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(54) Title: SHARED COOPERATIVE SPECTRUM SENSING METHOD, SENSING NODES AND FUSION CENTER IN COGNITIVE RADIO NETWORKS

(57) Abstract: A shared cooperative spectrum sensing method, local sensing nodes and fusion center in cognitive radio networks are provided in the embodiments of the present invention. According to the present invention, the sensing information collected from the sensing nodes in different cognitive radio networks is shared in shared cooperative spectrum sensing. At the fusion center, the spectrum decision is made based on the sensing information not only from its own sensing nodes but also from the adjacent sensing nodes who share their sensing information. Sharing sensing information among co-located cognitive radio networks is equivalent to extending the number of cooperative sensing nodes but it does not cause extra sensing overhead. Thus, the overall sensing performance is significantly improved.



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Shared Cooperative Spectrum Sensing Method, Sensing Nodes and Fusion Center in Cognitive Radio Networks

Field of the invention

5 The present disclosure relates to communication technology, more particularly, to a cooperative spectrum sensing method and sensing nodes in cognitive radio networks.

Background of the invention

10 In the spectrum shared system under the authorized spectrum, primary systems and secondary systems share certain spectrum resource. When the primary systems do not occupy the spectrum resource, the secondary systems can opportunistically use this free spectrum resource. The primary systems have a privilege for the use of the spectrum and can
15 access the spectrum at any time. The secondary systems use the spectrum opportunistically. When the spectrum doesn't be occupied by the primary systems, the secondary systems can use the spectrum described above; when the primary systems use this spectrum, the secondary system shall avoiding using this spectrum. In order to prevent from generating harmful
20 interference to the primary systems, the secondary systems must detect the existence status of primary systems periodically, namely the secondary systems shall sense the availability of spectrum resource periodically. If the spectrum resource is not occupied by the primary systems, the secondary system can use the spectrum resource; when the
25 spectrum resource is occupied by the primary systems, the secondary system cannot use the spectrum resource. In order to improve the frequency spectrum utilization, the secondary systems should find out the free spectrums as many as possible. On the other hand, the secondary systems should be prevented from generating harmful interference to the

primary systems. This demands the spectrum sensing of the secondary systems must be reliable. Thus, the spectrum sensing is the most basic requirement for the spectrum system. The accurate spectrum sensing is the foundation for the secondary systems to access the spectrum effectively and the reliable spectrum sensing can prevent from generating harmful interference to primary systems.

In cognitive radio networks, cognitive systems are usually secondary systems. Primary signals of the primary systems usually undergo fading and shadowing and it is difficult to obtain a reliable sensing. Thus, cooperative spectrum sensing with multiple sensing nodes has been suggested, such as the draft of IEEE 802.22. The cooperative spectrum sensing system includes a fusion center and a plurality of distributed sensing nodes. The distributed sensing nodes transmit the measurement results to the fusion center. The fusion center is the central processor and it conducts combination with different strategies and makes global spectrum decision based on the sensing information collected from the distributed sensing nodes. In general, the sensing nodes with more confidence will be allocated a larger weight and they contribute more to the final spectrum decision, while the sensing nodes with less confidence will be allocated a smaller weight and they contribute less to the final spectrum decision. Also, the fusion center guides the distributed sensing nodes to sense. For example, the fusion center inform the sensing nodes when to begin sensing, when to end sensing and to perform which sensing algorithms. And the fusion center broadcasts the sensing parameters, e.g., sensing period, maximum tolerable false alarm rate, threshold, etc. Guided by the fusion center, each sensing node conducts the local sensing and obtains the sensing measurement and then, the sensing nodes feed back the local measurement to the fusion center for central processing.

