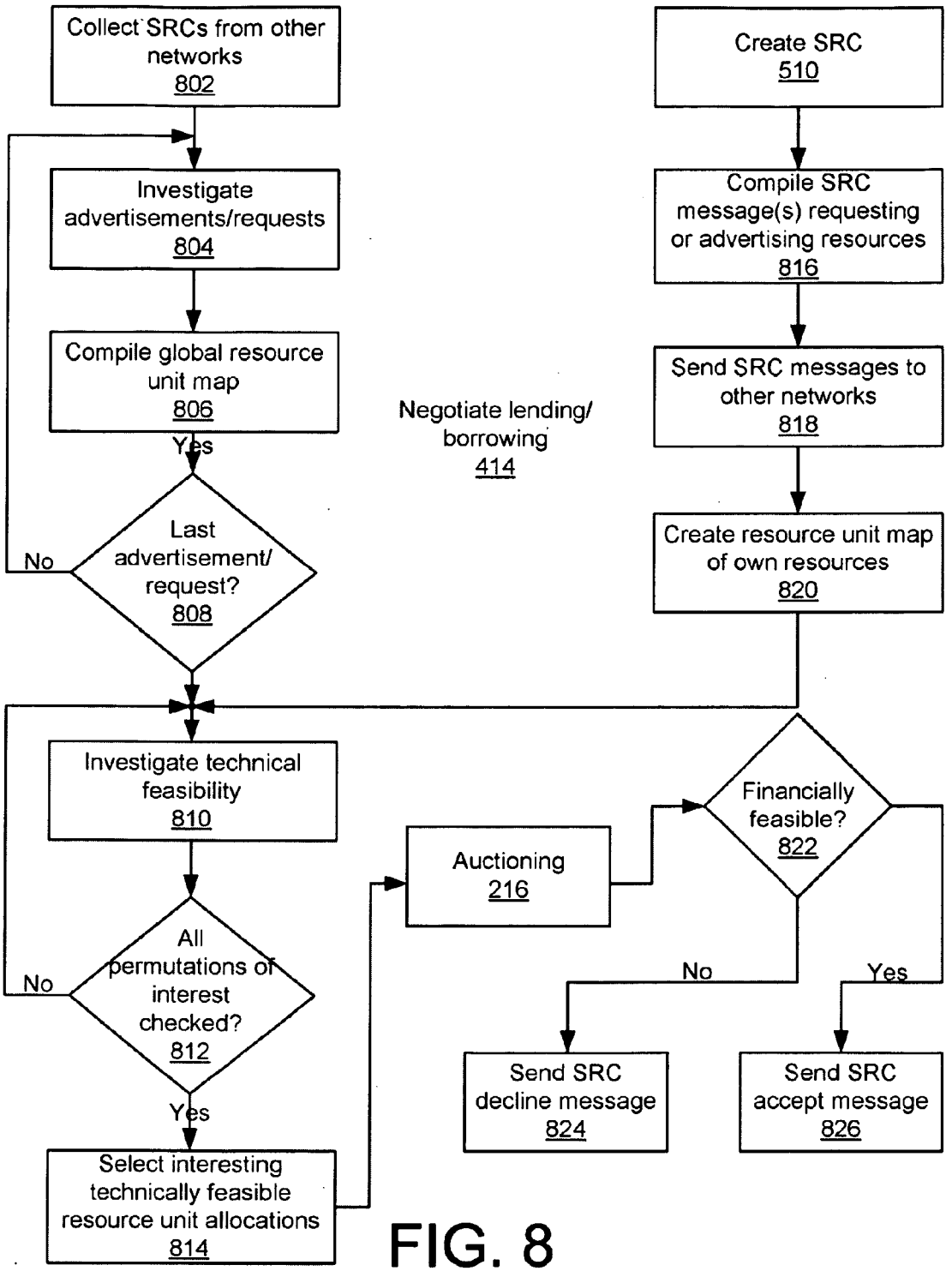

Collect SRCs from other networks 802
Investigate advertisements/requests 804
Compile global resource unit map 806
Yes
Last advertisement/ request? 808
No
Investigate technical feasibility 810
All permutations of interest checked? 812
No
Yes
Select interesting technically feasible resource unit allocations 814
Negotiate lending/ borrowing 414
Create SRC 510
Compile SRC message(s) requesting or advertising resources 816
Send SRC messages to other networks 818
Create resource unit map of own resources 820
Auctioning 216
Financially feasible? 822
No
Yes
Send SRC decline message 824
Send SRC accept message 826

FIG. 8

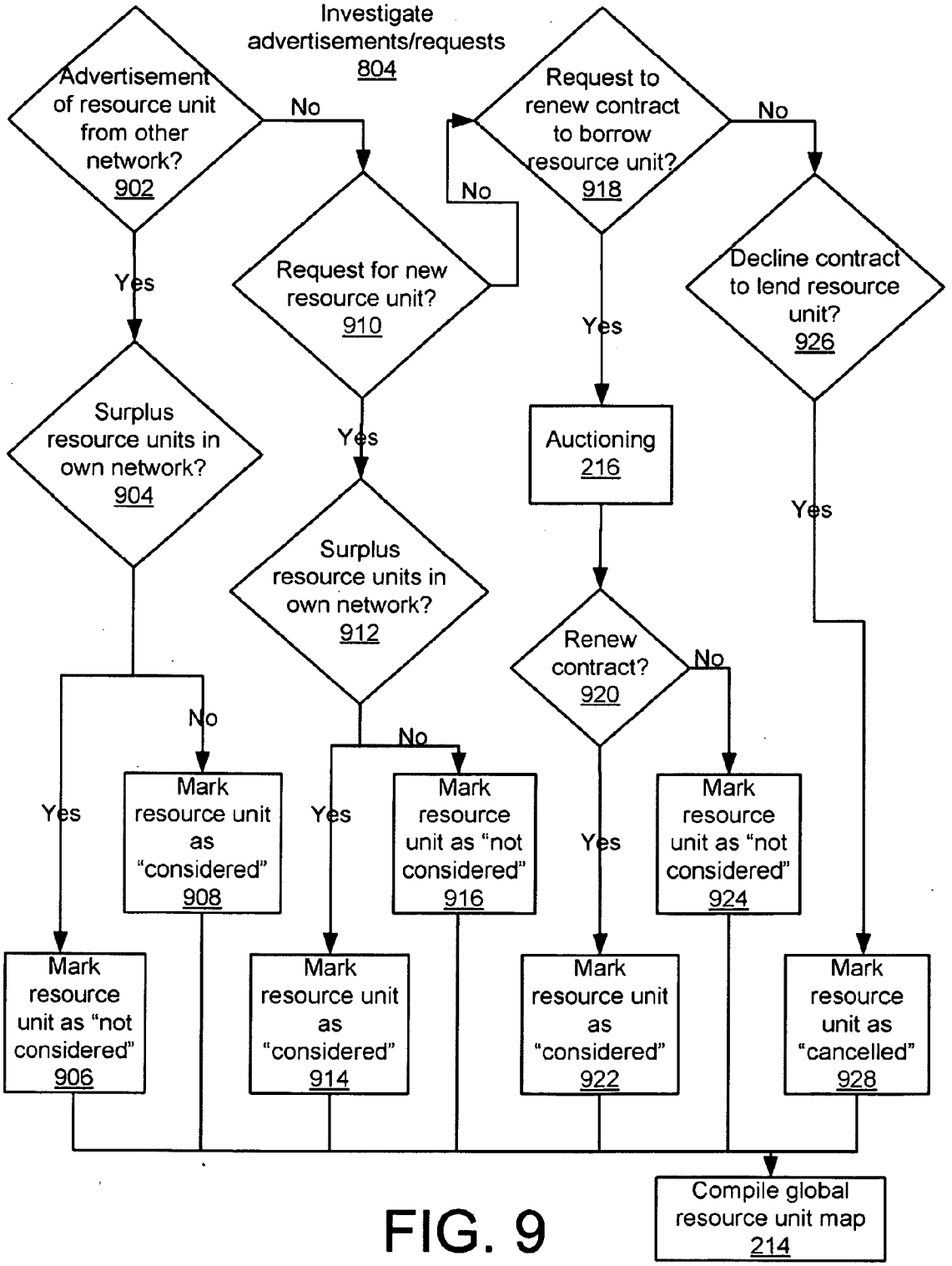

Investigate advertisements/requests 804
Advertisement of resource unit from other network? 902
No
Yes
Request for new resource unit? 910
No
Yes
Request to renew contract to borrow resource unit? 918
No
Yes
Decline contract to lend resource unit? 926
Yes
Surplus resource units in own network? 904
No
Yes
Mark resource unit as "considered" 908
Mark resource unit as "not considered" 906
Surplus resource units in own network? 912
No
Yes
Mark resource unit as "considered" 914
Mark resource unit as "not considered" 916
Auctioning 216
Renew contract? 920
No
Yes
Mark resource unit as "considered" 922
Mark resource unit as "not considered" 924
Mark resource unit as "cancelled" 928
Compile global resource unit map 214

FIG. 9

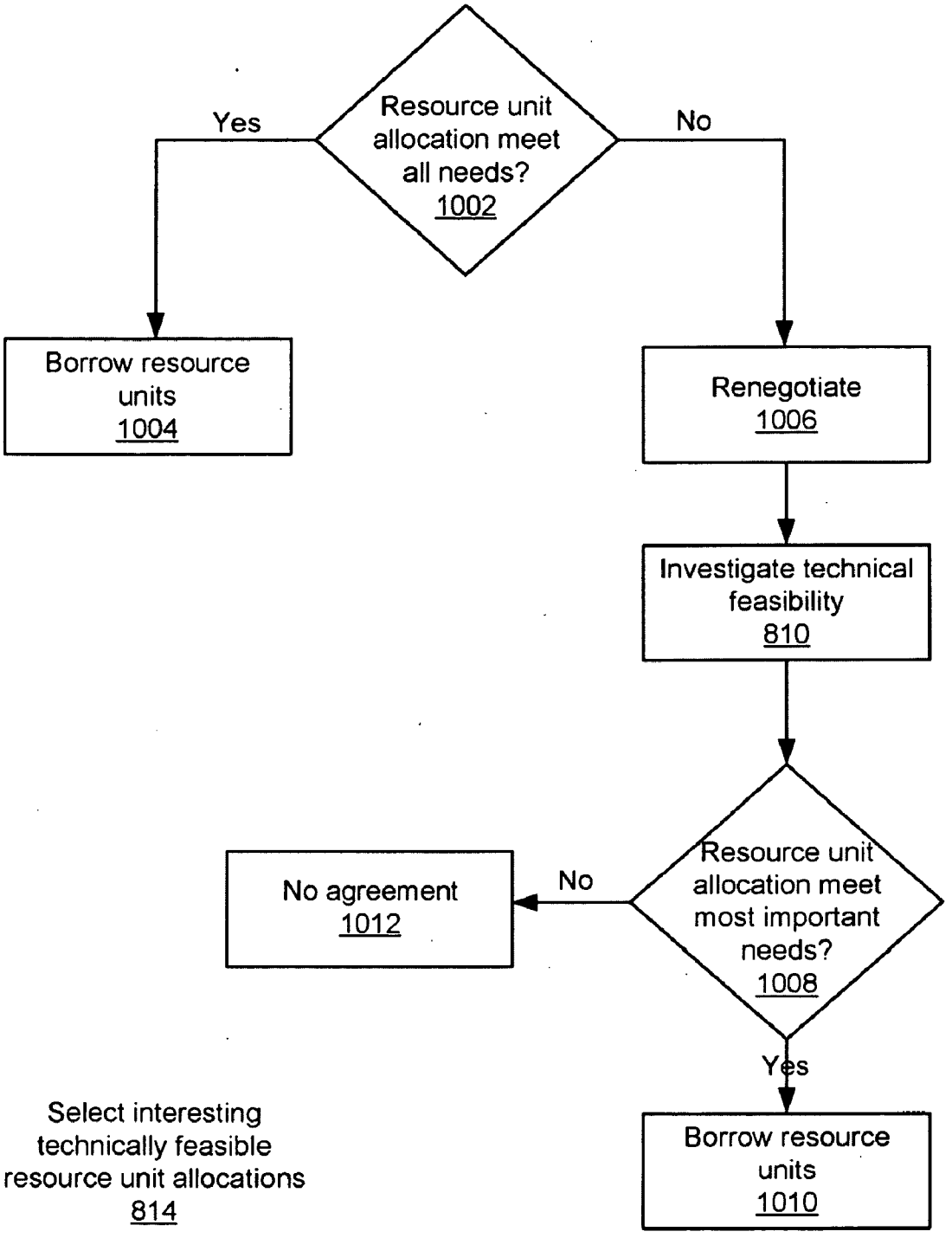

Resource unit allocation meet all needs? 1002
Yes
No
Borrow resource units 1004
Renegotiate 1006
Investigate technical feasibility 810
Resource unit allocation meet most important needs? 1008
No
No agreement 1012
Yes
Borrow resource units 1010
Select interesting technically feasible resource unit allocations 814