With the joint processing across a plurality of sensing nodes, the sensing accuracy is improved significantly. However, increasing the number of sensing nodes causes some drawbacks. First, it increases the

sensing overhead. As each sensing node needs to feedback their sensing measurements to the fusion center, more sensing nodes requires more transmission resources, which reduces the spectrum efficiency. Also, the sensing nodes usually are terminal users. The sensing consumes users' power. More sensing nodes causes more power consumption. Thus, increasing number of sensing nodes increases the sensing overhead as well. On the other hand, in a particular area, the number of users is limited, thus, the number of cooperative sensing nodes cannot be increased to improve the sensing performance. Additionally, in cognitive radio networks, secondary networks are peer and can be deployed at the same or overlapping areas, also adjacent co-located systems. For each secondary cognitive radio network, it performs cooperative spectrum sensing and feeds back the sensing information to the fusion center and then obtain the spectrum decision. At the same or overlapping areas, the spectrum availability status is the same. Thus, the secondary cognitive radio networks, which are deployed at the same or overlapping areas, shall achieve the same spectrum decision if their cooperative spectrum sensing is correct. In this invention, a shared cooperative spectrum sensing in cognitive radio networks is proposed to improve the sensing performance but it does not increase sensing complexity and overhead.

Summary of the invention

In order to solve the drawbacks described above in the prior art, a shared cooperative spectrum sensing method, sensing nodes and fusion center in cognitive radio networks are provided in the present invention.

According to the present invention, the sensing information collected from the sensing nodes in different cognitive radio networks is shared in shared cooperative spectrum sensing. At the fusion center, the spectrum decision is made based on the sensing information not only from its own sensing nodes but also from the adjacent sensing nodes who share their sensing information. Sharing sensing information among co-located

cognitive radio networks is equivalent to extending the number of cooperative sensing nodes but it does not cause extra sensing overhead. Thus, the overall sensing performance is significantly improved.

More particularly, according to an embodiment of this invention, a shared cooperative spectrum sensing method in a cognitive radio network is provided, the cognitive radio network including at least two adjacent co-located peer cognitive systems, each cognitive system including a fusion center and at least one local sensing node. The method comprises the step of sharing sensing information among co-located cognitive networks.

According to an alternative embodiment of this invention, said sharing sensing information among co-located cognitive networks indicates: the local sensing nodes conducting local sensing measurement, sending the sensing information to the fusion center and sending the sensing information to the adjacent shared cognitive systems.

According to an alternative embodiment of this invention, the fusion center makes spectrum decision based on the sensing information from the local sensing nodes and the adjacent sensing nodes who share their sensing information.

According to an alternative embodiment of this invention, the local sensing nodes send the sensing information directly to the fusion center of the adjacent shared cognitive system.

According to an alternative embodiment of this invention, the local sensing nodes send the sensing information to the sensing nodes of the adjacent shared cognitive system, and the sensing nodes of the adjacent shared cognitive system relay the sensing information to the fusion center of the adjacent shared cognitive system.

According to an alternative embodiment of this invention, the local sensing nodes send the sensing information to the adjacent shared cognitive systems in the form of broadcast.

According to an alternative embodiment of this invention, the sensing

information is shared among the co-located cognitive networks through inter-system communication mechanism.

According to an alternative embodiment of this invention, the fusion center combines the sensing information received from the local sensing nodes and the adjacent sensing nodes who share their sensing information together and makes spectrum decision.

According to an embodiment of this invention, a local sensing node in a cognitive radio network is provided, the cognitive radio network including at least two adjacent co-located peer cognitive systems, the cognitive system including a fusion center. The local cognitive node includes:

a receiving unit, configured to receive a sensing measurement instruction and spectrum sensing parameters from the fusion center;

a sensing unit, configured to perform spectrum sensing according to the sensing measurement instruction and the spectrum sensing parameters, and collect measurement results;

a transmitting unit, configured to feed back sensing information to the fusion center and send the sensing information to the adjacent co-located cognitive system.

According to an alternative embodiment of this invention, the transmitting unit sends the sensing information to the adjacent co-located cognitive system indicates that the transmitting unit sends the sensing information directly to the fusion center of the adjacent co-located cognitive system.

According to an alternative embodiment of this invention, the transmitting unit sends the sensing information to the adjacent co-located cognitive system indicates that the transmitting unit sends the sensing information to the sensing nodes of the adjacent co-located cognitive system.

According to an alternative embodiment of this invention, the receiving unit is configured to receive the sensing information from the

adjacent co-located cognitive system.

According to an alternative embodiment of this invention, the local sensing node further includes a relay unit, configured to send the sensing information received from the adjacent co-located cognitive system to the fusion center.

According to an implementation of this invention, a fusion center in a cognitive radio network is provided, the cognitive radio network including at least two adjacent co-located peer cognitive systems, the cognitive system including at least one local sensing node. The fusion center includes:

- a transmitting unit, configured to transmit a sensing measurement instruction and spectrum sensing parameters to the local sensing unit;

- a receiving unit, configured to receive sensing information from the local sensing unit and the adjacent co-located peer cognitive system;

- a combining unit, configured to combine the sensing information received from the local sensing nodes and the adjacent sensing nodes who share their sensing information together;

- a spectrum decision unit, configured to make spectrum decision according to the combined information.

According to an alternative embodiment of this invention, the combining includes OR-rule combining, weighting combining or sub-band selection combining.

According to an alternative embodiment of this invention, the receiving unit receives the sensing information from the adjacent co-located peer cognitive system indicates the receiving unit receives the sensing information directly from the local sensing nodes of the adjacent co-located peer cognitive system.

According to an alternative embodiment of this invention, the receiving unit receives the sensing information from the adjacent co-located peer cognitive system indicates the receiving unit receives the sensing information relayed by the local sensing nodes from the local

sensing nodes of the adjacent co-located peer cognitive system.

With the present invention, the shared sensing scheme realizes sharing sensing information among co-located cognitive radio networks. In this manner, it is equivalent to extending the number of cooperative sensing nodes but does not cause extra sensing overhead. Thus, the overall sensing performance is significantly improved.

Brief description of drawings

With reference to the following description of the figures and more thorough understanding of the present invention, other objects and effects of the present invention will be more apparent and easy to understand, wherein,

FIG.1 shows a schematic diagram of the cognitive radio network configuration according to an embodiment of the present invention;

FIG.2 shows a schematic diagram of the shared cooperative spectrum sensing process according to an embodiment of the present invention;

FIG.3 shows a schematic diagram of the structure of the local sensing nodes according to an embodiment of the present invention;

FIG.4 shows a schematic diagram of the structure of the fusion center according to an embodiment of the present invention;

Throughout the figures above, same reference numerals refer to same, similar or corresponding features.

Detailed description of embodiments

Embodiments of the present invention will be described in detail as follows with reference to the figures.

Embodiments of the present invention are realized based on the spectrum shared system. For illustrative purposes only, the embodiments of the invention will be described using a system based on IEEE 802.22 standard specification as an illustrative example. It shall be appreciated that the application of the invention is not limited to IEEE 802.22, and it

can also be applied for solving spectrum sensing problems in other spectrum shared systems. An example is given as follows to illustrate the shared cooperative spectrum sensing. Suppose that two cognitive radio networks A and B are deployed with overlapping areas as shown in FIG.1.

Both cognitive radio network A and B have a plurality of UEs (User Equipments) in the overlapping areas who act as the sensing nodes, wherein, UEs A represent the UEs of the cognitive radio network A, while UEs B represent the UEs of the cognitive radio network B; eNB A (Evolved NodeB A) belongs to the fusion center of the cognitive radio network A, while eNB B belongs to the fusion center of the cognitive radio network B. To facilitate coexistence, eNB A and eNB B have set up cooperation through a pre-defined inter-system communication mechanism, like beacon-based communication mechanism defined in IEEE 802.22.

FIG.2 shows a schematic diagram of the shared cooperative spectrum sensing process according to an embodiment of the present invention. The shared cooperative spectrum sensing process will be described in detail as follows with reference to FIG.2.