FIG. 10

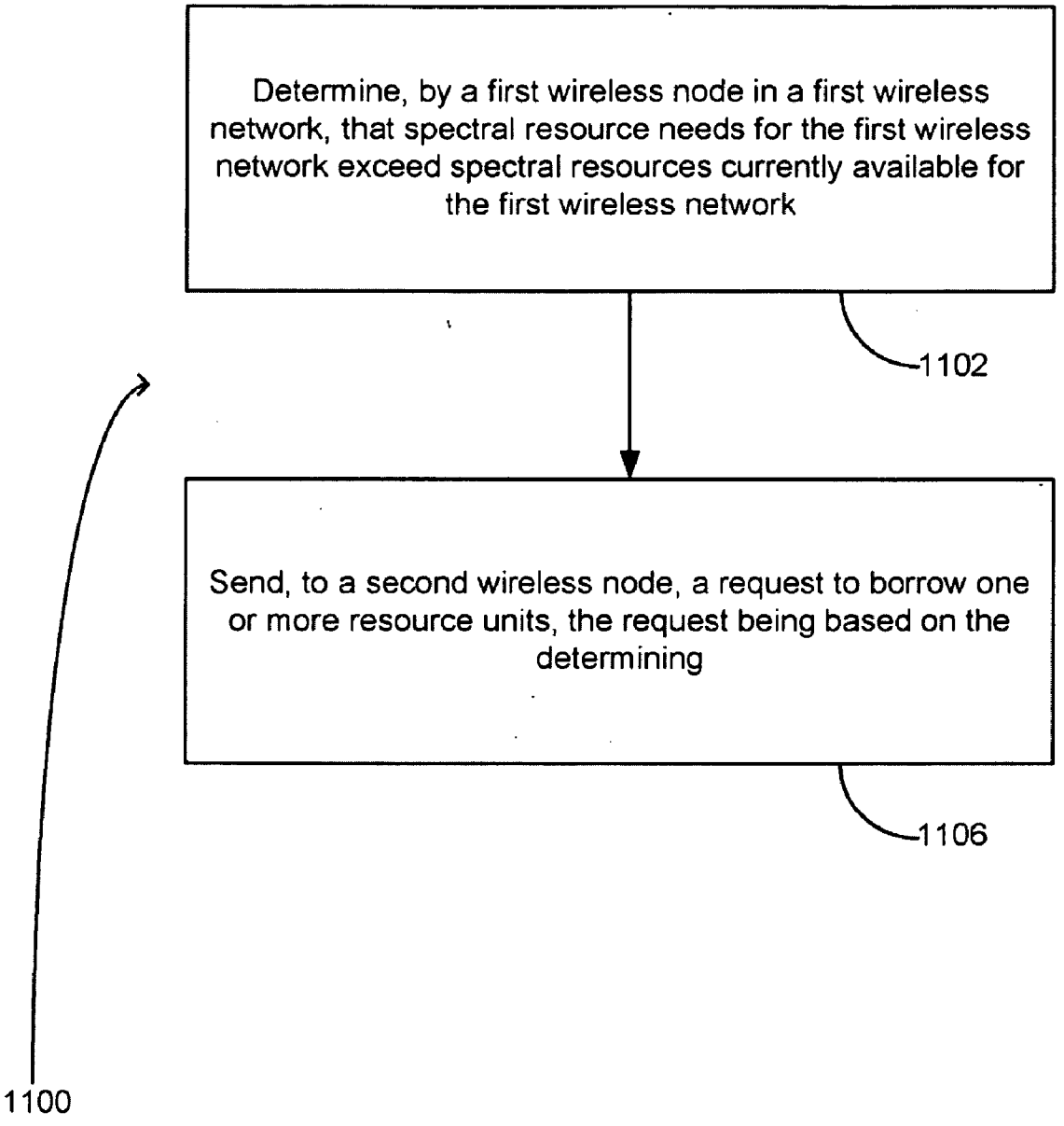

Determine, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network
1102
Send, to a second wireless node, a request to borrow one or more resource units, the request being based on the determining
1106
1100

FIG. 11

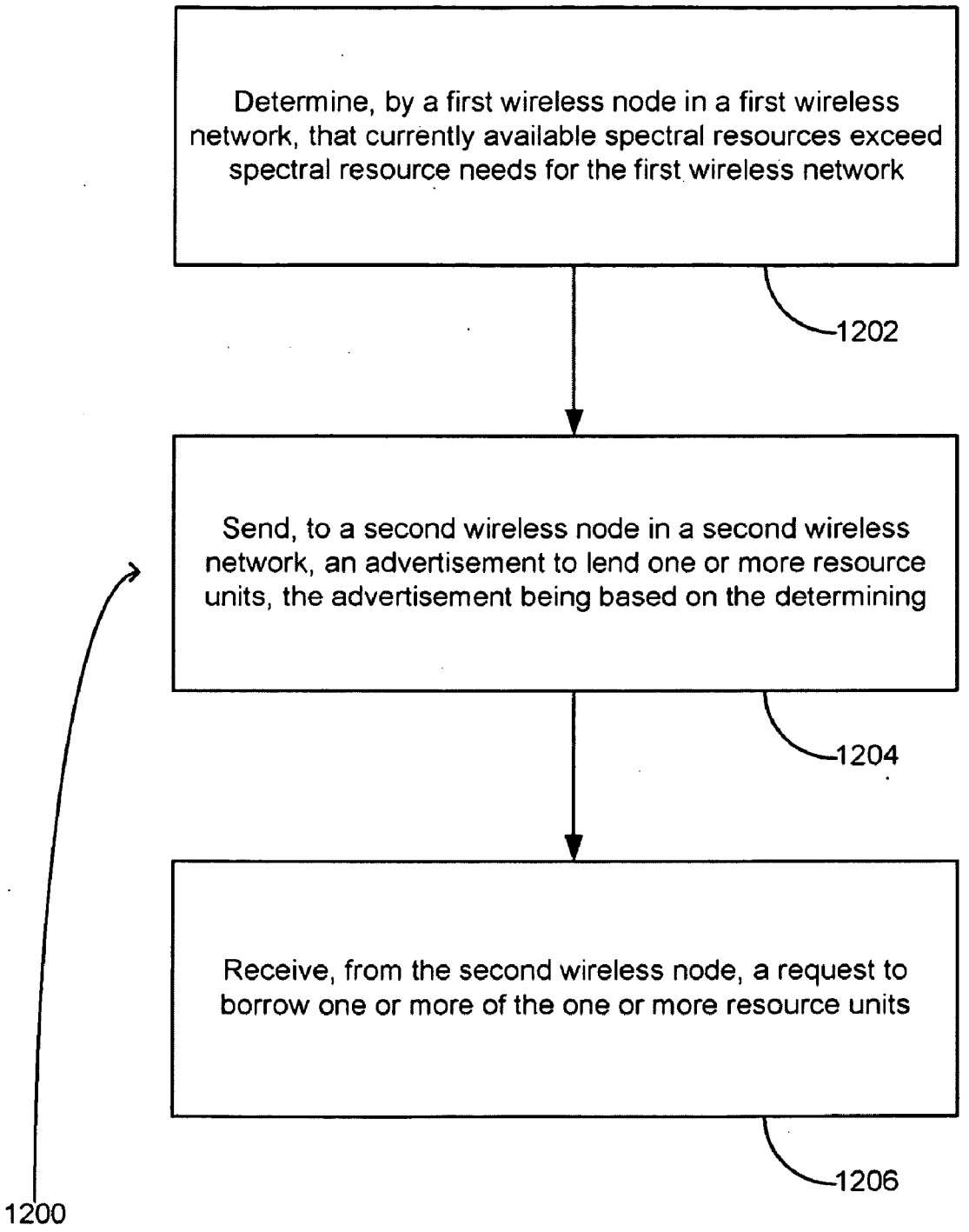

Determine, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs for the first wireless network
1202
Send, to a second wireless node in a second wireless network, an advertisement to lend one or more resource units, the advertisement being based on the determining
1204
Receive, from the second wireless node, a request to borrow one or more of the one or more resource units
1206
1200

FIG. 12

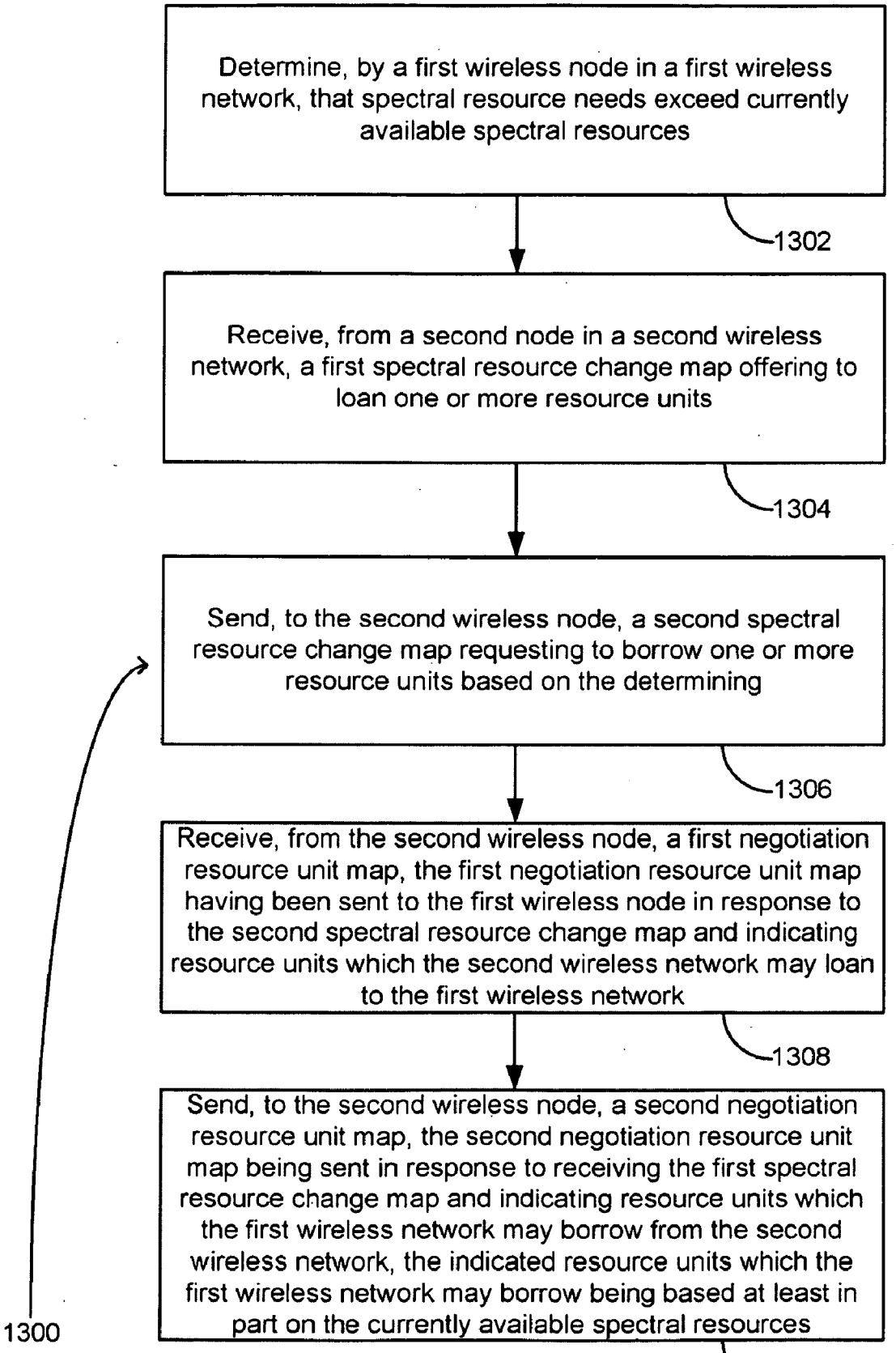

Determine, by a first wireless node in a first wireless network, that spectral resource needs exceed currently available spectral resources
1302
Receive, from a second node in a second wireless network, a first spectral resource change map offering to loan one or more resource units
1304
Send, to the second wireless node, a second spectral resource change map requesting to borrow one or more resource units based on the determining
1306
Receive, from the second wireless node, a first negotiation resource unit map, the first negotiation resource unit map having been sent to the first wireless node in response to the second spectral resource change map and indicating resource units which the second wireless network may loan to the first wireless network
1308
Send, to the second wireless node, a second negotiation resource unit map, the second negotiation resource unit map being sent in response to receiving the first spectral resource change map and indicating resource units which the first wireless network may borrow from the second wireless network, the indicated resource units which the first wireless network may borrow being based at least in part on the currently available spectral resources
1310
1300