Upon the sensing requests, eNB A and eNB B send the instruction of performing spectrum sensing to their UEs to guide their UEs in the overlapping areas to conduct cooperative spectrum sensing. Upon the guidance from eNBs, UEs perform the local spectrum sensing and collect the sensing information. After the completion of local sensing, UEs belonging to eNB A (represented as UEs A) feed back the sensing information to eNB A. Meanwhile, UEs A broadcast their sensing information to the neighboring UEs B who belong to eNB B and/or eNB B. The broadcasting of sensing information can re-use the inter-system communication mechanism defined in cognitive radios. For example, UEs A may send their sensing information directly to eNB B. In case that eNB B cannot receive, UEs B can relay the sensing information from UEs A to eNB B. This inter-system communication mechanism guarantees that the

sensing information from UEs A can be safely delivered to eNB B. The inter-system communication mechanism shall already be defined in cognitive radios to facilitate efficient coexistence, as the beacon-based communication mechanism defined in IEEE 802.22. The beacon is
5 utilized to exchange the coexistence information between base stations. With the exchanged information through beacons, better scheduling and other coexistence mechanisms can be realized promptly. With the guarantee of inter-system communication, the sensing information from UEs A can be safely and timely distributed to eNB B. The same procedure
10 is conducted in UEs B and then, eNB A can receive the sensing information from UEs B as well.

At eNBs, the sensing information from both UEs A and UEs B is decoded. Based on all the sensing information, eNBs obtain the spectrum decision according to various combining algorithms, such as OR-rule
15 combining, weighting combining, sub-band selection combining, etc.

FIG.3 shows a schematic diagram of the structure of the local sensing nodes according to an embodiment of the present invention.

In the embodiment of the present invention, the local sensing node includes a first receiving unit, a sensing unit, a first transmitting unit, a
20 second transmitting unit, a second receiving unit and a relay unit. Wherein, the first receiving unit is configured to receive a sensing measurement instruction and spectrum sensing parameters from the fusion center; the sensing unit is to perform spectrum sensing according to the sensing measurement instruction and the spectrum sensing parameters, and collect
25 measurement results; the first transmitting unit is configured to feed back sensing information to the fusion center; the second transmitting unit is configured to send the sensing information to the adjacent co-located cognitive system. According to the system configuration, the second transmitting unit sends the sensing information to the adjacent co-located
30 cognitive system indicates that the second transmitting unit sends the sensing information directly to the fusion center of the adjacent co-located

cognitive system or/and the second transmitting unit sends the sensing information to the adjacent co-located cognitive system indicates that the second transmitting unit sends the sensing information to the sensing nodes of the adjacent co-located cognitive system. The second receiving unit is configured to receive the sensing information from the adjacent co-located cognitive system. The relay unit is configured to send the sensing information received from the adjacent co-located cognitive system to the fusion center.

FIG.4 shows a schematic diagram of the structure of the fusion center according to an embodiment of the present invention. In the embodiment of the present invention, the fusion center includes a transmitting unit, a first receiving unit, a second receiving unit, a combining unit and a spectrum decision unit. Wherein, the transmitting unit is configured to transmit a sensing measurement instruction and spectrum sensing parameters to the local sensing unit; the first receiving unit is configured to receive sensing information from the local sensing unit; the second receiving unit is configured to receive the sensing information from the adjacent co-located peer cognitive system, that is the second receiving unit receives the sensing information from the adjacent co-located peer cognitive system indicates the second receiving unit receives the sensing information directly from the local sensing nodes of the adjacent co-located peer cognitive system and/or the second receiving unit receives the sensing information relayed by the local sensing nodes from the local sensing nodes of the adjacent co-located peer cognitive system. The combining unit is configured to combine the sensing information received from the local sensing nodes and the adjacent sensing nodes who share their sensing information together. The combining includes OR-rule combining, weighting combining or sub-band selection combining; the spectrum decision unit is configured to make spectrum decision according to the combined information.