FIG. 13

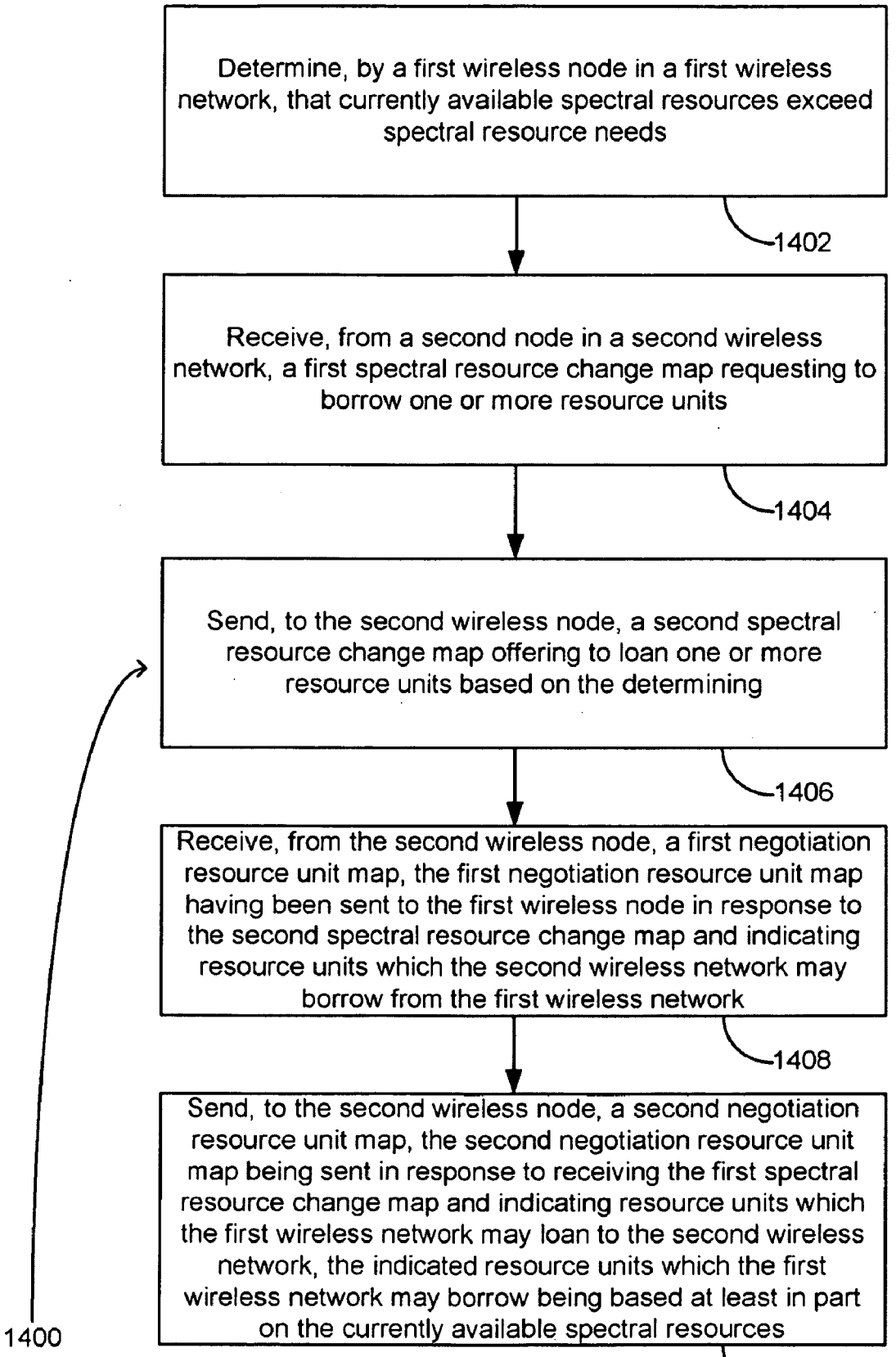

Determine, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs
1402
Receive, from a second node in a second wireless network, a first spectral resource change map requesting to borrow one or more resource units
1404
Send, to the second wireless node, a second spectral resource change map offering to loan one or more resource units based on the determining
1406
Receive, from the second wireless node, a first negotiation resource unit map, the first negotiation resource unit map having been sent to the first wireless node in response to the second spectral resource change map and indicating resource units which the second wireless network may borrow from the first wireless network
1408
Send, to the second wireless node, a second negotiation resource unit map, the second negotiation resource unit map being sent in response to receiving the first spectral resource change map and indicating resource units which the first wireless network may loan to the second wireless network, the indicated resource units which the first wireless network may borrow being based at least in part on the currently available spectral resources
1410
1400

FIG. 14

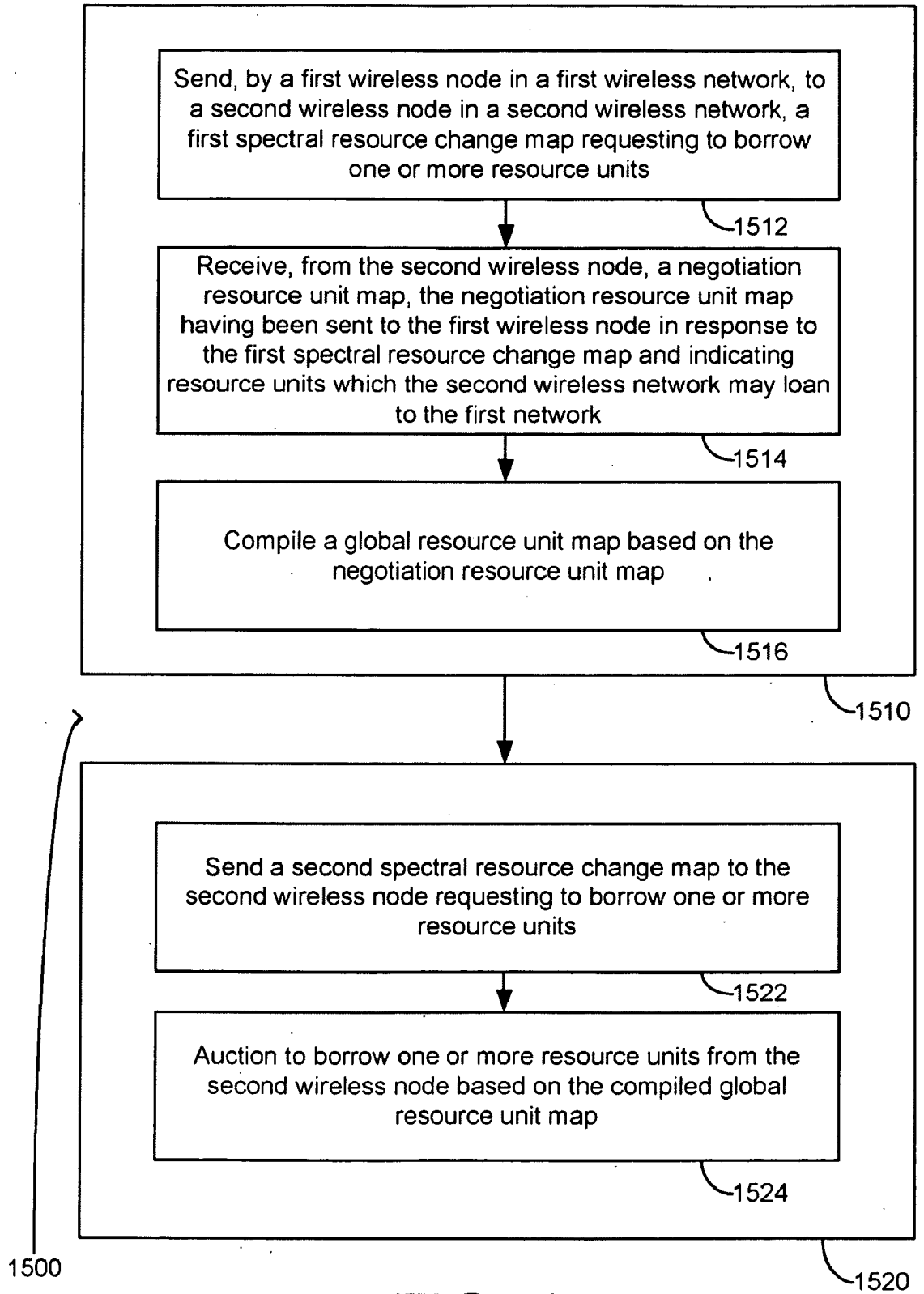

Send, by a first wireless node in a first wireless network, to a second wireless node in a second wireless network, a first spectral resource change map requesting to borrow one or more resource units
1512
Receive, from the second wireless node, a negotiation resource unit map, the negotiation resource unit map having been sent to the first wireless node in response to the first spectral resource change map and indicating resource units which the second wireless network may loan to the first network
1514
Compile a global resource unit map based on the negotiation resource unit map
1516
1510
Send a second spectral resource change map to the second wireless node requesting to borrow one or more resource units
1522
Auction to borrow one or more resource units from the second wireless node based on the compiled global resource unit map
1524
1520
1500

FIG. 15

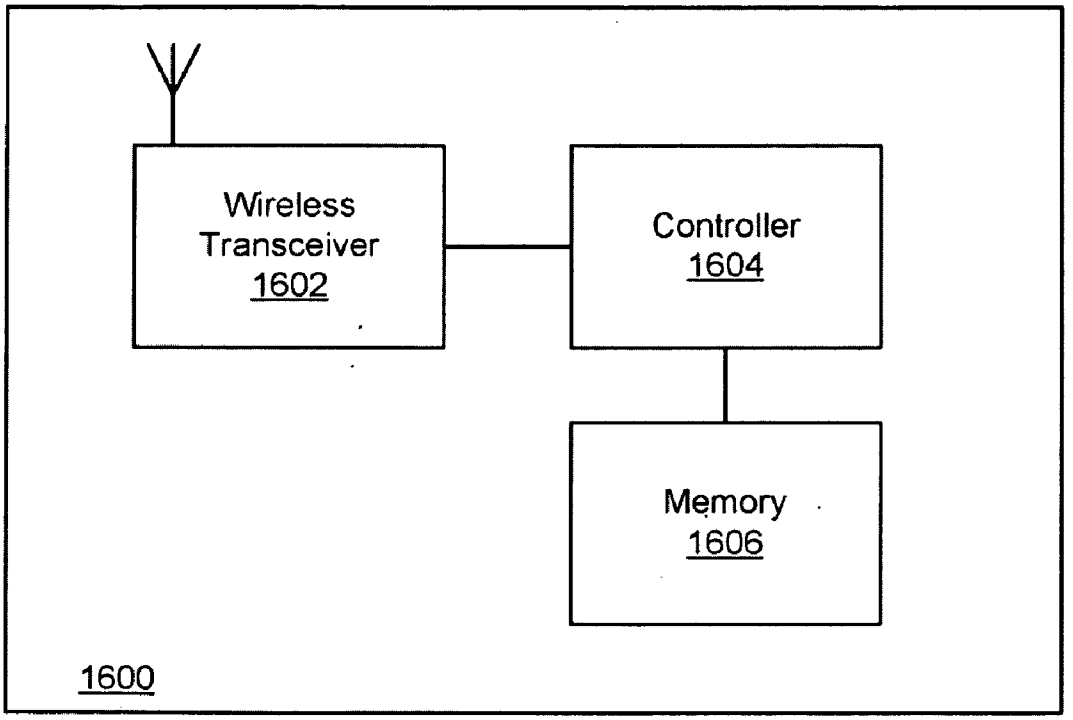

Wireless
Transceiver
1602
Controller
1604
Memory
1606
1600

FIG. 16

SPECTRUM SHARING

PRIORITY CLAIM

[0001] This application claims the benefit of priority based on U.S. Provisional Application No. 60/955,139, filed on Aug. 10, 2007, entitled, "Spectrum Sharing," the disclosure of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] This description relates to wireless networks.

BACKGROUND

[0003] Wireless networks may use spectral resources, such as different time slots, frequencies or carriers or subcarriers, or other spectral resources. More than one wireless network may be present in a geographical location. These networks may be of the same radio technology or of different radio technologies and may operate in the same frequency band. Thus, the spectrum resources can potentially be shared among these wireless networks. Different wireless networks typically use different resources to decrease interference. However, spectral resources available to a wireless network may not always be allocated to make efficient use of the resources. For example, the spectral resources allocated to each wireless network may not always correspond to the wireless network's load.

SUMMARY

[0004] According to one example embodiment, a method may include determining, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network. The method may further include sending, to a second wireless node in a second wireless network, a request to borrow one or more of the resource units, the request being based on the determining.

[0005] According to another example embodiment, a method may include determining, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs for the first wireless network. The method may further include sending, to a second wireless node in a second wireless network, an advertisement to lend one or more resource units, the advertisement being based on the determining. The method may further include receiving, from the second wireless node, a request to borrow one or more of the one or more resource units.

[0006] According to another example embodiment, a method may include determining, by a first wireless node in a first wireless network, that spectral resource needs exceed currently available spectral resources. The method may further include receiving, from a second wireless node in a second wireless network, a first spectral resource change map offering to loan one or more resource units. The method may further include sending, to the second wireless node, a second spectral resource change map requesting to borrow one or more resource units based on the determining. The method may further include receiving, from the second wireless node, a first negotiation resource unit map, the first negotiation resource unit map having been sent to the first wireless node in response to the second spectral resource change map and indicating resource units which the second wireless network may loan to the first wireless network. The method may further include sending, to the second wireless node, a second negotiation resource unit map, the second negotiation resource unit map being sent in response to receiving the first spectral resource change map and indicating resource units which the first wireless network may borrow from the second wireless network, the indicated resource units which the first wireless network may borrow being based at least in part on the currently available spectral resources.

[0007] According to another example embodiment, a method may include determining, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs. The method may further include receiving, from a second wireless node in a second wireless network, a first spectral resource change map requesting to borrow one or more resource units. The method may further include sending, to the second wireless node, a second spectral resource change map offering to loan one or more resource units based on the determining. The method may further include receiving, from the second wireless node, a first negotiation resource unit map, the first negotiation resource unit map having been sent to the first wireless node in response to the second spectral resource change map and indicating resource units which the second wireless network may borrow from the first wireless network. The method may further include sending, to the second wireless node, a second negotiation resource unit map, the second negotiation resource unit map being sent in response to receiving the first spectral resource change map and indicating resource units which the first wireless network may loan to the second wireless network, the indicated resource units which the first wireless network may borrow being based at least in part on the currently available spectral resources.

[0008] According to another example embodiment, an apparatus may include a controller. The apparatus may be configured to determine, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network, to receive, from a second wireless node in a second wireless network, an advertisement indicating availability of one or more resource units, and to send, to the second wireless node, a request to borrow one or more of the one or more resource units.

[0009] According to another example embodiment, an apparatus may include a controller. The apparatus may be configured to determine, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs, to send, to a second wireless node in a second wireless network, an advertisement to lend one or more resource units, and to receive a request to borrow one or more of the one or more resource units.

[0010] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a block diagram showing two wireless networks according to an example embodiment.

[0012] FIG. **2**A is a vertical-time sequence diagram showing messages sent between, and processes performed by, a first wireless node and a second wireless node, according to an example embodiment.

[0013] FIG. **2**B is a vertical-time sequence diagram showing messages sent between, and processes performed by, the

first wireless node and the second wireless node, according to another example embodiment.

[0014] FIG. **2**C is a vertical-time sequence diagram showing messages sent between, and processes performed by, the first wireless node and the second wireless node, according to another example embodiment.

[0015] FIG. **3** is a block diagram of a resource unit map according to an example embodiment.

[0016] FIG. **4** is a flowchart of a spectrum sharing sub-function according to an example embodiment.

[0017] FIG. **5** is a flowchart of a sub-function for identifying resource units for release according to an example embodiment.

[0018] FIG. **6** is a flowchart of a sub-function for identifying needed resource units according to an example embodiment.

[0019] FIG. **7** is a flowchart of a sub-function for creating spectrum resource change messages according to an example embodiment.

[0020] FIG. **8** is a flowchart of a sub-function for negotiating exchange of resource units according to an example embodiment.

[0021] FIG. **9** is a flowchart of a sub-function for investigating advertisements or requests according to an example embodiment.

[0022] FIG. **10** is a flowchart of a sub-function for selecting interesting technically feasible resource unit allocations according to an example embodiment.

[0023] FIG. **11** is a flowchart showing a method according to an example embodiment.

[0024] FIG. **12** is a flowchart showing another method according to another example embodiment.

[0025] FIG. **13** is a flowchart showing another method according to another example embodiment.

[0026] FIG. **14** is a flowchart showing another method according to another example embodiment.

[0027] FIG. **15** is a flowchart showing another method according to another example embodiment.

[0028] FIG. **16** is a block diagram showing an apparatus according to an example embodiment.

DETAILED DESCRIPTION

[0029] FIG. **1** is a block diagram showing two wireless networks **102**, **104** according to an example embodiment. The first wireless network **102** may include a first wireless node **106** and a plurality of other wireless nodes **108**, **110**. The wireless nodes **106**, **108**, **110** in the first wireless network **102** may include, for example, base stations, node Bs, gateways, relay stations, or access points. The wireless nodes **106**, **108**, **110** may serve a plurality of mobile nodes (not shown) such as cellular telephones, WLAN (wireless local area network) devices, WiMAX devices, smartphones, personal digital assistants (PDAs), or laptop or notebook computers, such as by communicating with the mobile nodes via an air interface, according to various example embodiments.

[0030] The second wireless network **104** may include a second wireless node **112** and a plurality of other wireless nodes **114**, **116**. These wireless nodes **112**, **114**, **116** may also include base stations, node Bs, gateways, relay stations, or access points, according to various example embodiments. The wireless nodes **112**, **114**, **116** may serve a plurality of mobile nodes such as cellular telephones, WLAN (wireless local area network) devices, WiMAX devices, smartphones, PDAs, or laptop or notebook computers.

[0031] The first wireless network **102** and second wireless network **104** may occupy or serve overlapping geographical areas. To avoid interference between the wireless networks **102**, **104**, each wireless network **102**, **104** may be allocated distinct spectral resources. The spectral resources may be allocated to the wireless networks **102**, **104** by regulation, by auction, or by agreement between operators of the wireless networks **102**, **104**, according to example embodiments. Spectral resources may be measured or represented in units of bandwidth (e.g., Hz), time slots (or time), or other units, and may also take into consideration the frequency of the bands, a level of fragmentation, or location of the wireless nodes.

[0032] The load on the wireless networks **102**, **104** created by exchanging data with the mobile nodes may vary in time and/or location. For example, the first wireless network **102**, may at one time have spectral resource needs, e.g., caused by the load on the first wireless network **102**, that exceed the spectral resources currently available to the first wireless network **102**, and may at another time have available spectral resources which exceed the spectral resource needs for the wireless network **102**. The second wireless network **104**, or other wireless networks (not shown), may also have varying spectral resource needs. Accordingly, it may be desirable for the wireless networks **102**, **104** to share or exchange spectral resources to accommodate varying spectral resource needs, and to allow a more efficient use of the available resources.

[0033] The spectral resource needs may be current or projected. Current spectral resource needs may reflect current load or demand on the network; for example, mobile nodes within the first wireless network **102** may be requesting transfer of data with the wireless nodes **106**, **108**, **110** which exceed the currently available spectral resources. Projected spectral resource needs may be based on past network loads, such as based on network loads during certain days of the week or certain hours of the day, or based on a number of subscribers within a geographical area served by the first wireless network **102**.

[0034] Spectral resources may be assigned or exchanged according to long term schemes or short term schemes. Long term schemes may negotiate spectral resources over a longer time scale, and/or may negotiate or assign the spectral resources within multiple network operators. Long term schemes may take into account load prediction or estimates of network load, vertical sharing (information about spectrum availability based on priorities between technologies), a spectrum register with information on exclusion zones or spectrum sharing functions, and/or a spectrum manager that oversees spectrum usage (such as the Spectrum Manager as defined by the IST-WINNER project).

[0035] Short term schemes may negotiate smaller amounts of spectral resources, and/or, for example, may negotiate or assign the spectral resources at the cell level. Short term schemes may incur lower signaling and/or processing overhead than long term schemes, according to an example embodiment. Short term schemes may take into account the long term scheme, vertical sharing, horizontal sharing or information about spectrum availability with no priority between technologies, the spectrum register, and/or a constraint processor. The constraint processor may provide information about the technical feasibility of borrowing or lending spectral resources or resource units, such as information from the physical layer on the usability of chunks of spectral

resources or predefined spectral chunk patterns, or information about radio channel conditions or average attainable spectral efficiency.

[0036] A node, such as the first wireless node **106**, may determine spectral resource needs of a network such as the first wireless network **102** (or other radio access network), based on the factors taken into account by the long term scheme and/or short term scheme. The first wireless node **106** may add a margin to the determined spectral resource needs. The margin may be a fixed percentage, such as ten, fifteen, or twenty percent, and may account for inaccuracies in the load prediction, spikes in the load, guard bands, and/or for reserving additional spectral resources. The first wireless node **106** may determine its spectral resource needs based on the determined spectral resource needs plus the margin, according to an example embodiment.

[0037] The first wireless node **106** may compare the first wireless network's **102** spectral resource needs to its currently available spectral resources. If the first wireless node **106** determines that the first wireless network's **102** spectral resource needs exceed the first wireless network's **102** currently available spectral resources, the first wireless node **106** may seek to borrow spectral resources for the first wireless network **102** from another wireless network, such as the second wireless network **104**. If the first wireless node **106** determines that the first wireless network's **102** currently available spectral resources exceed the first wireless network's **102** spectral resource needs, then the first wireless node **106** may seek to lend (or make available for lending) some of the first wireless network's **102** spectral resources to another wireless network, such as the second wireless network **104**. If the first wireless node **106** determines that the first wireless network's **102** currently available spectral resources are just sufficient to meet the first wireless network's **102** spectral needs, then the first wireless node **106** may not seek to lend or borrow spectral resources on behalf of the first wireless network **102**. According to an example embodiment, the spectral resources may be broken into resource units; the wireless networks **102**, **104** may lend or borrow resource units to each other.

[0038] FIG. **2**A is a vertical-time sequence diagram showing messages sent between, and processes performed by, the first wireless node **106** and the second wireless node **112**, according to an example embodiment. These messages or processes may be sent or performed as part of either the long term scheme or the short term scheme, according to an example embodiment.

[0039] In the example shown in FIG. **2**A, the first wireless node **106** may have determined that spectral resource needs for the first wireless network **102** exceed spectral resources currently available to the first wireless network **102**, and the second wireless node **112** may have determined that currently available spectral resources exceed spectral resource needs for the second wireless network **104**. Based on these determinations, the first wireless node **106** may send to the second wireless node **112** a request to borrow spectral resources, such as spectral resources in the form of resource units, and the second wireless node **112** may send to the first wireless node an advertisement indicating availability of spectral resources such as one or more resource units.

[0040] The request and/or advertisement may include spectrum resource change maps (SRCs) **202**, **204**, according to an example embodiment. For example, the first SRC **202** may include one or more requests for new contracts for spectral resources, one or more requests to renew contracts for spectral resources, and/or one or more cancellations of contracts for spectral resources. According to this example, the second SRC **202** may include one or more advertisements or offers of new contracts for spectral resources, one or more offers to renew contracts for spectral resources, and/or one or more cancellations of contracts for spectral resources. While FIG. **2**A shows the first wireless node **106** sending the first SRC **202** before the second wireless node **112** sends the second SRC **204**, the second wireless node **112** may send the second SRC **204** first, or the SRCs **202**, **204** may be sent simultaneously, according to various example embodiments.