The advantage of the present invention is that the sensing information

among co-located cognitive radio networks can be shared by the proposed shared cooperative spectrum sensing. In this manner, it is equivalent to extending the number of cooperative sensing nodes but does not cause extra sensing overhead. Therefore, the sensing performance is also improved. Also, in some areas where the users acting as the sensing nodes are limited, the shared cooperative spectrum sensing is beneficial to improve sensing performance by “borrowing” sensing nodes from its adjacent cognitive radio networks. On the other hand, guaranteed inter-system communication mechanisms have been defined because the cognitive radios shall realize efficient coexistence. These communication mechanisms can be re-used to realize the shared cooperative spectrum sensing. Thus, the shared cooperative spectrum sensing does not increase the extra burden to define a new reliable inter-system communication mechanism and the impact on cognitive radio networks will also decrease.

The present invention may be implemented by hardware, software, firmware and their combination. It is intelligible to those skilled in the art that the present invention may be embodied in computer program products set up in the signals carrying medium used by any suitable data process systems. Such signals carrying medium may be transmission medium or recordable medium used to machine-readable information and includes magnetic medium, optical medium or other suitable medium. The exemplary of the recordable medium includes: floppy disks or hard disks in the hard disk drive, magnetic tapes, CD drivers used to the optical disk and other medium that could be imagined by those skilled in the art. It is intelligible to those skilled in the art that any communication equipments with suitable programming apparatuses can all execute the steps of the present invention method as embodied in the program products.

From the description above, it could be understood that many modifications and variations may be made in the embodiments of the present invention without departing from the spirit and scope of the present invention. The description in the present specification is only

illustrative and cannot be considered as limited. The scope of the present invention is only limited by the claims.

CLAIMS

1. A shared cooperative spectrum sensing method in a cognitive radio network, the cognitive radio network including at least two adjacent
5 co-located peer cognitive systems, each cognitive system including a fusion center and at least one local sensing node, wherein the method comprises the step of: sharing sensing information among co-located cognitive networks.

2. A method according to claim 1, wherein said sharing sensing information among co-located cognitive networks indicates:

10 the local sensing nodes conducting local sensing measurement, sending the sensing information to the fusion center and sending the sensing information to the adjacent shared cognitive systems.

3. A method according to claim 2, wherein the fusion center makes spectrum decision based on the sensing information from the local sensing
15 nodes and the adjacent sensing nodes who share their sensing information.

4. A method according to claim 2, wherein, the local sensing nodes send the sensing information directly to the fusion center of the adjacent shared cognitive system.

5. A method according to claim 2 or 4, wherein the local sensing nodes
20 send the sensing information to the sensing nodes of the adjacent shared cognitive system, and the sensing nodes of the adjacent shared cognitive system relay the sensing information to the fusion center of the adjacent shared cognitive system.

6. A method according to claim 2, wherein the local sensing nodes send
25 the sensing information to the adjacent shared cognitive systems in the form of broadcast.

7. A method according to claim 1, wherein, the sensing information is shared among the co-located cognitive networks through inter-system communication mechanism.

30 8. A method according to claim 3, wherein, the fusion center combines the sensing information received from the local sensing nodes and the

adjacent sensing nodes who share their sensing information together and makes spectrum decision.

9. A local sensing node in a cognitive radio network, the cognitive radio network including at least two adjacent co-located peer cognitive systems, the cognitive system including a fusion center, wherein the local cognitive node includes:

a first receiving unit, configured to receive a sensing measurement instruction and spectrum sensing parameters from the fusion center;

a sensing unit, configured to perform spectrum sensing according to the sensing measurement instruction and the spectrum sensing parameters, and collect measurement results;

a first transmitting unit, configured to feed back sensing information to the fusion center;

a second transmitting unit, configured to send the sensing information to the adjacent co-located cognitive system.