[0041] The SRCs **202**, **204** may indicate a status for each of one or more resource units, according to an example embodiment. The properties of resource units are discussed in further detail with reference to FIG. **3**. According to another example embodiment, the SRCs **202**, **204** may not indicate statuses for particular resource units, but may indicate a request or advertisement for spectral resources, and may include a measure of spectral resources requested or advertised, such as in bandwidth.

[0042] According to an example embodiment, the second wireless node **112** may not send the advertisement or SRC **204** to the first wireless node **106**. In this example, the following processes may be performed in response to the first wireless node **102** sending the request or SRC **202** to the second wireless node **112**.

[0043] The first wireless node **106** and the second wireless node **112** may each create resource units maps (**206**, **208**), which may be considered negotiation resource unit maps, according to an example embodiment. For example, the first wireless node **106** may create a first resource unit map (**206**) which indicates resource units that are occupied or allocated within the first wireless network **102**, resource units which are reserved as part of the first wireless network's **102** margin, resource units which are considered for borrowing by the first wireless network **102**, resource units which are not considered for borrowing by the first wireless network **102**, and resource units which are cancelled, meaning that the first wireless network **102** will not renew a contract to borrow the resource unit.

[0044] Similarly, the second wireless node **112** may also create a second resource unit map (**208**). For example, the second resource unit map may indicate resource units which are occupied and not available for lending, resource units which are reserved as part of the margin and not available for lending, resource units which the second wireless network **104** would consider lending, resource units which are not considered for lending, and resource units which are cancelled, meaning that the second wireless network **104** will not renew a contract to lend the resource unit.

[0045] The first wireless node **106** may send the first resource unit map **210** to the second wireless node **112**, and the second wireless node may send the second resource unit map **212** to the first wireless node **106**. While FIG. **2**A shows the first wireless node **106** sending the first resource unit map **210** before the second wireless node **112** sends the second resource unit map **212**, the second wireless node **112** may send the second resource unit map **212** first, or the resource unit maps **210**, **212** may be sent simultaneously, according to example embodiments.

[0046] In an example embodiment, one or more of the wireless networks **106**, **112** may not wish to divulge how it allocates its spectral resources. In this example, the resource

unit maps **210**, **212** may not indicate whether a resource unit is occupied or reserved, and instead may simply indicate whether the resource units are available or desired for lending or borrowing, respectively.

[0047] In another example embodiment, the process of sending SRCs **202**, **204** and sending resource unit maps **210**, **212** may be combined. In this example, instead of separately sending the SRCs, the wireless nodes **106**, **112** may send only the resource units maps **210**, **212**.

[0048] The wireless nodes **106**, **112** may each compile global resource unit maps (**214**). The global resource maps may be compiled based on the currently available spectral resources for each wireless network **102**, **104**, the received advertisement or request (such as the SRC **202**, **204** or resource unit map **210**, **212**), and/or based on spectral resources which will be retrieved upon expiration of a contract within a specified time period. The global resource map may identify spectral resource units, such as by frequency band, and may indicate a status of each spectral resource unit, such as whether the spectral resource units are occupied, reserved, available for lending, considered for borrowing, and/or that a contract to lend or borrow the spectral resource unit will or will not be renewed. An example method for compiling the global resource map is discussed further with reference to FIG. **9**.

[0049] After compiling the global resource map (**214**), the wireless nodes **106**, **112** may engage in an auctioning (**216**) or billing procedure, according to an example embodiment. The auctioning (**216**) may include negotiating or bidding for the prices of resource units, for example. The auctioning (**216**) may also include negotiating or bidding for other terms of contracts for resource units, such as length of the contracts, notice period for termination of the contracts, and/or a price or penalty to be paid for cancelling the contracts.

[0050] Based on the auctioning (**216**), the first wireless node **106** may determine whether to accept or decline a contract to borrow spectral resource units. In determining whether to accept or decline the contract, the first wireless node **106** may consider factors such as the price to borrow the spectral resource units, the load on the first wireless network **102**, and/or cost expectations for not serving the load on the first network **102**. Based on the determining, the first wireless node **106** may send an accept or decline message **218** to the second wireless node **112**. In an example embodiment, the second wireless node **112** may send an acknowledgment message to the first wireless node **106** acknowledging receipt of the accept or decline message **218**. If the contract to borrow one or more spectral resource units was accepted by the first wireless node **106** on behalf of the first wireless network **102**, then the first wireless network **102** may use the spectral resources represented by the spectral resource units for the contracted time period, and the second wireless network may cease using these spectral resources for the specified time period, according to an example embodiment.

[0051] FIG. **2**B is a vertical-time sequence diagram showing messages sent between, and processes performed by, the first wireless node **102** and the second wireless node **112**, according to another example embodiment. This example, which may include the additional processes of determining technical feasibility of the resource unit changes (such as borrowing or lending resource units) with neighboring cells (**220**, **222**), and/or updating the resource maps (**224**, **226**), may be performed as part of the long term scheme, according to an example embodiment.

[0052] For example, the first wireless node **106** may determine the technical feasibility of borrowing resource units with neighboring cells (**220**) by determining whether the total resulting spectrum would be too fragmented to maintain guard bands, whether neighboring wireless nodes **108**, **110** are already using adjacent spectra, which could result in interference, and/or whether the resulting spectrum would include an even number of subcarriers (if using orthogonal frequency division multiplexing, for example). The first wireless node **106** may exchange signals with some or all of the other wireless nodes **108**, **110** in the first wireless network **102** as part of determining the technical feasibility of borrowing resource units, according to an example embodiment. The determined technical feasibility may indicate whether the first wireless network **102** could meet the spectral resource needs of the first wireless network **102** needs after borrowing the resource units from the second wireless network **104**.

[0053] The second wireless node **112** may determine the technical feasibility of lending resource units with neighboring cells (**222**) by determining whether the resulting spectrum would be too fragmented to maintain guard bands, or whether the resulting spectrum would include an even number of subcarriers, according to an example embodiment. The second wireless node **112** may exchange signals with some or all of the other wireless nodes **114**, **116** in the second wireless network **104** as part of determining the technical feasibility of lending resource units, according to an example embodiment. The determined technical feasibility may indicate whether the second wireless network **104** could still meet the spectral resource needs of the second wireless network **104** after lending the resource units to the first wireless network **102**.

[0054] The first wireless node **106** may update the first resource unit map (**224**), such as based on the determined technical feasibility of borrowing resource units. For example, if the first wireless node **106** determined that the first wireless network **102** could not meet its spectral resource needs by borrowing certain resource units, then the status of these resource units may be changed from considered to not considered.

[0055] Similarly, the second wireless node may update its second resource map (**226**), such as based on the determined technical feasibility of lending resource units. For example, if the second wireless node **106** determined that the second wireless network **104** could not meet its spectral resource needs by lending certain spectral resource units, then the status of these resource units may be changed from considered to not considered.

[0056] The wireless nodes **106**, **112** may engage in auctioning for the resource units based on the updated resource unit maps, according to an example embodiment.

[0057] FIG. **2**C is a vertical-time sequence diagram showing messages sent between, and processes performed by, the first wireless node **106** and the second wireless node **112**, according to another example embodiment. These messages may be sent and processes performed according to the short term scheme, according to an example embodiment. According to an example embodiment, the messages may be sent and processes performed as shown in FIG. **2**C multiple times for each time the messages are sent and processes performed as shown in FIG. **2**B.

[0058] According to this example, the resource unit maps may have already been created by the wireless nodes **106**, **112**. Also, the technical feasibility of certain resource unit allocations may have already been determined, which may

obviate the need for signaling with other wireless nodes **108**, **110**, **114**, **116** within the respective wireless networks **102**, **104**.

[0059] In an example embodiment, the sent SRCs **202**, **204** may include only an indication of the amount of spectral resources needed to borrow or available to lend, such as a measure of spectral resources, which may be represented by a bandwidth requirement or bandwidth available. The wireless nodes **106**, **112** may update their resource unit maps (**224**, **226**) by, for example, selecting resources units which the wireless nodes **106**, **112** would consider borrowing or lending based on received SRCs **202**, **204**, according to an example embodiment. The wireless nodes **106**, **112** may then engage in auctioning for the resource units (**216**), and the first wireless node **106** may send an accept or decline message **218** to the second wireless node **112**.

[0060] FIG. **3** is a block diagram of a resource unit map **300** according to an example embodiment. The resource unit map **300** may include a plurality of fields corresponding to a plurality of resource units mapped by the resource unit map **300**, according to an example embodiment. For example, the resource unit map **300** may include a resource unit field **302** through an Nth resource unit field **304**, where 'N' is the number of resource units indicated by the resource unit map **300**.

[0061] Each resource unit field **302** may include a plurality of subfields, such as a resource unit keys subfield **306** and a resource unit status subfield **308**, according to an example embodiment. The resource unit keys subfield **306** may include a number of subfields.

[0062] Some or all of the subfields shown in FIG. **3** may be included in the resource unit keys subfield **306**. For example, the resource unit keys subfield **306** may include a carrier subfield **310** which may indicate a carrier frequency of the resource unit, such as in units of Hertz. The resource unit keys subfield **306** may also include a bandwidth subfield **312**, which may indicate a bandwidth of the resource unit, such as in units of Hertz. The resource unit keys subfield **306** may also include a subcarrier index subfield **314**, which may indicate a subcarrier index or number, such as where the wireless nodes **106**, **112** are using OFDM. The resource unit keys subfield **306** may also include an owner subfield **316**, which may indicate a name of an owner of the resource unit (which may be a wireless network **102**, **104**), and a borrower subfield **318**, which may indicate a name of a borrower of the resource unit (which may be a wireless network **102**, **104**). The resource unit keys subfield **306** may also include a time availability subfield **320**, which may indicate a time for which the resource unit may be available for lending for which the resource unit must be available for borrowing. The resource unit keys subfield **306** may also include a notice period subfield **322**, which may indicate a required or desired notice period for cancelling a contract to borrow or lend the resource unit.

[0063] The resource unit status subfield **308** may indicate any of a number of predefined statuses. According to an example embodiment, the predefined states may include 'occupied,' 'reserved,' 'considered,' 'not considered,' and 'cancelled.' According to this example, the occupied status may indicate that the resource unit is allocated within the network **102**, **104**, and not available for lending. The reserved status may indicate that the resource unit is reserved as part of the network's **102**, **104** margin, and not available for lending. The considered status may indicate that the wireless node **106**, **112** would consider borrowing or lending the resource unit (depending on whether the spectral resource needs exceed or are exceeded by the currently available spectral resources). The not considered status may indicate that the wireless node **106**, **112** will not consider borrowing or lending the resource unit. The cancelled status may indicate that a previous contract for borrowing or lending the resource unit will be canceled (the contract may be with a wireless node **106**, **112** to which the resource unit map **300** was sent, or with a third-party radio access network). While five predefined statuses have been described in this example, other example embodiments may use less than all of these statuses, or may define other statuses for the resource units.

[0064] FIG. **4** is a flowchart of a spectrum sharing subfunction according to an example embodiment. According to this example, a wireless node **106**, **112** may determine spectral resource needs (**402**). The wireless node **106**, **112** may determine current or projected spectral resource needs, according to example embodiments. Current spectral resource needs may reflect current load or demand on the wireless network **102**, **104**, such as requests for transfer of data by the wireless nodes **106**, **108**, **110**, **112**, **114**, **116**. Projected spectral resource needs may be based on past network loads, such as based on network loads during certain days of the week or certain hours of the day, or based on a number of subscribers within a geographical area served by the first wireless network **102**.

[0065] The wireless node **106**, **112** may add a margin to the determined spectral resource needs (**404**). The margin may be a fixed percentage, such as ten, fifteen, or twenty percent, and may account for inaccuracies in the load prediction, spikes in the load, guard bands, and/or for reserving additional spectral resources.

[0066] The wireless node **106**, **112** may map the load prediction to currently available spectral resources (**406**). For example, the wireless node **106**, **112** may compare the load prediction, which may be based on the determined spectral resource needs plus the margin, to the currently available spectral resources. The currently available spectral resources may include spectral resources allocated to or owned by the wireless node **106**, **112**, plus or minus spectral resources borrowed or lent by the wireless node **106**, **112**.

[0067] The wireless node **106**, **112** may determine whether the available spectral resources are sufficient to meet the predicted load (**408**). The wireless node **106**, **112** may determine whether the available spectral resources are sufficient to meet the predicted load based, for example, on the load prediction being mapped to the currently available spectral resources.

[0068] If the currently available spectral resources are more than sufficient to meet the predicted load, the wireless node **106**, **112** may identify resource units for release or lending (**410**). The identification of resource units for release (**410**) is described with reference to FIG. **5**. The wireless node **106**, **112** may then negotiate lending or borrowing of resource units (**414**). The negotiation of lending or borrowing of resource units is discussed with reference to FIG. **8**. If the currently available spectral resources are less than sufficient to meet the predicted load, the wireless node **106**, **112** may identify needed resource units (**412**). The identification of needed resource units is discussed with reference to FIG. **6**. After identifying the needed resource units, the wireless node **106**, **112** may negotiate the lending or borrowing of resource units. If the currently available spectral resources are suffi-

cient to meet the predicted load, the wireless node **106**, **112** may negotiate the lending or borrowing of resource units (**414**), or may determine not to lend or borrow any resource units, according to an example embodiment.

[0069] After negotiating the lending or borrowing of resource units (**414**), the wireless node **106**, **112** may update the resource unit map **300** (**416**). The wireless node **106**, **112** may update the resource unit map **300** (**416**) based on the negotiations for lending or borrowing resource units (**414**). For example, the resource unit map **300** may indicate which resource units have been lent or borrowed, and the term or length of lending or borrowing.

[0070] FIG. **5** is a flowchart of the sub-function for identifying resource units for release (**410**) according to an example embodiment. According to this example, the wireless node **106**, **112** may determine whether its wireless network **102**, **104** is using resource units which were borrowed from another wireless network **102**, **104** (**502**). If the wireless node's **106**, **112** wireless network **102**, **104** is not using resource units which were borrowed from another network, the wireless node **106**, **112** may optimize or defragment its wireless network's **102**, **104** resource units (**504**). The wireless node **106**, **112** may optimize or defragment the resource units (**504**) by, for example, organizing the resource units into as few chunks or blocks as possible.

[0071] If the wireless node's **106**, **112** wireless network **102**, **104** is using resource units which were borrowed from another wireless network **102**, **104**, then the wireless node **106**, **112** may determine the earliest expiring contracts (**514**). For example, the wireless node **106**, **112** may determine which contracts to borrow resource units will expire first. Determining the earliest expiring contracts (**514**) may provide information about how soon the borrowed resource units may be released to the originating wireless network **102**, **104** (such as a radio access network), which may be the owner of the resource units. The wireless node **106**, **112** may also determine a cost to cancel the contracts (**516**). The contracts may, for example, include an early termination fee or cancellation fee for cancelling the contract before their expiration.

[0072] After determining the earliest expiring contracts (**514**) and determining the cost to cancel contracts (**516**), the wireless node **106**, **112** may compile information about resource units for which contracts may be canceled (**518**). For example, the wireless node **106**, **112** may compile a list of resource units for which contracts may be cancelled, how soon the contracts may be cancelled (with or without an early termination fee), and/or a cost associated with cancelling the contract for each resource unit. Based on the compiled information, the wireless node **106**, **112** may select resource units for which contracts may be cancelled (**520**). The wireless node **106**, **112** may, for example select the resource units for cancellation based on a sorting algorithm to minimize the cost of cancelling the contracts. The complexity of the sorting algorithm may be limited by time and/or size constraints, according to an example embodiment. After selecting the resource units, the wireless node **106**, **112** may mark the resource units as 'cancelled' on the resource unit map **300** (**522**). After marking the resource units as 'cancelled,' the wireless node may optimize or defragment the resource units (**504**).

[0073] After optimizing or defragmenting the resource units (**504**), the wireless node **106**, **112** may determine the resource units available for release (**506**). The wireless node **106**, **112** may determine a number of resource units available for release by subtracting a number of resource units needed (which may be based on the spectral resource needs plus the margin) from the currently available spectral resources. The wireless node **106**, **112** may determine which resource units may be released based on, for example, the optimizing or defragmenting the resource units (**504**). After determining which resource units are available for release or lending (**506**), the wireless node **106**, **112** may mark these resource units as 'available' or 'considered' on the resource unit map **300** (**508**).

[0074] The wireless node **106**, **112** may determine the technical feasibility of the resource unit changes (in this case lending the resource units) with neighboring cells (**222**). After checking the feasibility of the resource unit changes with neighboring cells (**510**), the wireless node **106**, **112** may have determined which of its own resource units are available for negotiation, and which may be returned to the originating wireless network **102**, **104** (or other radio access network), and may create a spectral resource change map message (SRC) **202**, **204** (**512**). The creation of an SRC **202**, **204** is described with reference to FIG. **7**.

[0075] FIG. **6** is a flowchart of the sub-function for identifying needed resource units (**412**) according to an example embodiment. The wireless node **106**, **112** may determine whether resource units have been lent out by its wireless network **102**, **104** to other networks **102**, **104** (or other radio access network) (**602**). If no resource units have been lent out to other networks, the wireless node **106**, **112** may identify resource units to be obtained from the other wireless network **102**, **104** (**610**). The wireless node **106**, **112** may identify resource units to be obtained from the other wireless network **102**, **104** based on, for example, its own spectral resource needs and its own resource unit map **300**, which may indicate which of the other wireless network's **102**, **104** resource units are available or 'considered' for lending. After identifying the resource units to be obtained from the other network **102**, **104** (**610**), the wireless node **106**, **112** may determine the technical feasibility of the resource unit changes (in this case borrowing the resource units) with neighboring cells (**220**).

[0076] If the wireless node **106**, **112** determines that resource units have been lent out to other wireless networks, the wireless node **106**, **112** may determine whether any of the contracts to loan the resource units are expiring soon (**604**), such as within a predetermined time period. If none of the contracts are expiring within the predetermined time period, the wireless node **106**, **112** may identify resource units to be obtained from the other wireless network **102**, **104** (**610**). If some of the contracts are expiring within the predetermined time period, the wireless node **106**, **112** may identify which resource units may be retrieved upon expiration of the contracts (**606**). The resource units may be identified based on, for example, selecting the resource units with contracts which will expire within the predetermined time period.

[0077] After identifying the resource units to be retrieved, the wireless node **106**, **112** may determine whether the retrieved spectral resource units will be sufficient to meet the wireless network's **102**, **104** spectral resource needs (**608**). If the retrieved spectral resource units will be sufficient, the wireless node **106**, **112** may determine the technical feasibility of the resource unit changes with the neighboring cells (**220**). After determining the technical feasibility of the resource unit changes (**220**), the wireless node **106**, **112** may create a SRC **204**, **204** (**510**), as described with reference to FIG. **7**.

[0078] FIG. **7** is a flowchart of the sub-function for creating spectrum resource change messages (SRCs) (**510**) according to an example embodiment. According to this example, the wireless node **106**, **112** may determine whether its wireless network **102**, **104** needs new resource units (**702**). The wireless node **106**, **112** may determine whether its wireless network **102**, **104** needs new resource units (**702**) based, for example, on comparing its wireless network's **102**, **104** spectral resource needs to its wireless network's **102**, **104** currently available spectral resources. If the wireless node **106**, **112** determines that its wireless network **102**, **104** does need new resource units, then the wireless node **106**, **112** may create a 'request for new resource units SRC' (**704**), and may create a body for the SRC **202**, **204** (**706**).

[0079] If the wireless node **106**, **112** determines that its wireless network **102**, **104** does not need new resource units, then the wireless node **106**, **112** may determine whether its wireless network **102**, **104** should renew resource unit contracts (**708**). The wireless node **106**, **112** may determine whether its wireless network **102**, **104** should renew resource unit contracts (**708**) based, for example, on whether it could meet its spectral resource needs based on presently available spectral resources without the contracted-for resource units. If the wireless node **106**, **112** determines that its wireless network **102**, **104** should renew resource unit contracts, then the wireless node **106**, **112** may create a 'renewal SRC' (**710**), and may create the body for the SRC **202**, **204** (**706**).

[0080] If the wireless node **106**, **112** determines that its wireless network **102**, **104** does not need to renew resource unit contracts, then the wireless node **106**, **112** may determine whether its wireless network **102**, **104** should cancel resource unit contracts (**712**). The wireless node **106**, **112** may determine whether its wireless network **102**, **104** should cancel resource unit contracts (**712**) based, for example, on whether its network's **102**, **104** currently available spectral resources would still exceed its spectral resource needs after cancelling the contracts, and/or based on whether it would cost less to pay a cancellation fee to cancel the contracts than to fulfill the contracts. If the wireless node **106**, **112** determines that its wireless network **102**, **104** should cancel resource unit contracts, then the wireless node **106**, **112** may create a 'cancellation SRC' (**714**), and may create the body for the SRC **202**, **204** (**706**).

[0081] If the wireless node **106**, **112** determines that its wireless network **102**, **104** should not cancel resource unit contracts, then the wireless node **106**, **112** may determine whether its wireless network **102**, **104** has unused surplus resource units (**716**). The wireless node **106**, **112** may determine whether its wireless network **102**, **104** has unused surplus resource units (**716**) based, for example, on comparing its wireless network's currently available spectral resources to its spectral resource needs. If the wireless node **106**, **112** determines that its wireless network **102**, **104** has unused surplus resource units, then the wireless node **106**, **112** may create an 'advertisement SRC' (**718**), and may create the body for the SRC **202**, **204** (**706**). If the wireless node **106**, **112** determines that its wireless network **102**, **104** does not have unused surplus resource units, then the wireless node **106**, **112** may not create an SRC **202**, **204**, according to an example embodiment.

[0082] FIG. **8** is a flowchart of the sub-function for negotiating exchange of resource units (**414**) according to an example embodiment. In this example, the processes **802**, **804**, **806**, **808** may occur in parallel with the processes **510**, **816**, **818**, **820**.

[0083] The wireless node **106**, **112** may collect SRCs **202**, **204** from other networks **102**, **104** (**802**). The wireless node **106**, **112** may collect the SRCs **202**, **204** by, for example, receiving the SRCs **202**, **204** from other nodes **106**, **112** and storing the SRCs **202**, **204** in memory. After collecting the SRCs **202**, **204**, the wireless node **106**, **112** may investigate the advertisements or requests indicated by the SRCs **202**, **204** (**804**), as described with reference to FIG. **9**. After investigating the advertisements or requests (**804**), the wireless node **106**, **112** may compile a global resource unit map (**806**). The wireless node **106**, **112** may compile the global resource unit map (**806**) by, for example, storing in memory an entry for each resource unit and a status for each resource unit that is either owned by the wireless node's **106**, **112** wireless network **102**, **104**, borrowed by its wireless network **102**, **104**, or indicated by a received SRC **202**, **204**. The wireless node **106**, **112** may then determine whether it has received and compiled the last advertisement or request (**808**). If the wireless node **106**, **112** has received and compiled the last advertisement or request, then the wireless node **106**, **112** may investigate the technical feasibility of resource unit changes (**810**). If the wireless node **106**, **112** has not received and compiled the last advertisement or request, then the wireless node **106**, **112** may repeat (**804**) and (**806**) until the wireless node has received and compiled all of the advertisements and requests.

[0084] The wireless node **106**, **112** may create its own SRCs **202**, **204** (**510**), as described with reference to FIG. **7**. The wireless node **106**, **112** may compile the SRCs **202**, **204** which request or advertise resources (**816**). The wireless node **106**, **112** may compile the SRCs **202**, **204** by, for example, storing the SRCs in memory. The wireless node **106**, **112** may send the SRCs **202**, **204** to other wireless networks **102**, **104** (**818**). The wireless node **106**, **112** may create a resource unit map **300** of its own spectral resources (**820**). The wireless node **106**, **112** may mark its resource units as occupied when used by its wireless network **102**, **104**, reserved when part of its wireless network's **102**, **104** margin, and considered when available for negotiation, according to an example embodiment.