10. A local sensing node according to claim 9, wherein the second transmitting unit sends the sensing information to the adjacent co-located cognitive system indicates that the second transmitting unit sends the sensing information directly to the fusion center of the adjacent co-located cognitive system.

11. A local sensing node according to claim 9 or 10, wherein the second transmitting unit sends the sensing information to the adjacent co-located cognitive system indicates that the second transmitting unit sends the sensing information to the sensing nodes of the adjacent co-located cognitive system.

12. A local sensing node according to any one of claims 9 to 11, wherein the local sensing node further includes a second receiving unit, configured to receive the sensing information from the adjacent co-located cognitive system.

13. A local sensing node according to claim 12, wherein the local sensing node further includes a relay unit, configured to send the sensing information received from the adjacent co-located cognitive system to the

fusion center.

14. A fusion center in a cognitive radio network, the cognitive radio network including at least two adjacent co-located peer cognitive systems, the cognitive system including at least one local sensing node, wherein the fusion center includes:

a transmitting unit, configured to transmit a sensing measurement instruction and spectrum sensing parameters to the local sensing unit;

a first receiving unit, configured to receive sensing information from the local sensing unit;

a second receiving unit, configured to receive the sensing information from the adjacent co-located peer cognitive system;

a combining unit, configured to combine the sensing information received from the local sensing nodes and the adjacent sensing nodes who share their sensing information together;

a spectrum decision unit, configured to make spectrum decision according to the combined information.

15. A fusion center according to claim 14, wherein the combining includes OR-rule combining, weighting combining, or sub-band selection combining.

16. A fusion center according to claim 14, wherein the second receiving unit receives the sensing information from the adjacent co-located peer cognitive system indicates the second receiving unit receives the sensing information directly from the local sensing nodes of the adjacent co-located peer cognitive system.

17. A fusion center according to claim 14, wherein the second receiving unit receives the sensing information from the adjacent co-located peer cognitive system indicates the second receiving unit receives the sensing information relayed by the local sensing nodes from the local sensing nodes of the adjacent co-located peer cognitive system.