[0085] After creating the resource unit map **300** of its own spectral resources (**820**), the wireless node **106**, **112** may investigate the technical feasibility of resource unit changes (**810**). The wireless node **106**, **112** may investigate the technical feasibility of resource unit changes in a manner similar to the determining technical feasibility of resource unit changes **220**, **222** (such as borrowing or lending resource units) with neighboring cells described with reference to FIG. **2**B, according to an example embodiment. After investigating the technical feasibility of the resource unit changes (**810**), the wireless node **106**, **112** may determine whether all permutations of interest have been checked (**812**). The wireless node **106**, **112** may determine whether all permutations of interest have been checked (**812**) based, for example, on whether the wireless node **106**, **112** has investigated all the possible combinations of borrowing or lending resource units. If the wireless node **106**, **112** determines that it has not checked all permutations of interest, then the wireless node **106**, **112** may investigate the technical feasibility of each possible resource unit allocation until all the permutations of interest have been checked. After all of the permutations of

interest have been checked, the wireless node may select the interesting technically feasible resource units allocations (**814**), as described with reference to FIG. **10**.

[0086] After selecting the interesting technically feasible resource unit allocations (**814**), the wireless node **106**, **112** may engage in the auctioning (**216**) for the resource units, as described with reference to FIG. **2**. After the auctioning (**216**), the wireless node **106**, **112** may determine whether it is financially feasible to borrow or lend the resource units (**822**). The wireless node **106**, **112** may determine whether it is financially feasible to borrow resource units based, for example, on comparing the cost of borrowing the resource units to the cost of not providing sufficient spectral resources to serve its wireless network's **102**, **104** load. The feasibility of lending resource units may be determined based only on the technical feasibility, according to an example embodiment. If the wireless node **106**, **112** determines that it is not financially feasible to borrow the resource unit(s), the wireless node **106**, **112** may send an SRC decline message to the other wireless node **106**, **112** (**824**). If the wireless node **106**, **112** determines that it is financially feasible to borrow or lend the resource unit(s), then the wireless node **106**, **112** may send an SRC accept message (**826**).

[0087] FIG. **9** is a flowchart of the sub-function for investigating advertisements or requests (**804**) according to an example embodiment. The wireless node **106**, **112** may determine if an SRC **202**, **204** includes an advertisement of a resource unit from another wireless network **102**, **104** (**902**). If the wireless node **106**, **112** determines that the SRC **202**, **204** includes an advertisement, then the wireless node **106**, **112** may determine whether its wireless network **102**, **104** has surplus resource units (**904**). If the wireless node's **106**, **112** wireless network **102**, **104** does have surplus resource units, then the wireless node **106**, **112** may mark the resource unit as 'not considered' (**906**). If the wireless node's **106**, **112** wireless network **102**, **104** does not have surplus resource units, then the wireless node **106**, **112** may mark the resource unit as 'considered' (**908**).

[0088] If the wireless node **106**, **112** determines that the SRC **202**, **204** does not include an advertisement for a resource unit, then the wireless node **106**, **112** may determine whether the SRC **202**, **204** includes a request for a new resource unit (**910**). If the wireless node **106**, **112** determines that the SRC **202**, **204** does include a request for a new resource unit, then the wireless node **106**, **112** may determine whether its wireless network **102**, **104** has surplus resource units (**912**). If the wireless node **106**, **112** determines that its wireless network **102**, **104** does have surplus resource units, then the wireless node **106**, **112** may mark the resource unit as 'considered' (**914**). If the wireless node **106**, **112** determines that its wireless network **102**, **104** does not have surplus resource units, then the wireless node **106**, **112** may mark the resource unit as 'not considered' (**916**).

[0089] If the wireless node **106**, **112** determines that the SRC **202**, **204** does not include a request for a new resource unit, then the wireless node **106**, **112** may determine whether the SRC **202**, **204** includes a request to renew a contract to borrow a resource unit (**918**). If the wireless node **106**, **112** determines that the SRC **202**, **204** does include a request to borrow a resource unit, then the wireless node **106**, **112** may engage in auctioning **216**, as described with reference to FIG. **2**A. After the auctioning **216**, the wireless node **106**, **112** may determine whether to renew the contract (**920**). The wireless node **106**, **112** may determine whether to renew the contract (**920**) based, for example, on whether the wireless node's **106**, **112** wireless network has surplus resource units. If the wireless node **106**, **112** determines that its wireless network **102**, **104** should renew the contract, then the wireless node may mark the resource unit as 'considered' (**922**). If the wireless node **106**, **112** determines that its wireless network **102**, **104** should not renew the contract, then the wireless node **106**, **112** may mark the resource unit as 'not considered' (**924**).

[0090] If the wireless node **106**, **112** determines that the SRC **202**, **204** does not include a request to renew a contract to borrow a resource unit, the wireless node may determine whether the SRC **202**, **204** includes an indication that the wireless node **106**, **112** which sent the SRC **202**, **204** is declining a contract to lend a resource unit to the receiving wireless node **106**, **112** (**926**). If the wireless node **106**, **112** determines that the SRC **202**, **204** does include an indication of declining a contract, then the wireless node **106**, **112** may mark the resource unit as 'cancelled' (**928**), according to an example embodiment. If the SRC **202**, **204** does not include an indication of declining a contract to lend a resource unit, then the SRC **202**, **204** may include an unknown or undetermined message, according to an example embodiment. Based on the marking of the resource units as 'considered,' 'not considered,' or 'cancelled,' the wireless node **106**, **112** may compile its global resource map **214**, according to an example embodiment.

[0091] FIG. **10** is a flowchart of the sub-function for selecting interesting technically feasible resource unit allocations (**814**) according to an example embodiment. According to this example, the wireless node **106**, **112** may determine whether a resource unit allocation will meet all of its wireless network's **102**, **104** needs (**1002**). The wireless node **106**, **112** may determine whether the resource unit allocation would meet all of its wireless network's **102**, **104** needs (**1002**) based, for example, on whether all mobile nodes in the wireless network **102**, **104** would be able to transfer data at the desired rates. If the resource unit allocation would meet all of the wireless network's **102**, **104** needs, then the wireless node **106**, **112** may agree to borrow the resource units (**1004**).

[0092] If the wireless node **106**, **112** determines that the resource unit allocation would not meet all of the wireless network's **102**, **104** needs, then the wireless node **106**, **112** may renegotiate for a different resource unit allocation (**1006**). After renegotiating for a different resource unit allocation (**1006**), the wireless node **106**, **112** may investigate the technical feasibility of the renegotiated resource unit allocation (**810**). The wireless node **106**, **112** may then determine whether the renegotiated resource unit allocation would meet its wireless network's **102**, **104** most important needs (**1008**). The wireless node **106**, **112** may determine whether the renegotiated resource unit allocation would meet its wireless network's **102**, **104** most important needs (**1008**) based, for example, on whether certain high priority mobile nodes in the wireless network **102**, **104** would be able to transfer data at desired rates, and/or whether the mobile nodes would be able to transfer data at minimum required data rates. If the resource unit allocation would meet the wireless network's **102**, **104** most important needs, then the wireless node **106**, **112** may agree to borrow the resource units (**1010**). If the resource unit allocation would not meet the wireless network's **102**, **104** most important needs, then no agreement may be reached (**1012**), according to an example embodiment.

[0093] FIG. **11** is a flowchart showing a method **1100** according to an example embodiment. According to this example, the method **1100** may include determining, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network (**1102**). The method **1100** may further include sending, to the second wireless node, a request to borrow one or more of the resource units, the request being based on the determining (**1104**).

[0094] According to an example embodiment, the determining that spectral resource needs exceed available spectral resources (**1102**) may include determining whether contracts to loan spectral resources owned by the wireless network will or will not expire within a specified time.

[0095] According to an example embodiment, the method **1100** may further include receiving, from a second wireless node in a second wireless network, an advertisement indicating availability of one or more resource units. The advertisement may further indicate a total amount of spectral resources available to lend. According to another example embodiment, the advertisement may include a map (such as a resource unit map **300**) identifying the one or more resource units, such as by frequency band, subcarrier index, owner, borrower, and/or time availability. The advertisement may indicate whether the identified resource units are available to lend, a notice period for cancelling a contract to borrow the identified resource units, and/or whether the second wireless network will cancel a present contract to lend the one or more resource units.

[0096] According to another example embodiment, the method **1100** may further comprise determining the spectral resource needs based on predicted network load.

[0097] According to another example embodiment, the request may identify desired spectral resource units by frequency band.

[0098] According to another example embodiment, the method **1100** may further comprise compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement. According to an example embodiment, the resource unit map may be compiled based on the advertisement, the currently available spectral resources, and/or spectral resources which will be retrieved upon expiration of a contract within a specified time period. According to example embodiments, the resource unit map may identify spectral resources by frequency band and indicate whether the spectral resource units are occupied, reserved, and/or available for lending by the second wireless network, and/or whether the resource units are considered for borrowing by the first wireless network. The resource units may or may not be included in the currently available spectral resources of the first wireless network. According to an example embodiment, the advertisement may indicate that a contract to lend at least one of the one or more resource units to the first wireless network will not be renewed.

[0099] According to another example embodiment, the method **1100** may further comprise compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, and determining whether the spectral resource needs could be met based on the resource unit map. The determining may be further based on a predicted level of fragmentation of a spectrum which includes the currently available spectral resources and at least one of the advertised resource units, on a level of interference by at least some of the advertised resource units with other wireless nodes in the first wireless network, and/or on a compatibility of subcarriers included in the advertised resource units with the currently available spectral resources. The method **1100** may further include sending the second wireless node an acceptance message based on the determining that the spectral resource needs could or could not be met based on the resource unit map, and sending the wireless node an acceptance or decline message based on the determining or a request for alternative spectral resources. The method **1100** may further include determining that most important spectral resource needs could be met based on the resource unit map, and sending a request to borrow at least some of the advertised spectral resource units based on the determining that most important resource needs could be met based on the resource map.

[0100] FIG. **12** is a flowchart showing another method **1200** according to another example embodiment. According to this example, the method **1200** may include determining, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs for the first wireless network (**1202**). The method **1200** may further include sending, to a second wireless node in a second wireless network, an advertisement to lend one or more resource units, the advertisement being based on the determining (**1204**). The method **1200** may further include receiving, from the second wireless node, a request to borrow one or more of the one or more resource units (**1206**).

[0101] According to an example embodiment, the advertisement may include a map (such as a resource unit map **300**) identifying the one or more resource units and indicating whether the identified one or more resource units are available to lend. The method **1200** may further include determining which of the one or more resource units are available to lend based at least in part by minimizing fragmentation of the available spectral resources, based on determining whether an interference threshold will be satisfied after lending one or more of the one or more resource units, and/or based on determining whether a minimum guard band will still be present after lending one or more of the one or more resource units.

[0102] According to another example embodiment, the advertisement may include an offer to renew a contract to lend one or more of the one or more resource units.

[0103] According to another example embodiment, the advertisement may include a map identifying the one or more resource units and indicating whether the identified one or more resource units are subject to contracts with third-party wireless nodes which will be cancelled. According to this example, the method **1200** may further comprise determining which of the one or more resource units are subject to contracts with third-party wireless nodes which will be cancelled based at least in part by determining a set of earliest expiring contracts.

[0104] According to another example embodiment, the method **1200** may further comprise receiving, from the second wireless node, a request to borrow one or more resource units, and compiling a resource unit map at least in part on the request including a request to borrow a resource unit which is included in the available spectral resources, or at least in part on the request including a request to renew a contract to borrow a resource unit from the first wireless node.

[0105] FIG. **13** is a flowchart showing another method **1300** according to another example embodiment. According to this example, the method **1300** may include determining, by a first

wireless node in a first wireless network, that spectral resource needs exceed currently available spectral resources (**1302**). The method **1300** may further include receiving, from a second wireless node in a second wireless network, a first spectral resource change map offering to loan one or more resource units (**1304**). The method **1300** may further include sending, to the second wireless node, a second spectral resource change map requesting to borrow one or more resource units based on the determining (**1306**). The method **1300** may further include receiving, from the second wireless node, a first negotiation resource unit map, the first negotiation resource unit map having been sent to the first wireless node in response to the second spectral resource change map and indicating resource units which the second wireless network may loan to the first wireless network (**1308**). The method **1300** may further include sending, to the second wireless node, a second negotiation resource unit map, the second negotiation resource unit map being sent in response to receiving the first spectral resource change map and indicating resource units which the first wireless network may borrow from the second wireless network, the indicated resource units which the first wireless network may borrow being based at least in part on the currently available spectral resources (**1310**).