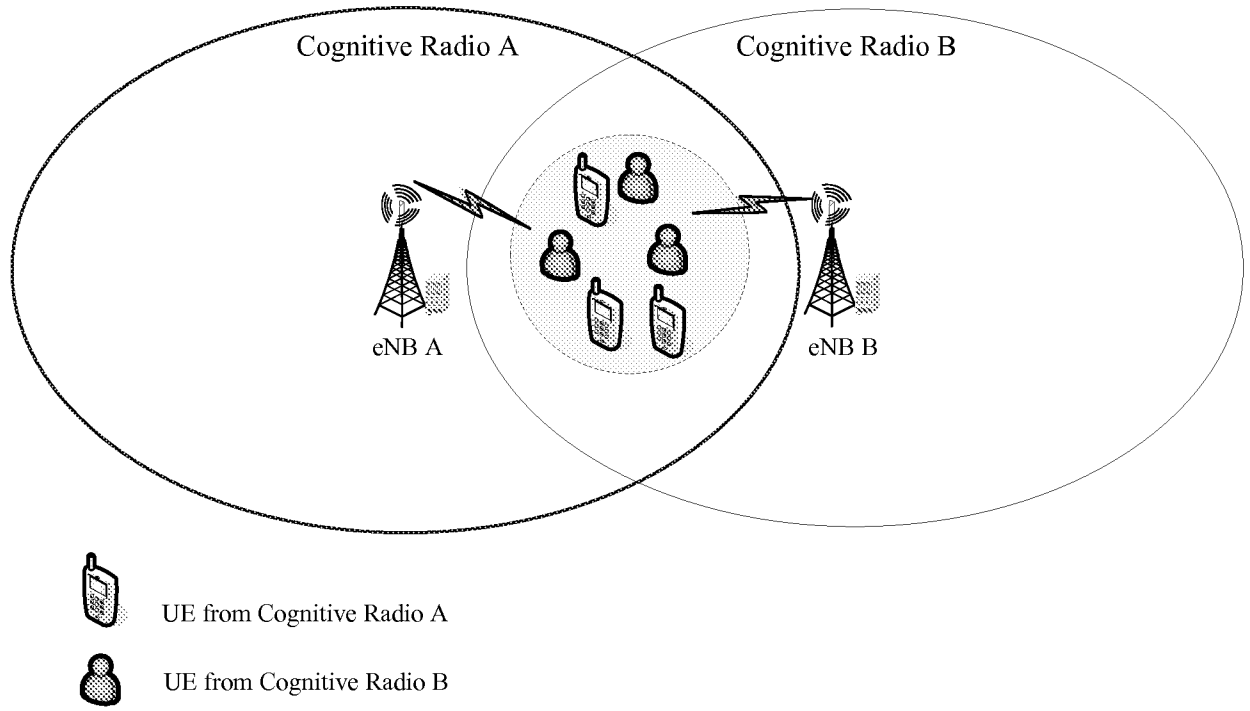


FIG.1

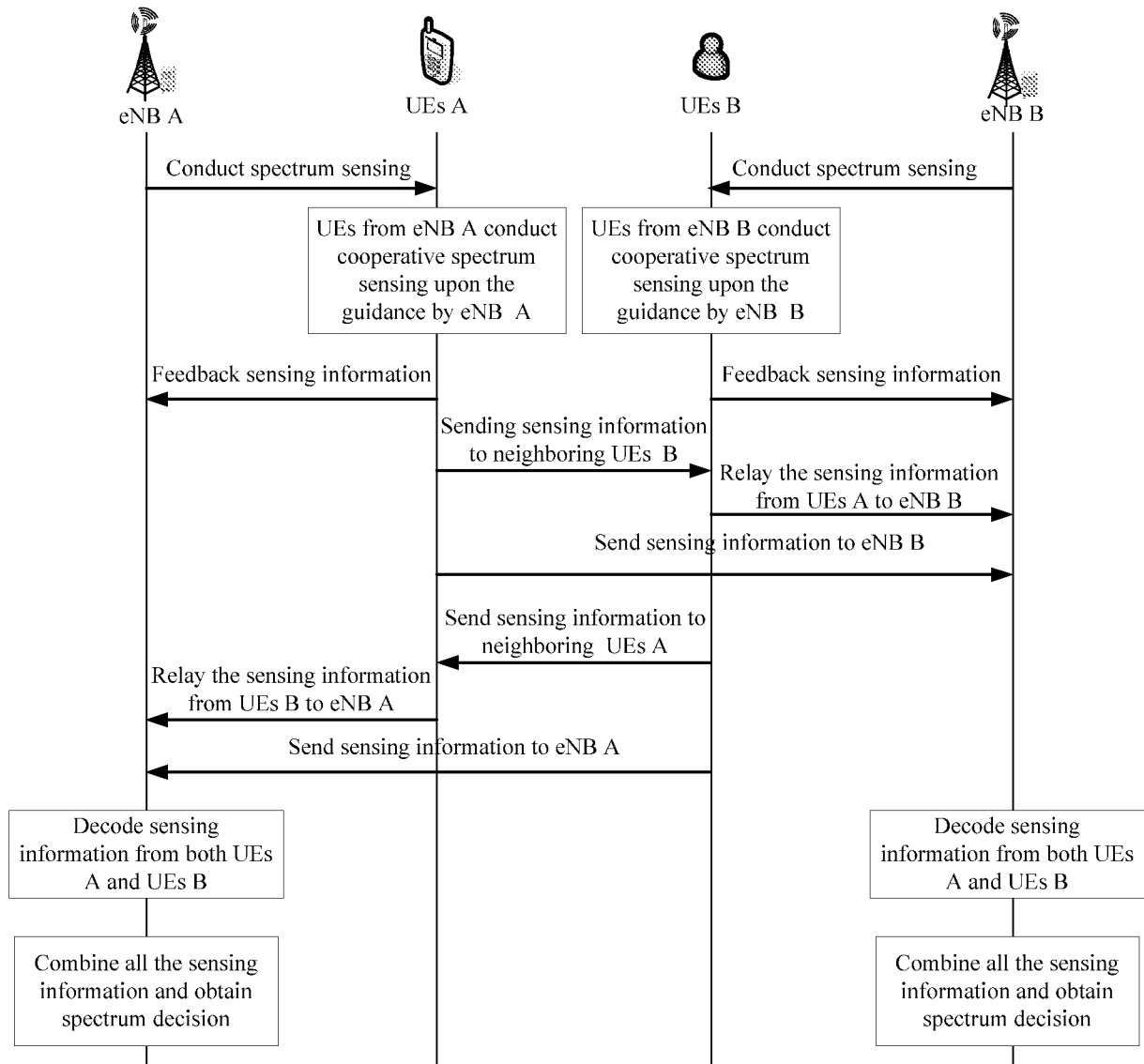


FIG.2