[0106] FIG. **14** is a flowchart showing another method **1400** according to another example embodiment. According to this example, the method **1400** may include determining, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs (**1402**). The method **1400** may further include receiving, from a second wireless node in a second wireless network, a first spectral resource change map requesting to borrow one or more resource units (**1404**). The method **1400** may further include sending, to the second wireless node, a second spectral resource change map offering to loan one or more resource units based on the determining (**1406**). The method **1400** may further include receiving, from the second wireless node, a first negotiation resource unit map, the first negotiation resource unit map having been sent to the first wireless node in response to the second spectral resource change map and indicating resource units which the second wireless network may borrow from the first wireless network (**1408**). The method **1400** may further include sending, to the second wireless node, a second negotiation resource unit map, the second negotiation resource unit map being sent in response to receiving the first spectral resource change map and indicating resource units which the first wireless network may loan to the second wireless network, the indicated resource units which the first wireless network may borrow being based at least in part on the currently available spectral resources (**1410**).

[0107] FIG. **15** is a flowchart showing a method **1500** according to another example embodiment. According to this example, the method may include a first process (**1510**) and a second process (**1520**). The first process (**1510**) may include some or all of the messages and processes of the long term scheme described with reference to FIG. **2**B. The second process (**1520**) may include some or all of the messages and processes of the short term scheme described with reference to FIG. **2**C.

[0108] The first process (**1510**) may, for example, include sending, by a first wireless node in a first wireless network, to a second wireless node in a second wireless network, a first spectral resource change map requesting to borrow one or more resource units (**1512**). The first process (**1510**) may further include receiving, from the second wireless node, a negotiation resource unit map, the negotiation resource unit map having been sent to the first wireless node in response to the first spectral resource change map and indicating resource units which the second wireless network may loan to the first network (**1514**). The first process (**1510**) may further include compiling a global resource unit map based on the negotiation resource unit map (**1516**).

[0109] The second process (**1520**) may, for example, include sending a second spectral resource change map to the second wireless node requesting to borrow one or more resource units (**1522**). The second process (**1520**) may further include auctioning to borrow one or more resource units from the second wireless node based on the compiled global resource unit map (**1524**).

[0110] According to an example embodiment, the second process (**1520**) may be performed a plurality of times for each performance of the first process (**1510**).

[0111] FIG. **16** is a block diagram of a wireless node **1600** according to an example embodiment. The wireless node (e.g. wireless node **106**, **108**) may include, for example, a wireless transceiver **1602** to transmit and receive signals, a controller **1604** to control operation of the station and execute instructions or software, and a memory **1606** to store data and/or instructions.

[0112] Controller **1604** may be programmable and capable of executing software or other instructions stored in memory or on other computer media to perform the various tasks and functions described above, such as one or more the tasks or methods described above.

[0113] In addition, a storage medium may be provided that includes stored instructions, when executed by a controller or processor that may result in the controller **1604**, or other controller or processor, performing one or more of the functions or tasks described above.

[0114] Implementations of the various techniques described herein may be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Implementations may implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. A computer program, such as the computer program(s) described above, can be written in any form of programming language, including compiled or interpreted languages, and can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

[0115] Method steps may be performed by one or more programmable processors executing a computer program to perform functions by operating on input data and generating output. Method steps also may be performed by, and an apparatus may be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

[0116] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of

any kind of digital computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. Elements of a computer may include at least one processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer also may include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory may be supplemented by, or incorporated in special purpose logic circuitry.

[0117] To provide for interaction with a user, implementations may be implemented on a computer having a display device, e.g., a cathode ray tube (CRT) or liquid crystal display (LCD) monitor, for displaying information to the user and a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input.

[0118] Implementations may be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation, or any combination of such back-end, middleware, or front-end components. Components may be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network (LAN) and a wide area network (WAN), e.g., the Internet.

[0119] While certain features of the described implementations have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the embodiments of the invention.

1. A method comprising:

determining, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network; and

sending, to a second wireless node in a second wireless network, a request to borrow one or more resource units, the request being based on the determining.

2. The method of claim **1** wherein the determining that spectral resource needs exceed available spectral resources includes determining whether contracts to loan spectral resources owned by the wireless network will not expire within a specified time.

3. The method of claim **1** further comprising receiving, from the second wireless node, an advertisement indicating availability of one or more resource units.

4. The method of claim **1** further comprising receiving an advertisement indicating a total amount of spectral resources available to lend.

5. The method of claim **1** further comprising receiving an advertisement, including a map identifying one or more resource units and indicating whether the identified resource units are available to lend.

6. The method of claim **1** further comprising receiving an advertisement including a map identifying one or more resource units by frequency band and indicating whether the identified resource units are available to lend.

7. The method of claim **1** further comprising receiving an advertisement including a map identifying one or more resource units by subcarrier index and indicating whether the identified resource units are available to lend.

8. The method of claim **1** further comprising receiving an advertisement including a map identifying one or more resource units by owner and indicating whether the identified resource units are available to lend.

9. The method of claim **1** further comprising receiving an advertisement, the advertisement including a map identifying one or more resource units by borrower and indicating whether the identified resource units are available to lend.

10. The method of claim **1** further comprising receiving an advertisement, the advertisement including a map identifying one or more resource units by time availability and indicating whether the identified resource units are available to lend.

11. The method of claim **1** further comprising receiving an advertisement including a map identifying one or more resource units and indicating whether the identified resource units are available to lend, and further indicating a notice period for cancelling a contract to borrow the identified resource units.

12. The method of claim **1** further comprising receiving an advertisement including a map identifying one or more resource units and indicating whether the second wireless network will cancel a present contract to lend the one or more resource units.

13. The method of claim **1** further comprising determining the spectral resource needs based on predicted network load.

14. The method of claim **1** further comprising determining the spectral resource needs based on predicted network load and adding a margin to the predicted network load.

15. The method of claim **1** wherein the sending includes sending the second wireless node a request to borrow one or more of the resource units based on the determining, the request identifying desired spectral resource units by frequency band.

16. The method of claim **1** further comprising:

receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and

compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement.

17. The method of claim **1** further comprising:

receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and

compiling a resource unit map based at least in part on the advertisement, the currently available spectral resources, and spectral resources which will be retrieved upon expiration of a contract within a specified time period.

18. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, the resource unit map identifying spectral resource units by frequency band and indicating whether the spectral resource units are occupied by the first wireless network.

19. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, the resource unit map identifying spectral resource units by frequency band and indicating whether the spectral resource units are reserved by the first wireless network.

20. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, the resource unit map identifying spectral resource units by frequency band and indicating whether the spectral resource units are available for lending by the second wireless network.

21. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, the resource unit map identifying spectral resource units by frequency band and indicating whether the spectral resource units are available for lending by the second wireless network and whether the spectral resource units are considered for borrowing by the first wireless network.

22. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, the advertisement indicating that at least one of the resource units, which is not included in the currently available spectral resources of the first wireless network, is available to lend.

23. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units; and
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement, the advertisement indicating that a contract to lend at least one of the resource units to the first wireless network will not be renewed.

24. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement; and
determining whether the spectral resource needs could be met based on the resource unit map.

25. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement; and
determining whether the spectral resource needs could be met based on the resource unit map based on a predicted level of fragmentation of a spectrum which includes the currently available spectral resources and at least one of the advertised resource units.

26. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement; and
determining whether the spectral resource needs could be met based on the resource unit map based on a level of interference by at least some of the advertised resource units with other wireless nodes in the first wireless network.

27. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement; and
determining whether the spectral resource needs could be met based on the resource unit map based on a compatibility of subcarriers included in the advertised resource units with the currently available spectral resources.

28. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement;
determining that the spectral resource needs could be met based on the resource unit map; and
sending the second wireless node an acceptance message based on the determining that the spectral resource needs could be met based on the resource unit map.

29. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement;
determining that the spectral resource needs could not be met based on the resource unit map; and
sending the another wireless node a decline message based on the determining that the spectral resource needs could not be met based on the resource unit map.

30. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement;
determining that the spectral resource needs could not be met based on the resource unit map; and
sending a request for alternative spectral resources to the second wireless node.

31. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement;
determining that the spectral resource needs could not be met based on the resource unit map;
determining that most important spectral resource needs could be met based on the resource unit map; and
sending a request to borrow at least some of the advertised resource units based on the determining that the most important spectral resource needs could be met based on the resource unit map.

32. The method of claim **1** further comprising:
receiving, from the second wireless node, an advertisement indicating availability of one or more resource units;
compiling a resource unit map based at least in part on the currently available spectral resources and the advertisement;
determining that the spectral resource needs could be met based on the resource unit map; and
sending a request to borrow at least some of the advertised resource units based on the determining that the spectral resource needs could be met based on the resource unit map.

33. A method comprising:
determining, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs for the first wireless network;
sending, to a second wireless node in a second wireless network, an advertisement to lend one or more resource units, the advertisement being based on the determining; and
receiving, from the second wireless node, a request to borrow one or more of the resource units.

34. The method of claim **33** wherein the sending the advertisement to lend one or more resource units includes sending the advertisement, the advertisement including a map identifying the one or more resource units and indicating whether the identified resource units are available to lend.

35. The method of claim **33** wherein the sending the advertisement to lend one or more resource units includes sending the advertisement, the advertisement including an offer to renew a contract to lend one or more of the one or more resource units.

36. The method of claim **33** wherein:
the sending the advertisement to lend one or more resource units includes sending the advertisement, the advertisement including a map identifying the one or more resource units and indicating whether the identified one or more resource units are available to lend; and
the method further comprises determining which of the one or more resource units are available to lend based at least in part by minimizing fragmentation of the available spectral resources.

37. The method of claim **33** wherein:
the sending the advertisement to lend one or more resource units includes sending the advertisement, the advertisement including a map identifying the one or more resource units and indicating whether the identified one or more resource units are available to lend; and
the method further comprises determining which of the one or more resource units are available to lend based at least in part by determining whether an interference threshold will be satisfied after lending one or more of the one or more resource units.

38. The method of claim **33** wherein:
the sending the advertisement to lend one or more resource units includes sending the advertisement, the advertisement including a map identifying the one or more resource units and indicating whether the identified one or more resource units are available to lend; and
the method further comprises determining which of the one or more resource units are available to lend based at least in part by determining whether a minimum guardband will still be present after lending one or more of the resource units.

39. The method of claim **33** wherein:
the sending the advertisement to lend one or more resource units includes sending the advertisement, the advertisement including a map identifying the one or more resource units and indicating whether the identified one or more resource units are subject to contracts with third-party wireless nodes which will be cancelled; and
the method further comprises determining which of the one or more resource units are subject to contracts with third-party wireless nodes which will be cancelled based at least in part by determining a set of earliest expiring contracts.

40. The method of claim **33** further comprising:
receiving, from the second wireless node, a request to borrow one or more resource units; and
compiling a resource unit map at least in part on the request including a request to borrow a resource unit which is included in the available spectral resources.

41. The method of claim **33** further comprising:
receiving, from the second wireless node, a request to borrow spectral resources; and
compiling a resource unit map at least in part on the request including a request to renew a contract to borrow a resource unit from the first wireless node.

42. (canceled)

43. (canceled)

44. A method comprising:
a first process comprising:
sending, by a first wireless node in a first wireless network, to a second wireless node in a second wireless network, a first spectral resource change map requesting to borrow one or more resource units;
receiving, from the second wireless node, a negotiation resource unit map, the negotiation resource unit map having been sent to the first wireless node in response to the first spectral resource change map and indicating resource units which the second wireless network may loan to the first network; and
compiling a global resource unit map based on the negotiation resource unit map; and
a second process comprising:
sending a second spectral resource change map to the second wireless node requesting to borrow one or more resource units; and
auctioning to borrow one or more resource units from the second wireless node based on the compiled global resource unit map.

45. The method wherein the second process is performed a plurality of times for each performance of the first process.

46. An apparatus comprising:

a controller;

the apparatus being configured to:

determine, by a first wireless node in a first wireless network, that spectral resource needs for the first wireless network exceed spectral resources currently available for the first wireless network;

receive, from a second wireless node in a second wireless network, an advertisement indicating availability of one or more resource units; and

send, to the second wireless node, a request to borrow one or more of the one or more resource units.

47. An apparatus comprising:

a controller;

the apparatus being configured to:

determine, by a first wireless node in a first wireless network, that currently available spectral resources exceed spectral resource needs;

send, to a second wireless node in a second wireless network, an advertisement to lend one or more resource units; and

receive a request to borrow one or more of the one or more resource units.

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