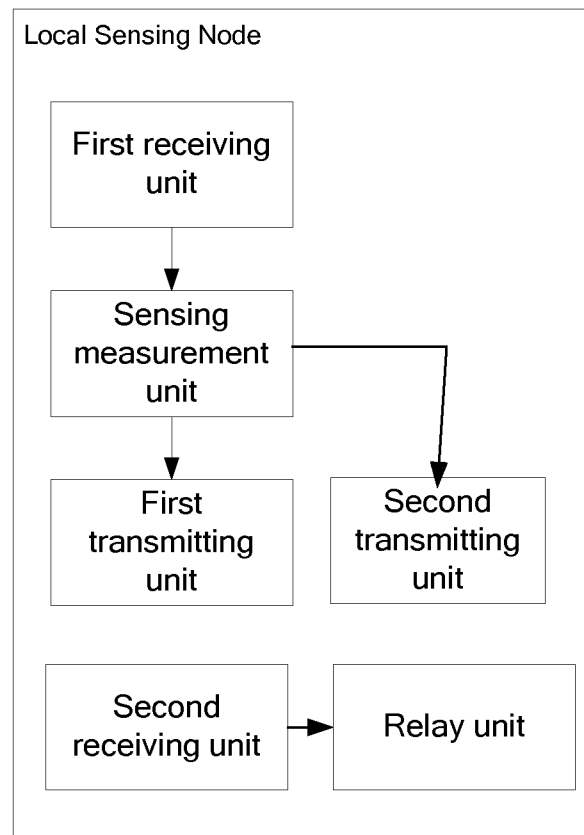


FIG.3

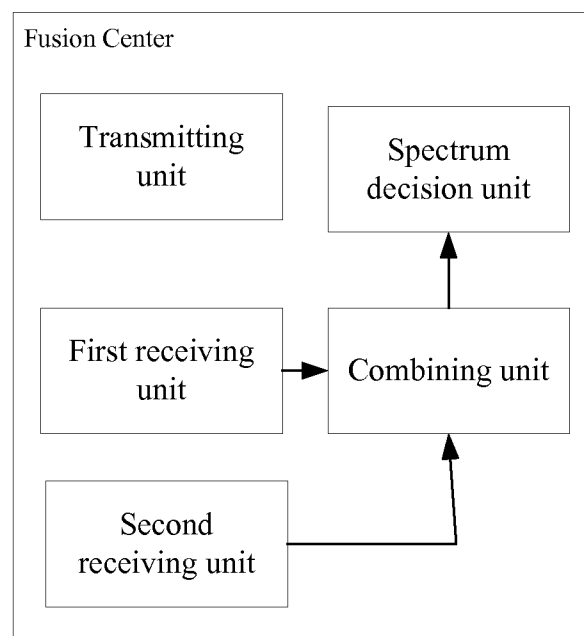


FIG.4